Safety of Radiation Sources and Security of Radioactive Materials

PROCEEDINGS OF A CONFERENCE,
DIJON, FRANCE, 14–18 SEPTEMBER 1998
JOINTLY ORGANIZED BY THE IAEA,
THE EUROPEAN COMMISSION, INTERPOL
AND THE WORLD CUSTOMS ORGANIZATION

SAFETY OF RADIATION SOURCES AND SECURITY OF RADIOACTIVE MATERIALS

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PROCEEDINGS SERIES

SAFETY OF RADIATION SOURCES AND SECURITY OF RADIOACTIVE MATERIALS

PROCEEDINGS OF AN INTERNATIONAL CONFERENCE
ON THE SAFETY OF RADIATION SOURCES
AND THE
SECURITY OF RADIOACTIVE MATERIALS
JOINTLY ORGANIZED BY
THE EUROPEAN COMMISSION,
THE INTERNATIONAL ATOMIC ENERGY AGENCY,
THE INTERNATIONAL CRIMINAL POLICE ORGANIZATION–INTERPOL
AND THE WORLD CUSTOMS ORGANIZATON,
AND HELD IN
DIJON, FRANCE, 14–18 SEPTEMBER 1998

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 1999

EDITORIAL NOTE

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FOREWORD

In virtually all countries of the world, use of radiation sources in industry, medicine, research and teaching is widespread and increasing. The safety and security record of these applications is good; however, there have been a number of radiological accidents caused by safety failures, some of which have led to serious consequences, including the death of some exposed persons.

In addition to the safety related problems, there have been events in which loss of security and control of radioactive materials has had serious, even fatal, consequences. Examples include incidents in which sources used in radiation therapy units have been unintentionally sold as scrap metal, found by unsuspecting individuals or stolen, causing multiple deaths. 'Orphan sources' often ended up in the public domain, in particular in scrap metal, causing a significant risk of contamination and exposure of workers, the public and the environment. Illicit trafficking in nuclear and other radioactive materials through States and across State borders has become a serious threat from the viewpoint of nuclear proliferation, terrorist potential and radiological hazard.

This International Conference, hosted by the Government of France and co-sponsored by the European Commission, the International Criminal Police Organization (Interpol) and the World Customs Organization (WCO), was the first one devoted to the safety of radiation sources and the security of radioactive materials and — for the first time — brought together radiation safety experts, regulators, and customs and police officers, who need to closely co-operate for solving the problem of illicit trafficking.

The technical sessions reviewed the state of the art of twelve major topics, divided into two groups: the safety of radiation sources and the security of radioactive materials. The safety part comprised regulatory control, safety assessment techniques, engineering and managerial measures, lessons from experience, international co-operation through reporting systems and databases, verification of safety through inspection and the use of performance indicators for a regulatory programme. The security part comprised measures to prevent breaches in the security of radioactive materials, detection and identification techniques for illicit trafficking, response to detected cases and seized radioactive materials, strengthening awareness, training and exchange of information.

The Conference was a success in fostering information exchange through the reviews of the state of the art and the frank and open discussions. It raised awareness of the need for Member States to ensure effective systems of control and for preventing, detecting and responding to illicit trafficking in radioactive materials. The Conference finished by recommending investigating whether international undertakings concerned with an effective operation of national systems for ensuring the safety of radiation sources and the security of radioactive materials, and attracting broad adherence, can be formulated. These recommendations were essentially adopted as a resolution of the Forty-second General Conference of the IAEA in September 1998[1].

These Proceedings contain the keynote address, the invited papers, summaries of discussions and session summaries, and the remarks presented at the opening of the Conference. The Conference Programme Committee accepted a number of contributed papers for consideration at the Conference, and these were published shortly before the Conference[2]. Together, these two volumes thus contain the complete record of the Conference.

The Joint IAEA/EC/Interpol/WCO Conference Secretariat gratefully acknowledges the support and generous hospitality extended to the participants by the authorities of France, in particular the French Atomic Energy Commission (CEA).

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[1] INTERNATIONAL ATOMIC ENERGY AGENCY, The Safety of Radiation Sources and Security of Radioactive Materials, GC(42)/RES/12, IAEA, Vienna (1998).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety of Radiation Sources and Security of Radioactive Materials, Contributed Papers, IAEA-TECDOC-1045, IAEA, Vienna (1998); available at no charge from the IAEA Department of Nuclear Safety, P.O. Box 100, A-1400 Vienna, Austria.

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OPENING SESSION

Chairperson

J.-P. GAYRAL
France

M.F. Ferrier

Secrétariat général de la défense nationale
France

On behalf of the French authorities, I have pleasure in welcoming you here, to Dijon, for the first conference organized by the IAEA on the safety of radiation sources and the security of radioactive materials.

The French Government has a particular interest in this subject — an interest that is widespread. Indeed, when the first plans for the holding of such a conference were made, all the French organizations concerned were very much in favour of holding such a meeting in France.

I can see that this interest is shared widely by many countries since, in addition to the four international organizations sponsoring this Conference, 83 countries are represented in this conference hall.

This Conference is not a routine one: the safety of radiation sources and the security of radioactive materials are extremely topical subjects.

Until recently, the international community was primarily interested in the safety of large nuclear facilities. This was perfectly understandable given the possibly dramatic consequences of the accidents that can occur in such facilities. International exchange of information and co-operation in this area were therefore already well organized.

On the other hand, as far as 'ordinary' radioactivity was concerned — that in the non-nuclear industry and in the field of medicine — each country was working in isolation with little, if any, international exchange of information.

I hardly need to dwell on the other topical area, namely, transfers of radioactive materials that are poorly controlled or not controlled at all. The geopolitical changes that have taken place in Eastern Europe have led to an increase in such trafficking. Paradoxically, despite the increased media attention given to the subject, the public interest and the considerable national resources provided to combat such trafficking, there has been little exchange of information.

After a few accidents had occurred and trafficking in radioactive material had been detected, the IAEA recognized the growing problem posed by the control of radioactive materials and undertook in-depth work in this area. It launched a programme to prevent and combat trafficking in radioactive materials and created an illicit trafficking database.

This Conference reflects this commitment and is the first event on such a scale in this field. It will provide an opportunity for the international exchange of information, making it possible to compare the strategies of each country and to draw lessons of benefit to all, against a background of security, objectivity and multidisciplinarity.

I have noticed that, in addition to specialists in the nuclear and radiation protection fields, there are customs officials, lawyers, doctors and policemen here. Apart from the international co-operation within each of these specialized fields, which is natural and has already begun, the mixing of specialists from all countries should have beneficial effects leading to the adoption of fresh approaches.

It is not by chance that organizations other than the IAEA, such as the World Customs Organization, Interpol and the European Community, are sponsoring this Conference.

In France, it is the Office of the Prime Minister, to which I belong, that is responsible for ensuring co-ordination among the different departments to prevent any loss of control of radioactive materials and their possible misuse. This proximity to the Prime Minister reflects the concern of the French authorities to cover all the areas involved. The task is an easy one since, in France, there is no fear of speaking publicly about the problems of nuclear security and radiation protection without any a priori assumptions. Furthermore, in Parliament an office has been given the task of auditing the French system of radiation protection, nuclear safety and control. The report on the audit has just been published.

The fact that we have long had a security culture and experience in this field does not mean that we should not review the situation from time to time.

I hope that this Conference will be an opportunity for everybody, including us, to benefit from the experience of other countries. I therefore hope that your work will be productive and that you will then enjoy discovering Burgundy's riches.

A.J. González

International Atomic Energy Agency
Vienna

It is my privilege to welcome you on behalf of the International Atomic Energy Agency to this important international conference which will, for the first time, openly and broadly foster information exchange on the safety of radiation sources and the security of radioactive materials at an international level.

Let my first words express our deep appreciation to the Government of France for agreeing to host the Conference and for arranging its organization. I am sure that you will join me in agreeing that the venue selected could not be better. To the natural beauty of Dijon and its surrounding region of Burgundy, and to the recognized hospitality of its inhabitants, the organizers have added the magnificence of this Conference Centre. You are well aware that, for a major event like this to be a success, a lot of hard work by many people takes place behind the scenes. We are extremely grateful to the many French officers, some of them sharing this podium, who, through their efforts, have made it possible for us to be here together. I kindly ask M. Ferrier, Director of the Secrétariat général de la défense nationale, and J. Bouchard, the President of the Conference and Director General of the Military Applications Directorate of the French Atomic Energy Commission (CEA/DAM), to convey our deep gratitude to all the local officers who have made this event possible.

My second remark is addressed to the sister organizations who are co-sponsoring this event with us. The IAEA is very honoured to co-sponsor this Conference with you all. We have a long history of co-operation with the European Union in the field of radiation protection and safety, but this is our first large venture with Interpol and the World Customs Organization (WCO). Their professional expertise and their mandate are key requirements for international success in tackling the elusive subject of the security of radioactive materials. I am convinced that my colleagues at the European Union will share my expressions of gratitude to Interpol and WCO for their support in this endeavour and our hope for further co-operative ventures in the future.

I would like now to emphasize the IAEA's recognition of the tireless efforts of the Scientific Programme Committee chaired by D. Beninson. Thanks to them, we have before us a programme which will encourage a rational and effective exchange of information among the many experts present here.

Let me also express our deep gratitude to the scientific secretaries and to the IAEA's Conference Service, whose relentless efforts have made all this possible.

And, last but not least, the IAEA is extremely indebted to all of you: to the various officers of the Conference, the President, the Chairpersons and the Rapporteurs; to the speakers, among whom I will specifically mention the keynote speaker, G. Dicus; to the authors of the contributed papers; and to all the participants. All of you are the real substance of the Conference. Thank you.

The topic of this Conference requires some words of clarification: 'safety' and 'security' — 'sûreté' and 'sécurité' — are two distinct terms in English and French only, a common word being used for these concepts in all other major languages. Not surprisingly, therefore, many people wonder what the distinction between safety and security actually is. If they reached for their dictionaries, they would perhaps be none the wiser, because one of the definitions of 'security' is 'safety' and vice versa.

By 'the safety of radiation sources' we mean the assembly of technical and managerial features that diminish the likelihood of something going wrong with a source as a result of which people are overexposed. By 'the security of radioactive material' we mean the assembly of technical and managerial features that prevent any unauthorized activity with radioactive materials by ensuring that their control is not relinquished or improperly transferred. We have limited the security issue to radioactive materials alone and not to radioactive sources (as a whole) because we believe that security issues with apparatus which generates ionizing radiation, such as X ray machines and accelerators, are of less significance. Security is required for two major purposes: on the one hand, to prevent strayed radioactive materials causing harm to people; on the other hand, to prevent the diversion of nuclear materials from legal to illegal, even criminal, uses. It is expected that this Conference will concentrate on the first of these two purposes. However, the IAEA will make a presentation which will also deal with its activities in the security of nuclear materials for safeguards purposes.

It is surprising that, after three quarters of a century of radiation protection, we are meeting together for the first time at an international level to foster the sharing of information on these two important topics. In its 70 years of existence, the International Commission on Radiological Protection (ICRP) has produced more than 70 publications with recommendations for protection against ionizing radiation that have been followed by national and international organizations. However, only two — very recent — ICRP publications deal with the problem of the safety of radiation sources, and none has ever dealt with the issue of the security of radioactive materials. For the IAEA, the balance is similar. The IAEA has taken the leading role in the United Nations system in establishing standards of radiation safety and has issued more than 100 documents on the subject. However, again, until the appearance of the latest Basic Safety Standards[1], the subject of safety had been loosely addressed in the IAEA's standards by the simplistic requirement that 'accidental exposures shall be prevented'. This is a fine 'motherhood and apple pie' statement but offers no guidance on to how to achieve safety. The security issue was also completely ignored by international standards. In the Basic Safety Standards some progress was achieved, and a full set of requirements for safety and security was established. However, they are general in nature and with very little quantification.

I must stress my amazement that this apparent lack of interest has occurred despite the fact that, as all of us know, many people have been injured and have even died because of failures in the safety of radiation sources and, in the last few years, a worrying number of accidents have occurred because of breaches in the security of radioactive materials.

It seems, I would like to suggest, that we were convinced that minimum requirements for safety and security were somehow automatically established and implemented. We all assumed, for instance, that all governments had radiation safety infrastructures in place which at least included a system of notification, registration, licensing and inspection of radiation sources. But this assumption proved to be wrong. We learned that among the IAEA's Member States alone, nearly half lacked the minimum infrastructure. This means more than 50 countries. And, in addition, there are at least 60 countries which are not Members of the IAEA and where, we can only guess, the situation may be even worse.

The IAEA is reacting to this serious situation. This afternoon, the IAEA's Deputy Director General, Jihui Qian, who is sitting here on my left, will brief you on the IAEA's technical co-operation measures which aim to solve the problem. The so-called Model Project in Radiation Protection is one of the largest efforts in the United Nations' history to enhance radiation safety infrastructure in States which need it most urgently. This IAEA initiative, involving an active approach rather than the traditional reactive approach to technical co-operation on the part of UN organizations, is Jihui Qian's personal initiative, and nobody could do a better job of telling you about it than he himself.

The IAEA would therefore like to see this Conference as a turning point for our focus on radiation protection. This should not be misinterpreted: we do not propose to diminish our efforts in the so-called normal operation of radiation sources. We have achieved a great deal in that field in protecting workers, the public and medical patients, and we should work hard to preserve all these achievements. What we mean is that we must put far more effort into safety and security than we have in the past.

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[1] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANISATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

This Conference is therefore a unique opportunity for fostering information exchange among you, la crème de la crème of experts gathered here. National and international organizations alike expect from you ideas and directions for further work in this field. The IAEA therefore looks forward with optimism to a set of recommendations from the Conference in this regard and commits itself to distributing them widely and to helping in their implementation.

J. Shaver

World Customs Organization,
Brussels

It is a great pleasure for me to welcome you to this opening session of the International Conference on the Safety of Radiation Sources and the Security of Radioactive Materials, organized by the International Atomic Energy Agency and co-sponsored by the European Union (EU), ICPO-Interpol and the World Customs Organization (WCO).

The WCO (established as the Customs Co-operation Council in 1952) is an independent, intergovernmental body with worldwide membership which brings together 147 customs services. The WCO's basic mission is to enhance the effectiveness and efficiency of customs services in the areas of compliance with trade regulations, protection of society and revenue collection, thereby contributing to the economic and social well-being of nations.

I would like to say a few words about the topics to be covered at this important Conference.

One of the main objectives of the Conference is to enable us to be more familiar with the technical subjects, to identify the various problems that arise in connection with the fight against the smuggling of radioactive materials and to help us to enhance our existing bilateral and multilateral co-operation in this area.

As you are well aware, the protection of the environment and the illicit trans-border movement of radioactive materials have been drawing much attention. It is clear that the smuggling of nuclear and other radioactive material has a close link to the security of our societies, the future of our planet and of future generations.

Customs administrations, as the principal border control agencies, are trying to increase their effectiveness in this area by developing new techniques and procedures and especially by closer co-operation with counterpart law enforcement agencies and the international community.

Customs officials strongly believe that unless we work together we are unlikely to overcome the problem of illicit trafficking in nuclear and other radioactive material. The implementation and further development of an internationally co-ordinated strategy is needed to eliminate this criminal activity.

The WCO enforcement programme on action to combat illicit trafficking in nuclear material dates back to 1992. The main goal of our programme has been to assist our members to detect and respond to such smuggling attempts.

We have made significant progress in the development of awareness programmes with the exchange of information and with collaboration between the WCO and international organizations such as the IAEA, ICPO-Interpol and the EU. For example, later this month the IAEA, WCO and ICPO-Interpol will be holding a training course for police and customs officers from the Eastern and Central Europe region.

To publicly demonstrate the improved co-operation between the WCO and the IAEA, we signed and exchanged a memorandum of understanding on 13 May 1998. The WCO and the IAEA will continue to co-operate closely in the area of international assistance in combating illicit trafficking in nuclear and other radioactive materials. This will include further development of joint documents and programmes on awareness, training and safety.

The primary objective of the IAEA/WCO joint activities is to assist Member States to reduce the potential threat of illegal movement of nuclear and other radioactive materials across international borders by raising awareness and improving the detection and response measures, especially by training and the exchange of information.

I am sure this global approach provides countries with the necessary international dimension in the fight against radioactive material smuggling.

In conclusion, the discussions to be held during the week ahead and the outcome of this Conference will make a major contribution to a review of current activities in this important area.

I would like to thank the IAEA for giving us the opportunity to be one of the co-sponsors of this Conference. Please let me also congratulate the French Atomic Energy Commission for the very professional arrangements made for this landmark Conference and for choosing this beautiful and historical city as a location for our discussion.

R.E. Kendall

Interpol General Secretariat,
Lyons

As the Secretary General of ICPO-Interpol, I am both pleased and honoured to welcome you to this important International Conference on the Safety of Radiation Sources and the Security of Radioactive Materials.

This is the first time that these important topics have been discussed and examined in the same Conference. The presence of so many authorities and specialists from different organizations gives us an excellent opportunity to exchange information and experience in order to enhance future co-operation.

Your presence is a testament to the importance that we all place on the agenda items, and I sincerely hope that each of you will derive the maximum benefit from the presentations and debate.

I would like to take this opportunity to thank the International Atomic Energy Agency for extending their invitation to law enforcement agencies of the Interpol member countries involved in combating the illicit trafficking in these kinds of material. Over the past few years, we have developed an excellent working relationship with the IAEA, and we are very pleased that the IAEA is sharing with us their technical and professional experience in this field.

The illicit traffic of nuclear and radioactive materials represents a fairly new and complicated kind of crime to law enforcement agencies worldwide. Combating it requires very specialized knowledge, and once the material has been detected the technical expertise of the competent national authorities is needed in order to seize, store and analyse the material.

Furthermore, the illicit traffic usually has international ramifications, and international co-operation with law enforcement agencies in other countries is therefore of paramount importance in order to identify the origin of the material, the persons involved, the transport routes used and other details of the case.

Even though the number of cases of illicit trafficking in nuclear and radioactive materials has not so far assumed major proportions, there is still a need to be concerned, because this traffic represents a real danger for both humans and the environment. A potential threat in terms of criminal use, e.g., terrorism, cannot be dismissed.

Although we have no clear evidence that organized crime groups or terrorists are involved in this kind of illegal trafficking, we still have to be aware of the fact that this situation could change rapidly.

It is important to highlight here the role and function of Interpol. We are here to assist with the criminal aspects of trafficking in nuclear and radioactive materials, which will undoubtedly include cross-border investigations and the need for rapid and safe exchange of intelligence and information. Our 177 member countries are all connected by a modern and secure communications system which ensures that they have the necessary services at their disposal to conduct such investigations outside their jurisdictions and across national borders. Our role within this partnership must continue to concentrate on criminal activity.

For many years the so-called multiagency approach has been proposed as the only way forward to combat many areas of international criminal activity. This meeting surely provides the best possible example of this much vaunted concept.

We will continue to support the initiatives being made to combat this illicit trafficking, and we applaud the efforts of the IAEA, which has been responsible for raising this issue to its current high profile.

I am delighted that we are involved in this partnership and in co-sponsoring the Conference. I am sure that the conclusions reached will be of great benefit to the organizations involved, to the participants and to the general public, who will be the ultimate beneficiaries from this desire to make our world a safer place.

K.E. Schnuer

European Commission,
Luxembourg

It would be negligent of me if I did not first express my thanks to the French Government, the local organizers of this International Conference, and to the French Atomic Energy Commission, particularly the Department of Military Applications, who invited us to the county of Burgundy and its beautiful capital, Dijon. I also would like to thank the International Atomic Energy Agency for its initiative and the World Customs Organization (WCO) and the International Criminal Police Organization, Interpol, for their support.

In view of the unmistakable problems facing us on all sides with respect to the use of nuclear technology, the European Commission welcomes the initiative of the IAEA in organizing this International Conference on the Safety of Radiation Sources and the Security of Radioactive Materials.

The responsible European Commission department, the Directorate for Nuclear Safety, was glad to accept the invitation to play an active part in this Conference and is committed to making it a success.

This Conference, jointly organized by the most important international organizations faced with the problems of illicit nuclear trafficking, demonstrates the excellent level of international co-operation in the field of safety of radiation sources and security of radioactive substances. This international event underlines the important role played by international organizations in meeting both their own objectives and those of the international community.

In 1990, after the collapse of the former Eastern Bloc, the Member States prompted the European Union (EU) to take action to deal with illicit trafficking in nuclear material and radioactive substances. The governments of the EU Member States fully supported the view of the European Commission and believe that only the broadest international collaboration can effectively counteract these new phenomena in the radiation protection field.

The Commission considers increased efficiency in using the financial and administrative resources as a central element in the international efforts in this field.

It is important to stress that the responsibility in the field of security of sources and safety of radioactive materials stays with the national competent authorities. However, the organizations of the respective national legal systems vary considerably between the different states, both in the Western world and in Central and Eastern Europe.

The EU is regularly examining the whole range of its legal activities in the fields of nuclear safety and radiation protection. On the basis of its overall view of the situation, the Commission is extending and initiating measures to help ensure that the best conditions are created to protect the health of the general public, workers and the environment against the dangers arising from illegal practices with radioactive sources or substances.

These activities are integrated with those of the International Atomic Energy Agency, and frequent consultations take place that allow for a mutual and fruitful exchange of experience and information.

Apart from nuclear safety and radiation protection, the EU acknowledges its responsibilities in the field of customs co-operation and welcomes the support provided by the WCO.

Furthermore, the EU is prepared to make specific proposals in order to find well balanced solutions for bringing Interpol into the solution of problems caused by illicit trafficking and other illegal activities involving radiation sources or radioactive substances.

In the near future it will be necessary to establish a common global understanding of the problems in the context of this Conference. The European Commission is hoping to receive from this Conference suggestions and criticisms which will lead to most effective measures for bringing about a substantial improvement in radiation protection and nuclear safety. In this context, I would like to thank all the international experts for their efforts in the preparation of the Conference and for all their contributions, which, I am sure, will make the Conference a success.

J. Bouchard

Commissariat à l'énergie atomique,
Paris

It is a great pleasure for me to join the representative of the French Government and the organizations which have organized this Conference in welcoming you to Dijon. In agreeing to organize this event, the French Atomic Energy Commission (CEA) was concerned not only with demonstrating France's interest in a subject which requires ever more constant attention, but also in recognizing the role which nuclear research organizations have to play in defining the nature of the problems raised and the technical and scientific means which could be used to help solve them.

The extensive development of applications utilizing radiation sources or radioactive materials in both the energy sector and other industrial sectors, in medicine and scientific research, has gone hand in hand with numerous efforts to ensure protection of the public and the workforce. The results obtained in the field of nuclear safety and radiation protection bear witness to that fact.

However, events in the world constantly show that there is no basis for resting on our laurels, a fact of which Governments and the public are more and more aware. Owing to the great variety of radioactive sources, the many different societies using them and the growing importance of transboundary movements, the subject rightly continues to be accorded high priority.

That priority attention is the obligation of all, and in particular of the bodies whose job it is to work with radiation sources and nuclear material. A recent incident in a CEA centre in the Paris region provides ample proof of this: a ^{90}Sr source — happily, one of low intensity — was erroneously diverted into a non-dangerous waste flow. It took several days to recover it at the incineration site where that waste was sent.

The variety of sources in use in industry, medicine and research poses tricky problems, not only as regards the drawing up of common regulations but also with respect to control of their use. Further progress is still required in the fields of prevention, control and intervention.

Though the nuclear material issue is theoretically less complex, owing to the extensive regulatory framework established by States and the smaller number of players involved, there have been a number of worrying incidents in that area too in recent years. This has given rise to international programmes to improve, in certain countries, the material accounting methods, physical protection resources at storage sites and detection resources at frontiers.

I am also happy to have the opportunity here to commend the IAEA's programme on security of nuclear material, which I have no doubt all the participants at this Conference support.

In my introduction, I stressed the role which players in the nuclear industry have in promoting the understanding and solution of the delicate questions which have brought us together here today. This is certainly the case for an organization like the CEA, which manages many sources and large quantities of material and has developed significant analytical capabilities and numerous technical resources. It is my fervent hope that the experts who have gathered here this week will find ample opportunity to share their knowledge.

In fulfilling our several responsibilities, we have established very effective relations with the customs and the police services at the national level and have developed international collaborative efforts in the fields of nuclear safety and radiation protection to which I attach great importance. You will not be surprised when I tell you that the IAEA, the main organizer of this Conference, occupies the first rank among these international contacts. This unique international organization has demonstrated its capacity to adapt to the new challenges with which developing circumstances continually confront it. Our technical collaboration, which covers various application areas, is aimed principally at promoting the safe utilization of nuclear energy.

Of the various topics on which we have worked together most recently, I would like to pay tribute to the remarkable work done by the international experts assembled by the IAEA to assess the current and future radiological consequences of our nuclear weapons tests in the Pacific Ocean. The international conference held in Vienna at the end of June 1998 gave some indication of the considerable breadth of that work and of the extent to which the results confirmed our own statements during the last test series. I hope you will excuse me if, in my capacity as Director of Military Applications of the CEA, I express here my satisfaction with the results of this independent enquiry.

You will soon be beginning your work. I hope that this week in Dijon will help you gain a good grasp of the main features of the current situation, the problems which remain to be solved and the most promising approaches. Only international exchange of expert knowledge can give us some hope of achieving these objectives. I would therefore like to thank all those who have come here, and in particular representatives of foreign countries, for their contribution to our joint deliberations. I look forward with great interest to the summary of achievements we will be drawing up together on Friday.

THE PROBLEM

(Briefing Session 1)

Chairperson

J.-P. GAYRAL
France

KEYNOTE ADDRESS

THE SIZE OF THE PROBLEM

G.J. DICUS
US Nuclear Regulatory Commission,
Washington, DC, United States of America

1. INTRODUCTION

It is a privilege to be invited to participate in this International Conference on the Safety of Radiation Sources and the Security of Radioactive Materials. It is again a pleasure to visit France, this time the historic city of Dijon and the acclaimed province of Burgundy. It is an excellent setting for this important Conference.

Much attention has been directed by international safety organizations and national authorities at the potential radiation and environmental hazards associated with the nuclear fuel cycle. The radiation and environmental risks resulting from hazards associated with the mining and milling of the raw materials of nuclear energy, uranium and thorium, are also well documented. The nuclear accidents in 1979 at Three Mile Island and in 1986 at Chernobyl, while significantly different in their impacts, reinforced the need to pay close, detailed attention to recognizing and controlling the risks associated with the operation of nuclear power plants. Equally important, we learned from these events important lessons to be applied in emergency response planning. Radioactive waste disposal presents different, but no less important, radiological and environmental protection challenges. In all of these areas, the work of safety professionals is carefully scrutinized and is often augmented by legislators, the communications media and the public. Ensuring that radiation and environmental safety in the nuclear fuel cycle is consistent with societal expectations is a constant challenge to all concerned.

But there is another challenge. That challenge is to ensure that, while focusing on the clearly visible and well publicized hazards associated with the use of nuclear power, sight is not lost of other radiological and environmental risks resulting from the use of radiation sources outside of the nuclear fuel cycle. The imprint upon the public psyche of events like Three Mile Island and Chernobyl is an incredibly strong one. One positive result of these events is that the impressions they leave create strong public and political support for international and national initiatives to improve the safety culture and regulatory infrastructures related to nuclear power and the fuel cycle. Nonetheless, it must be pointed out that, worldwide, the number of nuclear power reactors is relatively small, approximately 440, and that, except for those in ships, they are in fixed, known locations.

The foregoing cannot be said for radiation sources. The uses of radiation sources are myriad, and their applications are nearly universal. Further, accidents involving radiation sources do occur. Some accidents have resulted in serious, even fatal, radiation exposures. When radioactive materials are involved, radioactive contamination of the environment can also occur. However, accidents with radiation sources seem to not make the same strong imprint upon the public that accidents involving nuclear power reactors do. One consequence of this is that the public and political pressure for legislative and regulatory action in this area is not always as strong as that connected with nuclear power and the rest of the nuclear fuel cycle. As a result, regulatory efforts have not always been as effective as they should be in this area. Equally important, legislative bodies have not always provided the requisite resources to national regulatory authorities so that they can implement effective radiation safety regulatory programmes for radiation sources. Our challenge, then, is to ensure that all radiation sources receive appropriate levels of attention to protect public health and safety.

This Conference is a response to that challenge, and I am grateful to the sponsors, the European Commission, the International Atomic Energy Agency, Interpol and the World Customs Organization for organizing it.

2. SAFETY OF RADIATION SOURCES

To illustrate this challenge, let me begin by citing the US operational experience with licensed nuclear power plants and radioactive sources. In the USA there are 103 licensed operating nuclear power plants. Resident inspectors are present at all of these sites, and their inspection activities are routinely supplemented by inspections performed by regional and headquarters offices. The worst US nuclear power plant accident, at Three Mile Island Unit 2, resulted in the release of radioactive materials to the environment. However, no member of the public was exposed to radiation even in excess of the radiation dose limits for members of the public in normal situations from this accident nor from accidents or routine operations at any other US licensed nuclear power plant. This statement, however, cannot be made with respect to US operational experience with licensed radioactive sources.

In comparison to the 103 licensed nuclear power plants, about 190 000 licensees use radioactive materials subject to the US Atomic Energy Act, as amended either in accordance with a specific licence or in the form of devices containing radioactive sources authorized by a general licence. Over two million devices containing radioactive sources have been distributed to US licensees. It is important to note that the US Nuclear Regulatory Commission (NRC) does not license all radioactive sources — radium sources being the predominant category of unlicensed sources — and does not regulate radioactive sources used by the US Department of Energy.

US operational experience with radioactive materials includes serious accidents, some of them resulting in radiation injuries and death and others in radioactive contamination. The major applications in which most major accidents have occurred are irradiation, industrial radiography, brachytherapy and teletherapy. Accidents with radiation sources are also a worldwide problem. During this Conference, we will learn more about some of these individual accidents and about IAEA summary reports on them.

Another area of concern is lost, stolen and abandoned radioactive sources. Each year, the NRC receives about 200 reports of lost, stolen or abandoned radioactive sources and devices. It is important to note that such reports are received only when licensees recall that they have a source, know that is lost or stolen, know that there is a requirement to report the loss or theft and make that report. Therefore, the volume of reports received probably represents but the tip of the iceberg. In some of these cases, the loss of control of radioactive sources has resulted in radiation overexposures of unsuspecting members of the public or in radioactive contamination.

The US metal recycling industry has been particularly affected by losses and thefts of radioactive sources which subsequently became mixed with metal scrap destined for recycling. Since 1983, US steel mills accidentally melted radioactive sources on 20 occasions, and radioactive sources have been accidentally melted at other metal mills on 10 other occasions. While radiation exposures of mill workers and the public have, thus far, been low, the financial consequences have been large. US steel mills have incurred costs averaging US $8–10 million as a result of these events, and in one case the cost was US $23 million.

Lost, stolen and abandoned sources appearing in recycled metals also constitute a worldwide problem. Thirty other, similar events are reported to have occurred in at least 18 other countries (Table I [1]). Others may have occurred but have not come to our attention or cannot be confirmed. These events have the potential for international consequences as well, because of the transboundary transport of radioactive effluents from a mill that has accidentally melted a source, such as occurred recently in Spain, or as the result of international marketing of mill products and by-products that have become contaminated, such as ^{60}Co contaminated steel products. Radioactively contaminated products imported into the USA have been found on ten occasions (Table II). The sources of contamination in most of these cases are probably radioactive sources that became mixed with the raw materials used to make the products. Although none of these cases resulted in significant exposures of the public in the USA, another result of their unexpected appearance in the marketplace is to raise concerns about the effectiveness of regulatory programmes intended to ensure the safety of radiation sources.

TABLE I. MELTINGS OF RADIOACTIVE MATERIALS [1]

Item No.	Year	Metal	Location	Isotope	Activity (GBq)
1	—[a]	Gold	NY	^{210}Pb, ^{210}Bi, ^{210}Po	Unknown
2	1983	Steel	Auburn Steel, NY	^{60}Co	930
3	1983	Iron/steel	Mexico[b]	^{60}Co	15 000
4	1983	Gold	Unknown, NY	^{241}Am	Unknown
5	1983	Steel	Taiwan[b]	^{60}Co	>740
6	1984	Steel	US Pipe & Foundry, AL	^{137}Cs	0.37–1.9
7	1985	Steel	Brazil[b]	^{60}Co	Unknown
8	1985	Steel	Tamco, CA	^{137}Cs	56
9	1987	Steel	Florida Steel, FL	^{137}Cs	0.93
10	1987	Aluminium	United Technology, IN	^{226}Ra	0.74
11	1988	Lead	ALCO Pacific, CA	^{137}Cs	0.74–0.93
12	1988	Copper	Warrington, MO	Accelerator	Unknown
13	1988	Steel	Italy[b]	^{60}Co	Unknown
14	1989	Steel	Bayou Steel, LA	^{137}Cs	19
15	1989	Steel	Cytemp, PA	Th	Unknown
16	1989	Steel	Italy	^{137}Cs	1000
17	1989	Aluminium	Russian Federation	Unknown	Unknown
18	1990	Steel	NUCOR Steel, UT	^{137}Cs	Unknown
19	1990	Aluminium	Italy	^{137}Cs	Unknown
20	1990	Steel	Ireland	^{137}Cs	3.7
21	1991	Steel	India[b]	^{60}Co	7.4–20
22	1991	Aluminium	Alcan Recycling, TN	Th	Unknown
23	1991	Aluminium	Italy	^{137}Cs	Unknown
24	1991	Copper	Italy	^{241}Am	Unknown
25	1992	Steel	Newport Steel, KY	^{137}Cs	12
26	1992	Aluminium	Reynolds, VA	^{226}Ra	Unknown
27	1992	Steel	Border Steel, TX	^{137}Cs	4.6–7.4
28	1992	Steel	Keystone Wire, IL	^{137}Cs	Unknown
29	1992	Steel	Poland	^{137}Cs	Unknown
30	1992	Copper	Estonia/Russian Federation	^{60}Co	Unknown
31	1993	Unknown	Russian Federation	^{226}Ra	Unknown
32	1993	Steel (?)	Russian Federation	^{137}Cs	Unknown
33	1993	Steel	Auburn Steel, NY	^{137}Cs	37
34	1993	Steel	Newport Steel, KY	^{137}Cs	7.4
35	1993	Steel	Chaparral Steel, TX	^{137}Cs	Unknown
36	1993	Zinc	Southern Zinc, GA	U (dep.)	Unknown
37	1993	Steel	Kazakhstan[b]	^{60}Co	0.3
38	1993	Steel	Florida Steel, FL	^{137}Cs	Unknown
39	1993	Steel	South Africa[c]	^{137}Cs	<600 Bq/g

TABLE I. (CONT.)

Item No.	Year	Metal	Location	Isotope	Activity (GBq)
40	1993	Steel	Italy	^{137}Cs	Unknown
41	1994	Steel	Austeel Lemont, IN	^{137}Cs	0.074
42	1994	Steel	US Pipe & Foundry, CA	^{137}Cs	Unknown
43	1994	Steel	Bulgaria[b]	^{60}Co	3.7
44	1995	Steel	Canada[d]	^{137}Cs	0.2–0.7
45	1995	Steel	Czech Rep.	^{60}Co	Unknown
46	1995	Steel (?)	Italy	^{137}Cs	Unknown
47	1996	Steel	Sweden	^{60}Co	87
48	1996	Steel	Austria	^{60}Co	Unknown
49	1996	Lead	Brazil[b]	^{210}Pb, ^{210}Bi, ^{210}Po	Unknown
50	1996	Aluminium	Bluegrass Recycling, KY	^{232}Th	Unknown
51	1997	Aluminium	White Salvage Co., TN	^{241}Am	Unknown
52	1997	Steel	WCI, OH	^{60}Co	0.9 (?)
53	1997	Steel	Kentucky Electric, KY	^{137}Cs	1.3
54	1997	Steel	Italy	$^{137}Cs/^{60}Co$	200/37
55	1997	Steel	Greece	^{137}Cs	11 Bq/g
56	1997	Steel	Birmingham Steel, AL	$^{137}Cs/^{241}Am$	7 Bq/g
57	1997	Steel	Brazil[b]	^{60}Co	<0.2
58	1997	Steel	Bethlehem Steel, IN	^{60}Co	0.2
59	1998	Steel	Spain	^{137}Cs	>37
60	1998	Steel	Sweden	^{192}Ir	<90

[a] Multiple cases reported, earliest circa 1910.
[b] Contaminated product exported to USA.
[c] Contaminated vanadium slag exported to Austria; detected in Italy.
[d] Contaminated by-product (electric furnace dust) exported to USA.

To again cite from US experience, the NRC has a well developed regulatory programme for radioactive sources. Nonetheless, the data that have been collected on lost and stolen radioactive sources and on discoveries of uncontrolled sources in the public domain, such as in recycled metals, showed a clear need for modifications of that programme. In response, in 1998, the Commission directed that changes be made to provide more routine contacts with licensees using radioactive sources to remind them that they are responsible for the accounting, control and proper disposal of licensed material. The point of this example is that the Commission could not have

TABLE II. RADIOACTIVELY CONTAMINATED PRODUCTS IMPORTED INTO THE UNITED STATES OF AMERICA [2]

Item No.	Product	Contaminant	Year discovered	Country of origin
1	Steel, iron	^{60}Co	1984	Mexico
2	Steel	^{60}Co	1984	Taiwan
3	Steel	^{60}Co	1985	Brazil
4	Steel	^{60}Co	1988	Italy
5	Steel	^{60}Co	1991	India
6	Ferrophosphorus	^{60}Co	1993	Kazakhstan
7	Steel	^{60}Co	1994	Bulgaria
8	Furnace dust	^{137}Cs	1995	Canada
9	Lead	^{210}Pb, ^{210}Bi, ^{210}Po	1996	Brazil
10	Steel	^{60}Co	1998	Brazil

justified making this decision — which has resource implications — without the collection and analysis of operational data to support it. Equally important is the need to share this kind of information.

The IAEA has taken a leadership role in this regard. For example, with respect to operational experience with radiation sources, the IAEA has prepared nine reports on individual accidents, six of them published, as well as reports on lessons learned from approximately 140 accidents that occurred in irradiation, industrial radiography and radiation therapy. The IAEA has assisted in national efforts to 'condition' unused, surplus radium sources to prevent their entering the public domain in an uncontrolled manner. In another initiative the IAEA is working with individual competent authorities to strengthen national regulatory programmes to oversee the safety of radioactive sources.

When serious radiation accidents occur, the demands upon the responding national authorities can become overwhelming. In such cases, arrangements for interagency and intergovernmental assistance are essential. The IAEA has provided assistance in investigating and dealing with accidents involving radiation safety and security on ten occasions.

There are many lessons to be learned from these operational safety experiences. The most important of these is the need for strong, effective national regulatory programmes to oversee the use of radiation sources. This will be a recurrent theme in the papers to be presented this week. It is equally important that there be in place a programme to review and evaluate the effectiveness of regulatory programmes and, when appropriate, the will and the flexibility to enact changes to improve the effectiveness of those programmes. Considering the rather large number of radiation sources in use worldwide, the safety record is reasonably good. When used properly by trained personnel with effective regulatory oversight, radioactive sources are safe and their many uses provide a net benefit to society. It is only when proper procedures are not followed or when effective radiation control programmes are lacking or control of radiation sources is lost that our problems begin.

3. SECURITY AND ILLICIT TRAFFICKING OF RADIOACTIVE MATERIALS

Within the radiation protection community the security of radioactive materials is always an integral part of the normal radiation protection programme for radioactive materials. Historically, thefts of radioactive sources or devices are not unknown, but most such thefts were motivated by misguided thoughts on the part of the thieves that the stolen radioactive sources or devices had monetary value similar to that of metals or specialized equipment. Such motivation for thefts continues today. Unfortunately, when thieves learn that the stolen items cannot be sold, they often discard them in trash or metal scrap, creating radiological risks for people who handle and dispose of trash or process and use recycled metal scrap.

In comparison, the theft and smuggling of radioactive materials for malevolent purposes have historically been relatively rare. Even so, such activities have always been of concern to national authorities. Today, because of recent political changes, such events take on greater significance for safety and police authorities. The increases in the numbers of incidents where radioactive materials have been stolen or smuggled for malevolent purposes increase the risk that members of the public may be exposed and harmed by these incidents and increase the opportunities for actually using stolen materials to deliberately expose people or contaminate property.

The majority of the materials that have been offered for sale for malevolent purposes to date have not in fact been weapons-usable nuclear material. However, in some cases, they have been radioactive materials that, if handled improperly, could cause harm to the public health and safety. These incidents merit close attention. Although terrorists worldwide continue to utilize conventional weapons to commit their heinous crimes, the sarin attack by the Aum Shinrikyo cult against the Tokyo subway system brought to reality what had only been viewed as a crime of the future. The uses of chemical, biological or nuclear materials by terrorists as weapons of mass destruction and to create fear are no longer crimes of the future. We are confronted with them today.

Thus, it is important that we exchange information and expand our knowledge in this area as well as in the conventional areas of radiological protection.

4. CONCLUSIONS

This International Conference will serve to increase our ability to successfully meet the challenge of ensuring that radiation sources are used safely and securely. All of those involved with radioactive materials — suppliers, manufacturers and distributors, users, persons transporting radioactive materials, waste disposal facility operators and the national and international safety and police authorities — have a responsibility to apply that knowledge to enhance public and environmental safety. Successfully doing that will, in turn, enhance public confidence that radioactive materials can be used safely.

Finally, it should be noted that the consequences of losses, thefts and smuggling of radioactive sources and materials often cross national boundaries. For this reason, programmes to facilitate the international exchange of information and international co-operation in the control and security of radioactive materials are essential. In this respect, the International Atomic Energy Agency has been a leader and is to be commended. This International Conference is a key step to achieving these important objectives, and I suggest that we do our part by fully participating in it. Therefore, I look forward to the rest of this Conference and to meeting with you.

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SUMMARY OF MAJOR ACCIDENTS WITH RADIATION SOURCES AND LESSONS LEARNED

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Abstract

SUMMARY OF MAJOR ACCIDENTS WITH RADIATION SOURCES AND LESSONS LEARNED.

The paper reviews some of the major radiological accidents that have occurred around the world and identifies key lessons to be learned from them. It emphasizes the value of feedback from the reporting of accidents, the need for effective reporting mechanisms and, most important, the importance of acting on the lessons learned to ensure accident prevention.

1. INTRODUCTION

Technologies that make use of radiation continue to spread around the world. Millions of people are employed in radiation related occupations, and hundreds of millions of people benefit from these applications. Facilities using intense radiation sources for purposes such as radiotherapy, radiation processing of products, preservation of foodstuffs and gamma radiography require special care in the design and operation of equipment to prevent radiation injury to workers or to the public. Similarly, appropriate controls are required for the many other radiation sources used in a variety of ways, e.g., gauges. Experience has shown that such technology is generally used safely, but on occasions there has been a lack of appropriate controls or circumvention of those that exist, and serious radiological accidents have ensued.

To the extent that reports on such accidents are incomplete or are unavailable to the scientific community, potentially valuable information is lost. Although the causes of accidents may be highly case specific, review of the circumstances in which they have arisen can yield generally applicable lessons that are of help in preventing further accidents or in improving the response to those accidents that do occur. This paper provides a summary of major radiological accidents and the lessons to be learned from them. It draws heavily on the accident investigations carried out and published by the IAEA [1–6] and on the sector specific compilations of accident case histories the IAEA has produced [7–9].

2. OVERVIEW

Table I provides a list of the fatal radiation accidents (excluding nuclear accidents, suicides, patient overdose accidents and brachytherapy accidents) that have been reported to the IAEA [10, 11]; undoubtedly there are some that have not been reported. It will be noted that significantly more members of the public than workers have died as a result of these accidents. This reflects the fact that once radioactive materials are outside a controlled environment, the potential for detecting and terminating an accident situation is greatly reduced and the potential for serious consequences is greatly increased. This underlines the need not only for the safe use of sources but also for effective security of radioactive materials.

There have been many accidents that have not resulted in fatalities but have resulted in serious radiation injuries [10] or, where the integrity of a sealed source has been breached, in environmental and economic damage. Examples of the latter which are addressed below are the accidents at Juárez, Mexico [12], Hanoi, Vietnam [5], and

TABLE I. FATAL NON-NUCLEAR RADIATION ACCIDENTS REPORTED TO THE IAEA

Year	Location	Radiation source	Fatalities	
			Workers	Public
1961	Switzerland	Tritiated paint	1	
1962	Mexico City, Mexico	Lost radiography source		4
1963	China	Seed irradiator		2
1964	Federal Republic of Germany	Tritiated paint	1	
1975	Stimos, Italy	Irradiator	1	
1978	Algeria	Lost radiography source		1
1982	Kjeller, Norway	Irradiator	1	
1984	Mohammedia, Morocco	Lost radiography source		8
1987	Goiânia, Brazil	Abandoned teletherapy source		4
1989	San Salvador, El Salvador	Irradiator	1	
1990	Soreq, Israel	Irradiator	1	
1991	Nesvizh, Belarus	Irradiator	1	
1992	Xinzhou, China	Research source		3
1994	Tammiku, Estonia	Waste sealed source		1
1996	Kutaisi, Georgia[a]	Radiotherapy source		1
Totals			7	24

[a] Detailed information not available, but listed in Ref [11].

Lilo, Georgia [13]. Clearly there are lessons that can be learned from these and the many other, often less serious accidents.

To help identify generic lessons to be learned, it is convenient to present the accidents under three headings: radiography and lost or abandoned sources, irradiation facilities and major contamination accidents.

3. RADIOGRAPHY AND LOST OR ABANDONED SOURCES

3.1. Radiography accidents

Industrial radiography is undertaken both in fixed facilities and with mobile sources on work sites. The sources are typically ^{192}Ir (0.1 to 10 TBq), ^{60}Co (0.1 to 100 TBq), X ray sets (60 to 300 kV) and accelerators (1 to 8 MV).

Over the years, this sector of use has given rise to the greatest number of accidents resulting in overexposures and deterministic effects, often 'radiation burns' to the fingers. Site radiography using mobile sources is particularly prone to accidents. The work is often undertaken in remote, difficult or even hostile environments and often without supervision. It is a highly competitive business and difficult to regulate. This provides the potential for equipment and human failures — a potentially lethal combination, as will be seen in Section 3.2.

The IAEA is preparing a report on Accidents in Industrial Radiography and Lessons to be Learned. The current draft includes 43 case studies, demonstrating the following primary causes of accidents:

- — inadequate regulatory control,
- — failure to follow operational procedures,
- — inadequate training,
- — inadequate maintenance,
- — human error,
- — equipment malfunction or defect,
- — design flaw,
- — wilful violation.

The most frequent and crucial failure is that of operators not following procedures and not correctly using a radiation survey meter to confirm that a source has returned to a safe position. If the source has become stuck or decoupled, then we are into the realm of uncontrolled exposure, and the severity of the accident becomes a matter of chance. In some cases, as described in Section 3.2, the sources can enter the public domain.

3.2. Lost or abandoned sources

The three fatal industrial radiography accidents listed in Table I involved the loss of a radiography source and deaths of members of the public. The Moroccan accident, described in Section 3.2.1, is typical of such accidents. There have been many more lost radiography source accidents that have resulted in people receiving radiation burns.

It is not just radiography sources that get lost or abandoned. The brief descriptions of the accidents at Tammiku, Estonia (Section 3.2.2) and Lilo, Georgia (Section 3.2.3), provide examples of the external exposure hazards that can ensue. However, once sources are out of control it is not just external exposure that can be a problem. The integrity of the sources can be breached, resulting in the spread of contamination. This is dealt with in Section 5, but it is a potential end point for any lost or abandoned sources.

3.2.1. Lost radiography source, Morocco, 1984

In this serious accident, eight members of the public died from overexposure to radiation from a radiography source. A 1.1 TBq (30 Ci) ^{192}Ir source became disconnected from its drive cable and was not properly returned to its shielded container. Later the guide tube was disconnected from the exposure device and the source eventually dropped to the ground, where a passer-by picked up the tiny metal cylinder and took it home. The source was lost from March to June, and a total of 8 persons (the passer-by, members of his family and some relatives) died; the clinical diagnosis was 'lung haemorrhages'. It was initially assumed that the deaths were the result of poisoning. Only after the last family member had died was it suspected that the deaths might have been caused by radiation. The source was recovered in June 1984 [14].

This is a classic example of a radiography accident and of the consequences that can ensue when no radiation surveys are performed to ensure that a source has returned to the fully shielded position.

3.2.2. Fatal accident at Tammiku, Estonia

In January 1994 in a scrapyard in Tallinn, Estonia, routine radiation measurements with a hand held monitor of a consignment of scrap metal identified a metal container incorporating a radioactive source. The Estonian Rescue Board recovered the item and close to the container measured an absorbed dose rate in excess of 2 Gy/h. They did not have the necessary facilities to examine the container, and it was transferred in its entirety to the national waste disposal facility at Tammiku, some 20 km outside Tallinn.

The facility was in a desolate location, and it had inadequate security. The waste in the facility was poorly segregated; in particular, the source from the scrapyard was put with low level waste. On 24 October 1994, three unemployed brothers from the nearby village of Kiisa broke into the facility to look for items that they could sell to scrap metal dealers in Tallinn. One of the items removed was the metal container found in January. In the process a cylindrical source fell out, was picked up by one of the brothers and placed in a coat pocket. Very soon after entry into the repository he began to feel ill, and a few hours later he began to vomit. He was admitted to hospital with severe injuries to his leg and hip and died on 2 November 1994.

The injury and subsequent death were not attributed to radiation exposure, and the source remained in the man's house with his wife and stepson and the boy's great-grandmother. The boy was hospitalized on 17 November with severe burns on his hands, which were identified by a doctor as radiation induced. The authorities were alerted, and the Estonian Rescue Board recovered the source from the house and returned it to the Tammiku repository on 18 November. The occupants of the house and one of the two surviving brothers were hospitalized and diagnosed as suffering radiation induced injuries of varying severity. After treatment, all were released from hospital.

In view of the poor state of the repository, no attempt was made to remove the source to accurately assess its activity. However, an assessment by the Swedish Radiation Protection Institute suggests that the source was probably a ^{137}Cs source of about 3.7 TBq (100 Ci) that was part of the internal wall of a sterilization chamber of Russian origin [15]. As a result of the accident, the Estonian authorities established a programme of work to update the inventory of radiation sources and to inspect storage conditions. By chance, one of the radiation experts involved had a radiation survey instrument switched on while travelling on a highway between Tallinn and Narva. As a result a second ^{137}Cs source, with an activity of 1.6 TBq, in another metal container, was identified and recovered.

With the help of the Estonian authorities, the IAEA carried out an accident investigation [6]. The report highlights as a cause for concern the potential for sources to be found in scrap metal and the need to put in place procedures to recover them safely. The need for national source inventories is evident, but details of the various types and designs of radioactive sources must also be readily available. The report notes that "there appears to be little information on the range of sources manufactured in the former USSR". With respect to the waste disposal facility, the report identifies lessons on providing sufficient segregation or preconditioning of sources prior to disposal and, crucially, on having adequate security. Also, there were lessons to be learned on the content of emergency plans for such situations.

3.2.3. Abandoned sources, Lilo, Georgia

This accident is being investigated by IAEA, but preliminary information has been published by doctors involved in treating those involved [13].

This accident occurred at the Lilo training centre for frontier guards, situated 20 km east of Tbilisi, the Georgian capital. The centre's present function goes back to 1992, following Georgia's independence. Prior to that it was a nuclear, biological and chemical training camp of the Soviet army.

In the summer of 1996, a number of frontier guards presented symptoms that were identified as radiation induced lesions. Eventually 11 persons with lesions were identified, and the four most seriously affected were transferred to France for treatment. A search for radioactivity found 11 ^{137}Cs sources, each with an activity of about 150 GBq (4 Ci), and four sources of much lower activity. The 150 TBq sources were of a type used to train Soviet civil defence specialists (during training exercises to detect radiation sources), and the weaker sources were calibration sources. Some were found buried around the site, consistent with their use in training exercises, and others were found in more accessible locations; the source most relevant to the exposures was found in the pocket of a coat. Investigations into the potential exposure of earlier groups of trainees at the camp are continuing.

4. INDUSTRIAL IRRADIATOR ACCIDENTS

Irradiation facilities have been the source of a number of fatal and other serious accidents. A representative selection of these is listed in Table II [2–5, 8, 16].

There are a number of different categories of irradiators. Reference [17] provides details of these categories and guidance on radiation safety in their design and use. Irradiators can be used for research or, more likely, as part of an industrial process to sterilize products, induce chemical changes or otherwise change the characteristics of a product. A major element of an industrial irradiator is the transport system, e.g., a conveyor and containers suspended from an overhead rail which moves the product close to the radiation source to give the required dose. The source can be either a gamma emitter such as ^{60}Co or ^{137}Cs, with activities ranging from a fraction of a petabecquerel to 100 PBq (3 MCi), or an electron beam accelerator. The latter usually have an activity below 10 MeV to prevent activation of the product, but higher energies can be used for research. The gamma irradiators are of two basic types: either wet storage, where for the safe position the source rack is lowered into a deep water pit, or dry storage, where the source rack is lowered into a dry pit and covered with a shielding plug.

Inside the irradiation chamber, the dose rates are often such that a lethal dose could be received in under 1 min. It is therefore extremely important to have well designed safety features, appropriate procedures, trained staff, a management committed to a good safety culture and appropriate regulatory control. The design of the safety systems should provide 'defence in depth'. Such a system has the following main elements:

TABLE II. SOME OF THE MORE SERIOUS IRRADIATOR ACCIDENTS REPORTED TO THE IAEA [2–5, 8]

Year	Location	Type	Consequences
1965[a]	Illinois, USA	Accelerator	Amputation of leg and arm (290–2400 Gy)
1975[a]	Stimos, Italy	Gamma	1 fatality (~12 Gy)
1982[a]	Kjeller, Norway	Gamma	1 fatality (~22 Gy)
989[a,b]	San Salvador, El Salvator	Gamma	1 fatality (~8 Gy), 2 persons with whole body doses of 2.9 and 3.7 Gy, burns to feet
1990[a,b]	Soreq, Israel	Gamma	1 fatality (10–20 Gy)
1991[a,b]	Nesvizh, Belarus	Gamma	1 fatality (~11 Gy)
1991[a,b]	Hanoi, Viet Nam	Accelerator	Amputation of 1 hand and fingers of the other (10–50 Gy)
1991[a]	Maryland, USA	Accelerator	Exposure to 'dark current': amputation of four fingers of each hand (~55 Gy)
1991	Forbach, France [16]	Accelerator	Exposure to 'dark current': skin lesions (~40 Gy)

[a] Ref. [8].
[b] Refs [2–5].

(a) *Redundancy*: the use of more than the minimum number of items, e.g., interlocks, to accomplish a given safety function.
(b) *Diversity*: the redundant systems or components that perform the same safety function should be based on different attributes, e.g., different principle of operation, variable or operating conditions.
(c) *Independence*: this is achieved through functional isolation and physical separation. There is a need to ensure that there cannot be a single mode failure.

At first sight, the design of the transport system does not seem particularly relevant to radiation safety. However, a poorly designed or maintained transport system increases the frequency of transport jams that require the operator to enter the facility. This can significantly increase the number of times the adequacy of the safety systems is challenged. It may also induce staff to look for ways of circumventing the safety systems to speed up work. Sometimes this is done with the tacit acceptance of management. This is likely to lead to the introduction of further unsafe procedures, and without regulatory intervention this could lead to an ongoing degradation of safety.

In some designs of gamma irradiators, transport jams can distort the product packaging, which then prevents the source rack from returning to its fully shielded position. This was recognized many years ago, and the suppliers of the facilities recommended the fitting of a metal source shroud to prevent such interference. In several cases the management did not implement the recommendation because of cost, and, as described in Sections 4.1, 4.2 and 4.4, a transport jam interfering with the source was the initiating event for several accidents.

The following sections briefly identify key elements arising from the accidents investigated by the IAEA.

4.1. Nesvizh, Belarus, 1991

The facility was a dry storage irradiator with a 28.1 PBq (760 kCi) ^{60}Co source. The precise details of the accident are not known, but certain facts are clear [4].

The initiating event was a jam in the product transport system in the middle of the night. The key required to raise the source to the irradiation position was in the main operating console after the accident, and it is likely that, contrary to operating procedures, entry was achieved without removing the key. This same key was required to operate a moveable floor that covered a pit at the maze entrance to permit entry. After the accident, the moveable floor section was found in the retracted position, and it is assumed that the operator was able to cross the pit by stepping on the moveable floor drive motor, which was situated in the pit. Thus a design flaw and failure to follow procedures cut out a major part of the safety features. It is likely that prior to entry the operator had lowered the source to the safe position. This is supported by the fact that he had a fully functional dose rate meter with him on entry and that other parts of the safety system, notably a pressure plate in the maze entrance, were functional and would have caused the source to automatically lower as he walked over it. However, the important point was that when the operator entered the irradiation chamber, the key was in the control panel, the system was powered up and the operator was only one step from exposure. The exposure that did occur could have been from accidental depression of the exposure button, component failure or a fault in the logic circuit.

The operator was exposed for about 1 min, receiving a dose of about 11 Gy with localized areas up to 20 Gy. He died 113 days later.

4.2. Sor Van (Soreq), Israel, 1990

This facility was of a wet storage design and had a 12.6 PBq (340 kCi) ^{60}Co source. This incident was also initiated by a product jam. No source shroud was fitted, and the source rack was stuck in the 'up' position. The jam occurred outside normal working hours, and when the operator arrived he was confronted by two contradictory signals. One was the 'source down' (or 'safe' signal), and the other was from the installed gamma alarm, indicating that the source was exposed. The gamma alarm had malfunctioned in the recent past, and the operator chose to believe the source down signal. In fact, the sensing microswitch for the source down signal was not working correctly. Contrary to operating procedures, the operator decided to enter the irradiation chamber. To do this he disconnected the gamma alarm and used an established trick to bypass the monitor test safety feature associated with the gamma alarm. The design of this safety feature is such that unless the gamma alarm detects background radiation, power to open a solenoid lock on the access door will not be provided. The trick involved cycling a power switch so that the monitor test circuitry picked up electromagnetic pulses produced by the making and breaking of the electrical contacts. This trick had become established because of operational problems with getting sufficient counts with the normal monitor test to allow access. This was the result of degradation of the efficiency of the detectors, and could have been overcome during maintenance.

The operator did switch on a portable radiation monitor prior to entry, but did not check it against a radioactive check source in the door frame. Unfortunately, the monitor was not functioning on the lower dose range to which he had switched.

The operator received a whole body dose of between 10 and 20 Gy, and he died 36 days later.

Thus, the direct causes of the accident were a combination of equipment malfunction and failure to follow safety operating procedures. The Israeli committee investigating the accident also identified a number of contributing causes [3]:

(a) A less than adequate design or assembly of the switch sensing the position of the source rack;

(b) The reliability of the room monitor test procedure;

(c) Inadequate tamper proofing of the door interlock mechanism against simple bypassing;

(d) The omission on the part of the plant management to install the protective shroud;

(e) The omission on the part of the plant management to enforce, by means of clear written instructions and warnings, the strict precautionary procedures recommended by the supplier (the operating manual was in English, but the operators' language was Hebrew);

(f) The use of damaged cartons that caused frequent transport jams;
(g) The inadequacy of the authorities' inspection and enforcement programme.

4.3. Hanoi, Viet Nam, 1991

This accident involved a linear accelerator being used for research in a government organization. After initially leaving the irradiation chamber with another researcher, a physicist returned to the chamber to readjust the position of a sample. The researcher, believing that the physicist had left the irradiation chamber, told the operators that the experiment was ready and the machine could be switched on. The facility was not equipped with any access interlocks, warning signals or closed circuit viewing of the irradiation chamber. The physicist continued to manipulate the sample while the accelerator was operating at 15 MeV. During a 2–4 min period the physicist placed his hands within 5–30 cm of the tungsten target three times. The severity of the radiation damage to the hands led within months to the amputation of the right hand and two fingers of the left. The doses to the hands were in the range 10–50 Gy.

Although there were regulations in place, the regulatory inspection programme was limited. It was also noted that there was a necessity to separate the radiation regulatory body function from users and facility operators. While the regulatory situation contributed to the accident, the primary cause was lack of appropriate installed safety systems [5].

4.4. San Salvador, El Salvador, 1989

This was a wet storage facility with a 0.66 PBq (18 kCi) ^{60}Co source [2]. When commissioned in 1975, this facility incorporated state of the art safety features and had trained operators. However, for most of the period up to the accident the country had been in a state of civil war. The trained operators had left, subsequent staff received only informal word of mouth training, and safety messages became corrupted with time. The facility was regarded as a potential target for attack in the civil war. As a result, its presence was not advertised, and there was a reluctance to commit information, including safety and operational procedures, to writing. The operating manuals were in English, which the operators, who spoke only Spanish, could not understand. A 'make do and mend' approach was prevalent. No preventative maintenance was carried out; key safety systems were not repaired and in some cases were removed. There was no regulatory control and no contact with any radiological protection expertise. The overall state of affairs can be summarized as 'an accident waiting to happen'. At 02:00 on 5 February 1989, this potential was realized.

Again the initiating event was a transport jam, which in the absence of a source shroud had caused the source to be jammed in the 'up' position. The operator used a variety of 'usual' but highly dangerous procedures to overcome the situation. These included raising the source rack to its highest point and letting it drop under gravity to try to break through the obstruction, and when this did not work he used the same trick as in the Israeli incident to gain access. He had little or no understanding of what he was doing, and as a result he and two colleagues were able to gain access to the facility while the source was exposed. They received whole body doses between 3 and 8 Gy, with localized doses to their feet of tens of grays. The operator later died.

They had managed to free the source and return it to the safe condition. Within hours they were ill and went for medical treatment, but the cause had not been identified and management did not recognize that there had been an accident. The facility continued to operate for two more weeks, and a second accident developed. When the source rack was freed, its frame had become distorted, and individual source pencils, each of about 23 TBq (620 Ci) ^{60}Co, had started to fall out. Fortunately, most of the pencils went into the water filled source storage pit, but one dropped onto the conveyance system. Four more people were exposed to between 0.1 and 0.2 Gy before the significance of the accident was recognized and the facility closed until expert assistance to recover the sources was available.

There was significant potential for a source pencil to have been taken out with the product and then into the public domain. The accident scenario might then have developed along the lines of the Juárez and Goiânia accidents (Sections 5.1 and 5.2).

5. MAJOR CONTAMINATION ACCIDENTS

So far, this paper has focused on accidents which have only involved external exposure. However, there is always the potential for the integrity of the source containment to be breached and for the spread of radioactive contamination, giving rise to both internal and external exposure and to environmental and economic consequences.

The worldwide metals recycling industry is particularly vulnerable to being the unwitting recipient of radioactive material entering the public domain. The paper by Azuara [18] describes a recent significant accident in Spain. In a recent review [19], Lubenau lists 49 known accidental meltings of radioactive material (but indicates that many go unreported) and identifies this as "the most common and most visible manifestation of a larger problem — inadequate control, insufficient accountability and improper disposal of radioactive materials".

Where radioactive material has not been discovered until it has been melted with scrap metal, the metal mills and foundries have incurred costs for decontamination, waste disposal and shutdowns that typically amount to about US $10 million per event [19]. This has led many organizations in the metals recycling industry to install portal detectors to monitor all incoming consignments for radioactivity and to a wider use of hand held monitoring equipment. This will hopefully help to mitigate the consequences of some accidents, but there is a clear need to improve control measures to prevent sources reaching the public domain in the first place.

High activity sources, such as those used in radiotherapy, provide the potential for the most significant accidents, such as those in Juárez, Mexico [12], and Goiânia, Brazil [1], which are described below.

5.1. Juárez, Mexico, 1983

In 1977 a medical centre in the city of Juárez, Mexico, purchased a second-hand radiotherapy unit from the USA which incorporated 37 TBq of ^{60}Co in the form of 6000 cylindrical cobalt metal pellets, each 1 mm × 1 mm, inside a doubly encapsulated source capsule. The importation of this unit was not reported to the competent Mexican authority. Because of lack of resources, the unit was never used, and it was stored in a warehouse without any safety precautions. In December 1983, a technician who worked at the medical centre dismantled the unit, without authorization, in order to sell it for its scrap value. It was taken on a pick-up truck to a scrap yard, and during the journey the technician, out of curiosity, deliberately ruptured the unrecognized source capsule. Because of a mechanical failure on the return journey, the contaminated truck was left in a residential area for 40 days. At a distance of 1 m from the truck, dose rates of up to 650 mSv/h could be encountered. Source pellets were scattered throughout the scrap yard and surrounding areas, and along the transport route. However, most of the activity went into scrap metal consignments to various foundries, where it was incorporated into 'rebars' (reinforcing bars for concrete) and table legs.

The discovery of the accident occurred on 16 January 1984, when a lorry carrying rebars passed close to the Los Alamos National Laboratory, USA, and set off radiation alarms designed to warn of radioactive material leaving the site. In the intervening period, significant volumes of potentially contaminated metal had been produced and distributed by several foundries. A major survey programme to trace these materials had to be instituted. In Mexico, surveys were made of 17 600 houses which could have incorporated contaminated rebars, and as a result 814 houses were demolished. In the USA, a search for the table legs, which covered 1400 customers, revealed 2500 contaminated items, which were returned to Mexico for disposal. In addition, a major decontamination programme of the various sites in Juárez had to be undertaken. In total, active waste amounting to 16 000 m^3 of soil and 4500 tonnes of metal was collected. Reaching a decision on a repository for the waste was protracted and complicated the recovery programme.

Though the activity was widely dispersed, practically all the doses arose from external irradiation. Some 4000 people were exposed, 720 to doses between 0.005 and 0.25 Gy, 75 to between 0.25 and 3.0 Gy and 5 to between 3.0 and 7.0 Gy. Surprisingly — and thankfully — there were no fatalities.

5.2. Goiânia, Brazil, 1987

Following the break-up in 1985 of a medical partnership in a clinic in Goiânia, Brazil, a teletherapy unit containing a 50.9 TBq ^{137}Cs source was abandoned in the clinic's former premises, which were partly demolished. In September 1987, the source was removed from its protective housing in the teletherapy machine by local people who had no knowledge of what it was and were simply after its scrap metal value. The source was in the form of a highly soluble and readily dispersible caesium chloride salt, compacted to form a coherent mass within a doubly sealed stainless steel encapsulation. The source was later ruptured, and over the next few weeks the activity was widely dispersed in the city. Many people incurred large doses from both external and internal exposure. Four of these people died, and 28 suffered radiation burns. The extent and degree of contamination were such that seven residences and various associated buildings had to be demolished, and topsoil had to be removed from a significant area. The decontamination of the environment took about 6 months to complete and generated some 3500 m^3 of radioactive waste.

The IAEA's report on the accident [1] identified many lessons, and while these included lessons related to appropriate regulatory control, the report also clearly stated in respect of source security that "the regulatory system cannot and must not detract from managerial responsibilities; in particular, it cannot substitute for the licensee's responsibility for safety".

5.3. Accident preparedness

There are obviously lessons to be learned from these accidents in respect of accident preparedness arrangements. However, equally clearly, countries are not endowed with limitless resources and need to take into account the probability of occurrence, the potential scale of the problem and the possible use of existing arrangements. The Goiânia and Juárez accidents provide a benchmark for credible large scale radiological accidents against which one might review a country's emergency plans for dealing with such events. The potential scale of the problem can perhaps be gauged from some representative data for the Goiânia accident, given below.

Health consequences:

— 249 people were contaminated externally;
— 129 people had significant internal contamination (all were constantly producing external contamination due to the presence of ^{137}Cs in the sweat);
— 21 people received doses in excess of 1 Gy and were hospitalized;
— 10 needed specialist medical treatment;
— 4 died.

Localizing the activity:

— 67 km^2 of land area was monitored in the first few days (using monitors carried on foot or fitted in cars and helicopters);
— 7 major sites (each of about 100 m radius) were isolated and required full protective clothing and respirators to enter;
— 42 other significantly contaminated sites were identified;
— activity was transported to many other cities.

Monitoring regimes:

— 112 000 people were monitored;
— all banknotes in circulation were monitored;
— the city's bus fleet was monitored;
— the water supply and local produce needed monitoring.

Countermeasures and actions:

— 200 people were evacuated from 41 houses;
— 85 houses required significant decontamination;
— 7 houses were demolished;
— 3500 tonnes of active waste was produced.

By any standard, the effort involved in dealing with a Goiânia scale emergency would be very significant. The Brazilians used a total of 575 professional and technical staff and many support staff dedicated to the emergency and subsequent recovery over a period of about three months, with a lower level of involvement over another three months. The international community helped with the provision of consultants and specialized equipment.

A variety of specialized on-site functions were needed in Goiânia, e.g.,

(a) An instrument workshop to repair and maintain monitoring instruments.
(b) Training facilities for the many staff who had not used a monitor for years or had no operational experience.
(c) A dedicated laundry.
(d) A factory unit to produce the specialized waste containers.
(e) A suitable waste disposal site. In both Juárez and Goiânia, decisions on a disposal site delayed recovery.

While important, these specialized on-site facilities are mostly relevant to the recovery phase, and though they would benefit from planning there would be time, albeit limited, to put them in place. The key aspect is undoubtedly the response in the first few days, particularly on the first day, to obtain suitable monitoring data and make assessments so that

(a) the emergency can be brought under control,
(b) necessary countermeasures can be implemented,
(c) appropriate and accurate information can be made available to the public through the media.

6. CONCLUSIONS

This paper has summarized some of the world's major radiological accidents and the lessons to be learned from them. Over the last decade, the IAEA's reports of accident investigations [1–9] have contributed significantly to the process of learning these lessons. However, it is not only the big accidents from which we can learn; we can also learn from the smaller accidents and the near misses. This feedback is relevant to suppliers in improving the safety aspects of design, to management in developing radiation protection measures and the training of their staff, and to national and international authorities in helping them prioritize radiation resources and their use. While the reporting of radiation accidents and the dissemination of information are improving, there is still much that can be done to improve this process. This Conference provides a useful focus, but national [20] and international accident databases can play a significant role. Here it is important that the output from accident reporting is in a format that clearly identifies the lessons to be learned, is targeted at the appropriate audiences and can be readily used as the source of training material.

Putting feedback mechanisms in place is, however, only the first step in the process. Doing this helps raise awareness of the nature and magnitude of the problem, but action must still be taken to improve practical protection measures to prevent accidents or mitigate their consequences. Suppliers, management and radiation workers themselves have to accept responsibility for this process, but it is clear from many of the major accidents that an important prerequisite is an effective regulatory infrastructure for the control of radiation sources. The provisions embodied in the International Basic Safety Standards [21] and the programmes of work covered in the presentations at this Conference are focused on achieving this objective.

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MAIN ISSUES IN THE ACERINOX EVENT

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Abstract

MAIN ISSUES IN THE ACERINOX EVENT.

The paper sets out the main characteristics of the radiological incident which occurred in Spain in 1998 as a consequence of melting a radioactive source of ^{137}Cs. It is hoped that this story, as well as the considerations and arrangements adopted in Spain to avoid similar situations in the future, will be useful in this Conference oriented towards improving the safety of radiation sources and the security of radioactive materials.

1. FACTS

Very briefly, the facts are as follows:

On 30 May 1998, an unnoticed source of ^{137}Cs was (accidentally) placed into an electric furnace of Acerinox, a stainless steel factory located in Los Barrios (Cadiz, Spain). As a result, the source was melted down. Some of the vapours went out through the chimney flue; a fraction of this effluent was caught in the filter system used to collect the dust produced in the process of melting metal scrap. As a consequence, some 270 tonnes of dust already collected were contaminated.

On 1–2 June, as a result of the periodic maintenance and cleaning of the filter system, the dust was removed, and much of it was sent to two different factories, in settlements several hundreds of kilometres away from Acerinox.

One of these companies, Egmasa, received some 150 tonnes of the contaminated dust. Egmasa, located in Huelva, is engaged in stabilizing waste produced in the region's industrial activity, preparing with the dust, cement and sand a dough that is spread in layers in an old marshland. Some 500 tonnes of contaminated mass were produced as a consequence of this process. The second company, Presur, received some 20 tonnes. Presur is engaged in producing metals such as copper and nickel from such dust. The tooling of both companies was contaminated, but the most important result was the increase of contaminated lands and the spread of waste generated at Egmasa, raising the amount of contaminated material from 150 tonnes to some 500 tonnes.

The first warning of contamination was given on 2 June by a gate monitor installed at the door of the Acerinox factory on an empty truck coming back from carrying the dust.

On 9 June, the Spanish Nuclear Safety Council (NSC) was informed by Acerinox about "some caesium 137 radioactive contamination found in the dust kept in the filtering system".

On 10 June, the NSC sent an inspection team to collect enough information to make a first assessment and to carry out an additional plan.

On 11 and 12 June, the NSC sent Acerinox several binding conditions limiting the operation of the factory and preventing access into the contaminated areas. Arran-gements were made for immediately checking the possible contamination of workers.

In the afternoon of 11 June, the NSC received information, through the European Community Urgent Radiological Information Exchange (ECURIE) system, that a significant increase in the level of ^{137}Cs had been observed in the atmosphere in both southern France and northern Italy. The values found were in some cases as much as 1000 times above usual background values (2000 $\mu Bq/m^3$ compared with 2 $\mu Bq/m^3$). It was also estimated, according to meteorological information available, that the increase was probably related to a release coming from some point between the south of Spain and the north of Africa.

On 12 June, the CSN reported the Acerinox incident to the IAEA, international institutions, national authorities and the mass media. Because of the coincidence in time and the identical nature of the radioisotopes involved, the CSN assumed a link between the phenomenon observed in France and the Acerinox release as being "most probable".

2. MAIN CONSEQUENCES

The main consequences of this episode are as follows.

2.1. Human health and environment

Fortunately there have been no noticeable consequences to workers. To assure the absence of internal contamination, a sample of some four hundred people, among the total workforce of the different companies, were examined. Only six people were found to have slight levels of ^{137}Cs contamination.

Measurements of a large number of samples of water, air and vegetables taken in nearby towns and at some points several hundred kilometres away strengthen the view that the presence of caesium, where found, is negligible. The population will not suffer any increase in the total dose as a result of this episode.

In European countries outside Spain the environmental impact was minimal: although significant increases of caesium were found at some places in Italy, France and Switzerland, the absolute values were in all cases negligible from a radiological point of view.

On the other hand, the environmental consequences in Spain, already referred to, can be qualified as important — first, because of the great amount of waste generated, and second, and most important, because it will be impossible to restore the marshland, where boundary conditions must be established.

I would stress that the total amount of waste generated is close to 1000 tonnes, so that the initial figure of 270 tonnes was multiplied by a factor of about 4 by the movement of contaminated dust and the decontamination of the three factories involved. Happily, from the beginning, Enresa, the Spanish company responsible for the management of radioactive waste, took on the task of directing clean-up operations and storage in the El Cabril radioactive waste repository.

2.2. Economic implications

It will be difficult to establish an accurate figure for the economic cost of the whole process, because there are several aspects involved and some of them must be considered after a longer period of time.

Nevertheless, a rough estimation of the main items gives the following figures:

(a) Interruption of the factories' activities: more than US $20 million.
(b) Clean-up operations: more than US $3 million.
(c) Waste storage: more than US $3 million.

The total cost of this process is thus over US $25 million. Moreover, the impact upon Acerinox shares on the stock market should be considered in the long term, as well as the potential loss of sales contracts.

Finally, it must be stressed that no negative repercussions on either trading or tourist activities have occurred.

2.3. International repercussions

Throughout June 1998, most European countries asked for information about the characteristics of the episode and mainly about the radiological contamination of the environment, food, water, etc., in Spain. There was no anxiety about the situation in those countries, since they can control the increase of radioactivity on their own. Their disquiet was due to the heavy movement of people towards Spain in this holiday period and also to the potential repercussion on agricultural trading activities.

I would like to thank the IAEA and the European countries for their support and positive attitude during this episode.

2.4. Social alarm and mass media behaviour

The Acerinox episode gave rise to a lot of concern amongst the Spanish people: concern among the some 30 000 people making up the population of the three towns directly affected, and among the public generally, a concern well nurtured by the mass media. Local councils of the cities, regional governments and the national Parliament were involved, and the president of the NSC voluntarily appeared in Parliament to explain the characteristics and circumstances of the event.

To summarize the meaning of their questions in a few words, I can say that once the slight radiological importance had been clarified, three main questions remained:

(a) How was it possible that the source was not detected in any step of a long process before it was melted?
(b) Can a similar situation occur in the future?
(c) In such a case, is it fair to expect worse consequences on workers, the population or the environment?

On the other hand, it is interesting to stress that the main criticism of the activities of the Spanish NSC did not arise from its technical actions, but because it was generally believed that information was given out later than necessary. That is so despite the several hundreds of interviews given to local, national and international newspapers and TV channels. In such a situation, it is a mistake to forget that providing information to the media is almost as important as dealing with the problem, since they can both reduce or increase social alarm.

Starting from this short description of the event and its main consequences, let me mention some aspects that involve the main reflections and initiatives taken by the Spanish authorities.

3. CHARACTERISTICS OF THE ACTIVITY

Attention must be paid to the characteristics of scrap trading activities. This is because these activities are very important, since recycling scrap is actually a major way of producing fresh metal. It is estimated that the global movement of these 'raw materials' involves 400 million tonnes per year.

It is useful to keep in mind that trading means in fact a long concentration process that starts in the field of retail, with millions of small operations involving relatively small amounts of scrap. Part of this scrap is consumed on national markets, and the rest is placed on the international market through a small number of brokers; in both cases, the scrap is previously classified and grouped according to its final destination. In short, it is possible to acquire metal scrap coming from any country in the world without a clear reference to its origin. In Spain, some 12 million tonnes of metal scrap is used every year, and about half of it is bought on international markets.

Another aspect to be considered arises from the fact that, in general, neither scrap trading activities nor industrial processes using this raw material are subject to any specific regulation to cope with the possible presence of improper radioactive material. Concerning this specific event, it is important to stress that, under current rules, Acerinox was not obliged to have systems installed to detect the presence of radioactive materials nor to make a prompt report of the incident to the NSC. In fact, there was a period of 9 days between the source's melting and the first report from Acerinox. This delay was the cause of the main negative consequences: the dust was spread out, involving two other industrial processes; the amount of waste was increased by a factor of about 4; and some uncertainties about the health of the workers remained unresolved for longer than was appropriate. Nevertheless, following the legal reports, Acerinox should not have to face any legal responsibility for this.

A third aspect to be considered is the fact that this is the situation in Spain and in general in the world, although it is very well known that the existence of contamination among metal scrap and the undue appearance of radiation sources are frequent occurrences. In fact, this subject has already drawn the attention of the IAEA. This problem was analysed at international meetings in 1994 and 1996. I would point out that there have been more than 300 incidents related to the melting of radiation sources during the last ten years. That means an average of 30 incidents per year, almost three episodes per month.

By the way, steel factories are so aware of the problem that the contracts they sign usually include a clause establishing that the material supplied will be free of radioactivity. Moreover, some factories, like Acerinox, long ago installed gate monitor detection systems at the scrap entry point. This behaviour reflects a response to a possibility that the factories try to eliminate.

Nevertheless, the remedial actions taken have not been 100% effective, and we can expect similar incidents to happen in the future. The Acerinox case is only one more in the list of incidents that will be periodically reported, and the consequences that we will face in each case will vary.

4. INITIATIVES

The wide negative impact of the Acerinox event has created a great awareness among the people of Spain, and we have a firm will to take the actions, initiatives and measures necessary to ensure that the number and size of these episodes be kept as low as possible.

In this regard, several meetings have been held among representatives of the Spanish Ministry of Industry, the NSC, the National Scrap Traders Association and steel utilities. Though final conclusions have not yet been drawn, I shall describe the main guidelines and certain specific aspects already agreed upon.

First, the possibility of putting the whole of industrial activity into the framework of the regulations currently applied to radioactive plants has been rejected. It is thus considered that to control the key points of the process is equally effective and a better choice to not unduly increase burdens on enterprises.

Second, it has been considered that contaminated scrap and radioactive sources are in reality quite different issues, because of the potential damage they can cause. The presence of contaminated metal scrap is a rather general problem of steel factories, but the presence of radiation sources in a specific load is a consequence of a wider issue, namely the lack of effective control of these sources, which can involve quite a lot of different situations and circumstances.

Third, in order to achieve proper control it is useful to discuss the characteristics of the industrial process in which the control measures have to be taken. Control at the final destination can be effective for detecting contaminated scrap, but the problem of radiation sources must be faced by endeavouring to effect control at the origin.

4.1. Control at the final destination

Several actions have been considered appropriate to improve control at the final destination:

(a) To install detection systems at the entrances to factories to check loads coming by truck or by ship from abroad. Such action will be more effective for detecting contaminated metal scrap than for detecting encapsulated sources, because of their armour and the shielding effect of the scrap in which they are hidden. This initiative will affect the steel factories and national scrap traders, and it is estimated that about 12 million tonnes of metal scrap will be inspected at about 90 different points. As a result of the agreement with the Government, detection systems are being voluntarily installed. Nevertheless, the Spanish Ministry of Industry is considering the possibility of issuing an Act establishing compulsory fulfilment of this step.

(b) Training courses will be carried out free of charge in the short run to improve the knowledge and skills of workers dealing with radiation sources and contaminated scrap.

(c) In order to achieve good performance of the detection systems, gauging and maintenance will be done at least initially with the technical support of a specialized public laboratory.

(d) Additional studies are being carried out to define the procedures that must be followed in the event that some radioactive material is detected or a radiological incident occurs. These procedures are considered very significant in order to maintain an effective control in incident situations, even though the whole of industrial activity still remains 'unregulated'.

(e) Other possible actions are still under consideration. In this connection, the most important concerns are to always keep the load's origin clear and to reinforce clauses that define the responsibilities of suppliers.

4.2. Control at origin

We believe that effective control over radiation sources will only be possible if there is an organization in each country looking after throughout their useful lives and afterwards.

We know that this is the position taken by the IAEA, which is working on specific projects such as the model project described by J. Qian in the next session, in order to improve the infrastructure devoted to this activity in some countries. I would like to express Spanish support for this project and to stimulate the consideration of new activities that could gradually improve the current situation. In this regard, I would like to make three suggestions:

(a) The first is related to the possibility of warning the international community if it becomes known that a radiation source has been lost. We believe that this is feasible and, inexpensive and that it would help to establish a kind of international network of control.

(b) The second initiative is related to the need to improve knowledge of the number and characteristics of sources whose use in industrial processes began a long time ago and that in most cases will now be out of use. These are probably the most dangerous sources, because they are part of industrial processes that may be close to being dismantled, because their presence is unknown and because their capability of causing a radiological incident is still high.

(c) Finally, a third suggestion is oriented towards the analysis of the main processes that usually use radiation sources, looking for those aspects that could provide specific elements or points of control.

I would like to end this address by expressing the confidence of the Spanish Nuclear Safety Council that the remedial actions it carries out in the future will be able to define a satisfactory state in which episodes like that at Acerinox will be unknown.

RESPONSE FROM INTERNATIONAL ORGANIZATIONS

(Briefing Session 2)

Chairperson

J. SHAVER
World Customs Organization

INTERNATIONAL STANDARDS ON THE SAFETY OF RADIATION SOURCES AND THE SECURITY OF RADIOACTIVE MATERIALS

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Abstract

INTERNATIONAL STANDARDS ON THE SAFETY OF RADIATION SOURCES AND THE SECURITY OF RADIOACTIVE MATERIALS.

The paper treats its subject in the context of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS), published by the International Atomic Energy Agency in 1996. The BSS presume that governments ensure the safety of radiation sources and the security of radioactive materials through appropriate legislation and regulations and through the establishment of an independent regulatory authority with adequate funds and other resources. Many of these assumptions, however, are not valid in much of the world. To improve matters, the paper suggests (1) that international bodies adopt the technical recommendations concerning the safety of radiation sources made in ICRP Publication 76, (2) that the radioactive materials security requirements of the BSS be greatly expanded and (3) that the International Atomic Energy Agency encourage the application of the BSS throughout the world, e.g., through the provision of assistance through its Technical Co-operation Programme.

1. THE INTERNATIONAL BASIC SAFETY STANDARDS

In order to solve a problem, one first needs a yardstick for measuring its extent. In the case of the many problems related to the safety of radiation sources and the security of radioactive materials, the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources [1] — the so-called BSS — are such a yardstick. The BSS, which were published by the International Atomic Energy Agency in its Safety Series in 1996, will be the focus of my presentation.

The first point that I should like to underscore is the large number of relevant international organizations which co-sponsored the BSS. They were — in addition to the International Atomic Energy Agency itself — the Food and Agriculture Organization of the United Nations (FAO), the International Labour Organisation (ILO), the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (NEA/OECD), the Pan American Health Organization (PAHO) and the World Health Organization (WHO).

FAO became a co-sponsor because of its interest and expertise in the area of food contamination by radioactive substances, ILO because of its responsibilities in the area of occupational radiation protection, WHO because of its interest in the radiation protection of patients, and so on. At the time when the BSS were being formulated, it was not evident that we would have to tackle the security problems which are the subject of this Conference. If it had been, I am quite sure that the World Customs Organization, INTERPOL, the European Commission and other organizations would have joined the list of BSS co-sponsors.

The purpose of the BSS is simply to promote coherent and consistent approaches to radiation safety. The layout of the BSS is generally well known to people working in the radiation safety field, including most of those attending this Conference. The BSS include a Preamble entitled Principles and Fundamental Objectives, a main body entitled Principal Requirements and a series of Technical Appendices and Schedules. There are only a few principal requirements and a relatively modest Appendix devoted to the safety of sources; my presentation will concentrate on them.

2. PRESUPPOSING GOVERNMENTAL RESPONSIBILITIES FOR RADIATION SAFETY AND SECURITY

Let me first emphasize, as I did in my welcoming remarks, that the BSS do not (indeed *may* not) impose responsibilities on governments. Instead, they presuppose that governments have discharged their natural responsibilities. This is made clear in the Preamble to the BSS, which touches on the responsibilities of governments and to which I would like to refer very briefly.

The Preamble states that the BSS are based on the presumption that governments have proper legislation and regulations in place to deal with problems of the safety of radioactive sources and the security of radioactive materials and that they have established independent regulatory authorities able to license sources, inspect them and enforce safety requirements.

The BSS have in fact assumed that in every country there is a regulatory authority with the necessary powers and resources and with effective legal independence (I wish to emphasize *resources* in particular, because they are something that regulatory authorities are usually lacking). The BSS have also assumed that governments can provide, either directly or indirectly, essential support such as personal dosimetry services, calibration services, information exchange mechanisms and, of course, personnel training.

However, many of these assumptions, made back in the early 1990s when the BSS were being prepared, have proved to be wrong for a large part of the world: it is not true that there is proper legislation in most countries — indeed, many countries have no legislation at all; it is not true that all countries have proper regulations in place — many have no regulations at all; it is not true that in most countries there are independent regulatory authorities invested with the necessary powers to perform the work required of them; and, finally, it is not true that when a regulatory authority exists it always has the necessary resources at its disposal.

This is an important issue which this Conference must consider: Should governments be strongly urged to clearly undertake to discharge their natural responsibilities or not? A positive recommendation from you may be good not only for the outcome of this Conference, but also for the actual safety of radiation sources and the security of radioactive materials in the years ahead. That having been said, let me revert to the BSS themselves.

3. REQUIREMENTS FOR SAFETY AND SECURITY

The BSS contain a number of requirements which are relevant to safety and security. In the jargon of the BSS they are known as administrative requirements, radiation protection requirements, management requirements, technical requirements and verification of safety requirements.

In the light of what we have learned in recent years, it would now seem that the administrative requirements — which were previously thought to be of secondary importance, simply because they appeared to be so obvious — have become very important.

The administrative requirements of the BSS are extremely simple: the BSS rely on the existence, in every single country, of a system for the notification, registration and licensing of radiation sources. What is taken as a self-evident requirement in many Western countries is, I repeat, not met in many parts of the world. Indeed, many countries are not even aware of the need to meet this requirement, and consequently the authorities in those countries do not know how many sources exist within their territories or where the sources are, and, it follows logically, there is no registration of sources. That is why the administrative requirements are so important.

As the BSS regrettably took the existence of the administrative requirements for granted, they placed more emphasis on the three technical requirements, relating to security of sources, defence in depth and good engineering practice. With the benefit of hindsight, I feel that we were very naive in placing so much emphasis on the technical and management requirements when the basis — the administrative requirements — had not been established.

The defence in depth requirement — that is to say, the requirement that there be a multilayered system of safety provisions for the purpose of preventing accidents, mitigating the consequences of accidents and restoring sources to safe conditions — was, I think, highlighted in the excellent review presented by J. Croft in Briefing Session 1. Good engineering practice is something which we have taken for granted at times but which is not always in place. The BSS presume that sources are always reliable and built to approved engineering standards, with sufficient safety margins, and (this is very important) that they take account of research and development results — not being fossilized in time.

The security of sources requirement focuses on the prevention of theft, damage and unauthorized use by ensuring that control is not relinquished, that sources are not transferred to unauthorized users and that periodic inventories are conducted, particularly of movable sources. We continue to believe that this requirement covers all essential security issues and that the problem of security cannot be tackled by controlling illicit traffic at borders or asking the police to find sources. The problem of security will be solved only when there are everywhere national systems that ensure that control is not relinquished, that sources are not transferred to unauthorized users and that periodic inventories are being conducted. Unfortunately, however, we are not in such a situation. That is why the help of customs and border controls and of the police is at the moment essential.

The management requirements include — besides quality assurance, attention to human factors and the use of qualified experts — safety culture. This is a very elusive requirement. The expression 'safety culture' is not the most felicitous, and when it is translated into other languages there are problems. Basically, what was intended with the concept of safety culture was to make it clear that safety should be the highest priority in organizations handling radiation sources, which should be prepared to identify and correct problems promptly; that clear lines of responsibility should be established, not only for organizations in handling sources but in the governmental agencies controlling the use of sources. The lines of authority for decision making should be clearly defined, but, as you know, this is not normally the case, particularly in the medical field, where the highest authorities in hospitals are often unaware of the safety conditions in their radiology and nuclear medicine services.

The problem of safety culture — or lack of safety culture — is particularly critical, since the dissolution of the Soviet Union, in the Newly Independent States, where there is a lack of tradition in the control of radiation sources.

As regards the quality assurance requirement, the recent accident that occurred with radiation sources in Costa Rica, where several people were killed, clearly resulted from the fact that this requirement was not being met.

As regards the human factors requirement, the main point is that operating personnel should be properly trained and qualified. In many of the accidents reported at this Conference, lack of training and qualifications was a common cause of failure.

Also important are design in accordance with ergonomic principles, the availability of equipment and software for reducing the likelihood of human error, and the provision of means for detecting human error and facilitating intervention when it occurs.

The possibility of verifying safety is very important, but it does not exist in many countries, as they are failing to identify potential exposure pathways, to estimate probabilities and magnitudes of potential exposure, and to assess the quality and extent of safety provisions.

Last but not least, monitoring for the verification of compliance and record keeping are things which the BSS call for very specifically.

4. OUTLOOK

The foregoing is a summary of what the BSS offer the international community, but are the BSS requirements enough? In my opinion, they are a necessary but not a sufficient condition for ensuring safety and security.

First, sufficiency demands a higher level of quantification, and I would like to see international bodies adopting — as soon as possible — the ICRP's latest technical recommendations concerning the safety of sources, recently published as ICRP Publication 76 [2]. Those recommendations offer us an opportunity to embark on a more quantified approach to radiation safety.

Second, the security requirement should clearly be expanded; it takes up only half a page in the BSS. Even if countries, following what appears in the BSS Preamble, adopt legislation and establish regulatory authorities and, following the administrative requirements, adopt systems of notification, registration and licensing, and, following the technical requirements, adopt measures for ensuring that the control of radioactive sources is not relinquished, all that is not enough for tackling the problem of security.

The essential issue is not the existence of standards, but their application. Under its Statute, the International Atomic Energy Agency has to provide for the application of the BSS. There are several ways of providing for the application of such standards, a very important one, particularly for those countries where the situation is critical, being the provision of assistance through the IAEA's Technical Co-operation Programme. But this is the subject of the next presentation, by J. Qian, the IAEA's Deputy Director General for Technical Co-operation.

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THE IAEA TECHNICAL CO-OPERATION MODEL PROJECT ON UPGRADING RADIATION PROTECTION INFRASTRUCTURE

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Abstract

THE IAEA TECHNICAL CO-OPERATION MODEL PROJECT ON UPGRADING RADIATION PROTECTION INFRASTRUCTURE.

An unprecedented international co-operation effort has been launched to improve radiation and waste safety infrastructure in more than 50 International Atomic Energy Agency (IAEA) Member States within the framework of an IAEA Technical Co-operation Model Project. The objectives of the project are to establish, by the end of the year 2000, an adequate radiation and waste safety infrastructure in the Member States concerned, including a system of notification, authorization and control of radiation sources and an inventory of radiation sources and installations. These objectives are in line with the statutory mandate of the IAEA, which provides that safety standards are also to be applied to its own operations, including all technical co-operation activities. The adequate level of safety needs to be commensurate with the use of radiation sources in each country, based on the requirements of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS). For many years, the IAEA has been gathering information on national infrastructures for assuring safety in applications of nuclear and radiation technologies and has filed these data in its Country Safety Profiles. These profiles served as a basis for identifying Member States which needed assistance and for defining the required action plans for improvement. Project milestones were defined to facilitate the setting of priorities, the timing and monitoring of progress and the optimization of resources. With this integrated and synchronized approach, the first project milestone, aimed at bringing about a system for notification, authorization and control of radiation sources in all countries, is being achieved. These milestones are ensuring that the IAEA's guidance is optimally applied to achieve compliance with the BSS and with tools tailored to the implementation of these action plans, such as the Regulatory Authority Information System (RAIS), which has been developed to facilitate decision making in each Member State. Finally, methodology for peer reviews has been made available, the first estimated results of which are presented in the paper.

1. BACKGROUND

By its Statute, the IAEA is authorized to establish or adopt safety standards for the protection of health and minimization of danger to life and property, and to provide for the application of these standards to its own operations as well as to operations making use of materials, services, equipment, facilities and information made available by the IAEA.

The safety standards of reference are the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS) [1], which was published in 1996. Regarding technical assistance in this field, the IAEA's Statute further requires that its Board of Governors consider the "adequacy of proposed health and safety standards for handling and storing materials and for operating facilities" before giving approval to technical co-operation projects.

From 1984 to 1995, information specifically relevant to radiation safety was obtained through more than 60 Expert Team missions undertaken by Radiation Protection Advisory Teams (RAPATs) and follow-up technical visits and individual expert missions. The RAPAT programme documented major weaknesses, and the reports provided useful background for the preparation of national requests for IAEA technical assistance.

Building on this experience and subsequent policy reviews, the IAEA took steps to evaluate more systematically the needs for technical assistance in areas of nuclear and radiation safety. The outcome was the development of an integrated system designed to assess more closely national priorities and needs for upgrading radiation and waste safety infrastructures.

This paper reviews the IAEA's integrated approach and the Technical Co-operation Model Project to upgrade radiation and waste safety infrastructures in its Member States. The project currently involves 52 countries.

2. THE MODEL PROJECT

2.1. Project objectives

The objectives of the Model Project are to assist those IAEA Member States which have an inadequate radiation and waste safety infrastructure and are already receiving IAEA assistance, so that they can comply with the BSS by the year 2000. The project draws upon the findings of RAPAT missions to 64 countries, which had served to increase awareness of radiation safety issues, and upon numerous expert missions on radiation protection undertaken in the past ten years.

One of the first actions in implementing the project was to define more clearly what constituted an adequate radiation and waste safety infrastructure. This had to be done for different types of radiation application, ranging from common industrial and medical uses found in every country to the full nuclear fuel cycle, which exists in relatively few developing countries.

Decisions were taken about what was needed to bring each country up to an adequate level, about how to implement the provision of technical assistance and about how to verify results.

The main components of this process consist of collecting and evaluating information on the existing safety infrastructure, establishing and maintaining Country Safety Profiles and formulating and implementing Country Safety Action Plans. The latter are needed to rectify weak or non-existent infrastructure elements, to monitor the development of improvements in safety infrastructure, and to sustain an effective infrastructure and develop it for additional uses of radiation.

In 1994 it was originally envisaged that five or six countries would benefit each year from the Model Project. However, data gathered subsequently indicated that more than 50 countries were in need of assistance (Table I). Hence, programme and management adjustments had to be made, since achieving the objectives under an approach concentrating only on five or six countries per year would require more than a decade. An integrated management approach was thus developed, with the aim of achieving adequate national radiation and waste safety infrastructures in most participating countries by the year 2000. In support of the new approach, the Department of Technical Co-operation appointed Regional Managers for Africa, West and East Asia, Latin America, and Europe.

For all participating countries, assessments were made to identify their infrastructure weaknesses. These included, for example, legislative and regulatory weaknesses, inadequate information — or even a complete lack of information — on the radiation sources in the country, and deficiencies in radiation and waste safety regulations, personnel dosimetry services, and the calibration and state of repair of equipment. Shortcomings were discussed by the Regional Managers with national authorities as part of the preparation of detailed Country Safety Action Plans. In all of the participating countries, these plans have already been approved, and their implementation is now well under way.

2.2. Country Safety Profiles

The intention behind the establishment of a Country Safety Profile information system is to maintain and keep updated all the data known to the IAEA on the radiation and waste safety infrastructure of a given country. Although the system includes a computerized database which will be made available to all concerned, it is not limited to the database alone. It also includes the assembly of 'hard' information including laws and regulations, mission reports, papers describing the situation, and other material and relevant Safety Action Plans. The essential structure of the system relies on a questionnaire, the answers to which are the basic inputs for the database.

The questionnaire and the database comprise nine main sections: organizational infrastructure; legal and regulatory status, including training; extent of practices

TABLE I. COUNTRIES PARTICIPATING IN THE MODEL PROJECT TO UPGRADE RADIATION AND WASTE SAFETY INFRASTRUCTURE

Africa	East Asia and the Pacific	West Asia	Europe	Latin America
Cameroon	Bangladesh	Kazakhstan	Albania	Bolivia
Côte d'Ivoire	Mongolia	Jordan	Armenia	Costa Rica
Ethiopia	Myanmar	Lebanon	Belarus	Dominican Republic
Gabon	Sri Lanka	Qatar	Bosnia & Herzegovina	El Salvador
Ghana	Viet Nam	Syrian Arab Republic	Cyprus	Guatemala
Madagascar		United Arab Emirates	Estonia	Haiti
Mali		Uzbekistan	Georgia	Jamaica
Mauritius		Yemen	Latvia	Nicaragua
Namibia		Kyrgyzstan[a]	Lithuania	Panama
Niger			Moldova	Paraguay
Nigeria			The Former Yugoslav Republic of Macedonia	
Senegal				
Sierra Leone				
Sudan				
Uganda				
Dem. Rep. of Congo				
Zimbabwe				

[a] Not a Member State.

involving ionizing radiation; provisions for individual dosimetry; public exposure control; radiation protection and safety of patients in medical diagnosis and therapy; transport of radioactive material; planning and preparedness for radiation emergencies; and quality assurance.

3. METHODOLOGY

3.1. Commitment by the governments

It should be noted that the Model Project presumes that governments and national authorities are prepared to comply with their obligations as described in the

Preamble of the BSS. For this reason, firm commitments were obtained from all participating countries, and all Country Safety Action Plans were discussed and finalized with and approved by relevant counterparts and authorities in each participating Member State. The implementation of the Country Safety Action Plans could not start before official approval from the Member State concerned was obtained. As a result of this approach, Member States firmly committed themselves to establishing a national infrastructure which includes: an appropriate national legislation and/or regulations (the type of regulatory system will depend on the size, complexity and safety implications of the regulated practices and sources as well as on the regulatory traditions in the country); a regulatory body empowered and authorized to inspect radiation users and to enforce the legislation and/or regulations; sufficient resources; and adequate numbers of trained persons.

3.2. Country Safety Action Plans

Country Safety Action Plans were developed from an analysis of the Country Safety Profiles against the requirements for an adequate infrastructure. Missing or deficient items were identified and documented for the preparation of a Safety Action Plan specific to each country. The Action Plan includes actions that are needed for the country to achieve a full and adequate infrastructure commensurate with its existing and planned applications of ionizing radiation.

Once the Department of Technical Co-operation received the agreement by the government on the Action Plan, it would start implementing the scheduled activities. The Plans include both generic and specific activities. Generic activities apply to all countries and as a first priority cover notification, authorization, and control of all radiation sources — whatever their use — within the country. Later steps will cover protection of workers, patients receiving medical treatment and the public from environmental releases; emergency plans; transport arrangements; and other areas. Specific activities are tailored to each country's particular needs, such as personnel training or the provision of necessary equipment.

The development of human resources through training is an important component of the Model Project. It involves not only training in nuclear technologies but covers administrators, regulators, radiation protection specialists and medical personnel. The establishment and sustainability of a sound infrastructure for assuring radiation and waste safety depends heavily upon national capabilities in these areas.

3.3. Milestone setting

The first milestone to be achieved under the Model Project is the establishment of a system of notification and authorization as required by the BSS. The regional managers are expected to monitor and report on each country's compliance, and in

December 1998 the IAEA is scheduled to submit a comprehensive report on the progress achieved to its Board of Governors.

The approach used for the implementation of the Model Project represents a system that is being generalized to all Member States receiving IAEA assistance. It will provide the IAEA with a fully documented system for assessing the current status of any country with respect to its radiation and waste safety infrastructure and a prioritized and agreed set of needs that should form the basis of future technical assistance activities. There will also be enough data to assess the capacity of the country to assure the safety of other developments of technology or requested items of equipment that could pose radiation hazards.

Over time, the system should provide a firmer basis for the IAEA's co-operative work with its Member States and for the provision of technical assistance in areas of radiation and waste safety. Efforts can be better directed towards achieving a situation in which no Member State which actively co-operates with the IAEA can have an inadequate radiation and waste safety infrastructure. Under an agreed Action Plan, this work will encompass measures for improving the identification of needs and requirements and for enhancing the use of resources to further strengthen national capabilities to ensure safety in the peaceful applications of nuclear and radiation technologies.

3.4. Relevant IAEA standards and guidance

Regardless of its own stage of nuclear technological development, every country has a primary responsibility and a role to play in ensuring the safe use of radiation applications and the disposal of radioactive waste. To control the radiation exposure of workers, medical patients and the public, countries need laws and regulations supported by administrative measures and enforced by inspectors. Just as important are internationally agreed standards for radiation safety. The IAEA developed the BSS [1] in co-operation with the Food and Agriculture Organization of the United Nations, the International Labour Organisation, the OECD Nuclear Energy Agency, the Pan American Health Organization and the World Health Organization.

The BSS place requirements on registrants and licensees, who therefore have the primary responsibility for applying them; governments, however, have the responsibility to enforce the application of the requirements, generally through a system that includes a regulatory authority. Moreover, governments generally provide for certain services that exceed or complement the capabilities of the legal 'persons' authorized to conduct practices involving radiation sources. The BSS are therefore based on the presumption, outlined in their preamble, that a national infrastructure is in place enabling the Government to discharge its responsibilities for radiation protection and safety. The elements of the Country Safety Action Plans for the Model Projects are derived from the elements of the infrastructure as described in the preamble.

A document that is instrumental in the implementation of the first milestone of the Model Project is the Technical Document entitled Organization and Implementation of a National Infrastructure Governing Protection against Ionizing Radiation and the Safety of Radiation Sources; this document provides guidance on how to optimize and integrate each element of a regulatory infrastructure with its other elements. The elements covered include regulations, authorization, exemption, inspection, enforcement, accident investigation and dissemination of information. More specifically, the system of notification and authorization and the options for combining registration and licensing are discussed in terms of the number and size of radiation practices within the country, the number of staff involved and their level of training, and the availability of expert consultant assistance. Model legislation to establish a regulatory authority as contemplated in the BSS and model regulations based upon the BSS are also provided in an annex.

Once the system has been designed, there is a need for advice on how to implement it. A draft IAEA publication describes methods and review plans to facilitate authorization and inspection of radiation sources, including how to prepare and conduct an inspection and follow-up actions. The document includes specific checklists for the main practices (such as industrial radiography, industrial irradiators, gauges, radiotherapy, nuclear medicine and diagnostic radiology) to assist regulatory authorities in reviewing safety in the process of authorization and inspection.

3.5. Standardization of activities

The efficient use of resources implies a balance between standardized measures and respect for the peculiarities of each Member State. As described herein, a number of activities have been standardized:

(a) The Country Safety Action Plans contain the same elements for all Member States, although individual actions may differ depending on the country profiles used for tailoring the Action Plans.
(b) Model legislation and model regulations ensure a consistent and coherent international approach, and yet national legal traditions are respected by allowing for local adaptation.
(c) Checklists for the safety review of the main practices using radiation have been provided to more than 50 Member States.
(d) Training of personnel for the regulatory programme is being done in a synchronized and standardized manner, through regional training events, and information exchange is being fostered through regional workshops.
(e) The setting of milestones facilitates a common methodology and timing to monitor progress (see Section 4).

(f) An information system for regulatory authorities is being implemented simultaneously in more than 50 Member States (see Section 4).

4. MONITORING PROGRESS

4.1. Peer reviews

As the implementation of the Country Safety Action Plans progresses, both Member States and the IAEA need to appraise the effectiveness of the measures taken at the different stages of organization and implementation in order to correct weaknesses and optimize resources. For this purpose, a draft Safety Report entitled Assessment by Peer Review of the Effectiveness of Regulatory Programmes for Protection against Ionizing Radiation and for the Safety of Radiation Sources provides advice on the conduct of peer reviews using a methodology to obtain qualitative and quantitative information and on its analysis against performance criteria and indicators.

The methodology involves the analysis of both qualitative and quantitative information. Qualitative information (e.g., the quality of a safety assessment for licensing and inspection purposes) will be analysed by peer reviews through senior experts, but it will be greatly facilitated by prompt and reliable information concerning the regulatory programme, as described in Section 4.2.

4.2. The Regulatory Authority Information System

The management of the regulatory programme needs prompt and updated information on the location of radiation sources and facilities in the country, on the authorization process, on inspection and enforcement actions, on the dosimetry of occupationally exposed personnel and on the performance indicators for individual installations and for the overall regulatory programme. For this purpose, software called the Regulatory Authority Information System (RAIS) has been developed and provided to Member States.

The system is simple, to ensure prompt and regular updating, and comprehensive enough to avoid parallel systems that might otherwise naturally emerge for the same purposes.

RAIS is an essential tool for planning, optimization of resources, monitoring safety related data, disseminating safety information, making decisions and following up regulatory actions, including monitoring deadlines.

The option of issuing the authorization document, inspection reports and enforcement actions through RAIS will ensure continuous updating, thus turning RAIS into a reliable information tool for the managers of regulatory authorities. Periodic or ad hoc official reports on the regulatory activities and about the status of safety in Member States will be facilitated by the ready availability of reliable quantitative information provided by RAIS.

Finally, the information system will contribute to an easy monitoring of the progress of projects on upgrading regulatory infrastructures in Member States.

5. RESULTS ACHIEVED TO DATE

Results of the first peer review will be available only towards the end of 1998. However, Table II shows an estimate of the amount of information currently available.

6. CONCLUSIONS AND RECOMMENDATIONS

(a) Within the framework of a Technical Co-operation Model Project, the IAEA is assisting 52 of its Member States in setting up an adequate radiation and waste safety infrastructure by the year 2000. Never before have IAEA Safety Standards and guidance been widely implemented with such intensive effort and in such a short period of time.

(b) Through an active, systematic and integrated approach, the IAEA is upgrading and harmonizing infrastructure foundations and tools, such as model legislation and regulations, assessment and inspection, training, information exchange, management and information systems for regulatory authorities and progress monitoring by way of a comprehensive methodology.

TABLE II. PROGRESS TOWARDS COMPLETION (EXPRESSED AS PERCENTAGES) OF UPGRADES OF MAJOR ELEMENTS OF REGULATORY INFRASTRUCTURES FOR RADIATION PROTECTION IN MEMBER STATES

	Africa	East Asia and the Pacific	West Asia	Europe	Latin America
Legislation and regulations	65	80	80	85	90
System for notification, registration and licensing	50	20	30	80	80
Inventory of major radiation sources and installations	80	90	80	95	90

(c) Only two years after the inception of the Project, the first milestone towards regulatory control of radiation sources is close to completion. This milestone consists of legislation, regulations, a system for notification and authorization and the inventory of sources and installations. This important achievement contributes to the worldwide improvement of the safety and security of radiation sources and radioactive materials. However, sustainability will depend on Member States' continuous commitment.

(d) This approach can, of course, be used in non-Member States, provided that the international community makes available to the IAEA the necessary funds to cover administrative and other overhead costs. Based on IAEA experience and for less than US $0.5 million of international assistance per country, radiation and waste infrastructure can be upgraded to an acceptable level in every non-Member State.

(e) Following the completion of the Model Project on upgrading radiation protection infrastructure, the IAEA will concentrate its efforts on specific issues and not on general radiation protection infrastructure. It is expected that by the year 2000 Member States will reach self-reliance to sustain an adequate radiation and waste safety infrastructure.

(f) As a complement to these efforts, there is a need for countries exporting radiation sources to support recipient countries in achieving an effective control of all sources through co-operation between regulatory authorities. This support would bolster the exchange of information on export, on safety assessment, and on the disposal or return of radioactive materials no longer in use.

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MEASURES TO PREVENT ILLICIT TRAFFICKING IN NUCLEAR AND OTHER RADIOACTIVE MATERIALS

The IAEA Security of Material Programme

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Abstract

MEASURES TO PREVENT ILLICIT TRAFFICKING IN NUCLEAR AND OTHER RADIOACTIVE MATERIALS: THE IAEA SECURITY OF MATERIAL PROGRAMME.

Since 1995, the IAEA has implemented a programme called Security of Material, aimed at assisting Member States, through training, expert assistance, equipment and exchange of information, in their efforts to protect nuclear and other radioactive materials against unauthorized (criminal) activities and to provide them with the knowledge and tools necessary for detecting and responding to incidents of illegal trafficking should they occur. The programme includes legislative support, technical advice, peer review and co-ordination services, development of international standards, and training. An important element of the programme is the maintenance of the Illicit Trafficking Database Programme, in which the IAEA continuously registers confirmed incidents of illegal trafficking in radioactive materials.

1. PRESENT SITUATION IN ILLICIT TRAFFICKING

In the early 1990s, news media started reporting an increasing number of cases in which nuclear materials and radioactive isotope sources were subjects of illicit trafficking. These initial cases involved material emanating from the former Soviet Union. It was of great concern among States and international organizations that nuclear material involved in trafficking might become implicated in weapons production or that radioactive sources used in an unauthorized way might cause health and safety effects to individuals, the public in general or the environment.

Since then, illicit trafficking in these materials has continued. The IAEA monitors the situation by maintaining an Illicit Trafficking Database Programme together with 63 of its Member States, each of which has assigned a Point of Contact for reporting trafficking events to the IAEA. Since 1993, a total of 285 events have been reported. A slight majority of those cases involve nuclear material, although the quantities in most cases are small and the usability for weapons production is low. Only a few cases (13 confirmed) involve strategic material in the form of highly enriched uranium or plutonium. The potential for the smuggling of large quantities of weapons grade material may be low, but trafficking of even small quantities of such material deserves attention in the context of non-proliferation, since larger quantities of nuclear material of strategic value might be accumulated.

The smuggling of radioactive sources can impose a direct danger to public health and safety. Some cases have resulted in fatal ionizing radiation exposures to individuals. One example is the well known incident of the discarded radiation source in Goiânia, Brazil, in 1987–1988, which caused several deaths and radioactive contamination of a large part of a city of 1 million people.

Although the incidents of trafficking have decreased somewhat during the last two years, the fact that the IAEA still receives reports of trafficking from its Member States indicates the existence of weaknesses in the protection of radioactive materials at their storage locations. However, the database does not reveal evidence that this is a problem concerning only one State or a group of States; rather, it is a global problem of general concern.

2. EFFORTS TO PREVENT TRAFFICKING IN NUCLEAR AND RADIOACTIVE MATERIALS

It is generally agreed that the problem of illicit trafficking of nuclear materials and radioactive sources should be addressed first through prevention. The complex measures for safety, security, physical protection, accountancy and control (including the control of transborder movements) of these materials constitute the protective system as a whole. Much has been accomplished by the way of strengthening this system through the efforts of several Member States and of the IAEA.

International legal instruments provide a basis for national arrangements for preventing, detecting and responding to illicit trafficking. At present 127 States have, in accordance with the provisions of the Treaty on the Non-Proliferation of Nuclear Weapons, concluded safeguards agreements with the IAEA; 63 States are parties to the Physical Protection Convention; and 33 States have declared their intention to apply the Nuclear Suppliers' Guidelines (NSG) for nuclear related exports. These international undertakings lead to national measures that contribute to the prevention or detection of illicit trafficking. Most exporting States now require that adequate physical protection and accounting and control measures be in place in recipient States as a condition for granting export licences for nuclear material.

Several international organizations have taken an interest in preventing illicit trafficking and in mitigating the associated risks. The United Nations, the Commission of the European Union and the World Customs Organization (WCO) are among the organizations that have addressed the problem. These and others have joined in the IAEA's information exchange efforts and have participated in IAEA training activities.

Several Member States have assigned significant amounts of resources to bilateral co-operation with the Newly Independent States (NIS) to support their efforts to establish nuclear material accountancy and control systems, physical protection systems and radiation protection systems. These programmes cover a period of several years, because installation of new equipment and implementation of new techniques often require extensive training and acquisition of experience with the new system.

In summit meetings held in 1996 and 1997, the so-called Eight States[1] underlined the need for the safe management of fissile materials as a barrier against the risk of illicit trafficking in such materials. Co-operative intelligence, customs and law enforcement efforts have been recognized as necessary for preventing the sale and diversion of nuclear materials. Through their programmes for preventing and combating illicit trafficking in nuclear materials, these States have demonstrated their concern and determination to prevent illicit trafficking.

3. THE IAEA SECURITY OF MATERIAL PROGRAMME

3.1. Information exchange

By maintaining the Illicit Trafficking Database Programme, the IAEA provides a focal point for the exchange of information on trafficking. At present 63 States participate in the Database Programme. When a trafficking incident in a State occurs, the Point of Contact in the State reports the incident as soon as possible, often within 48 hours of the event, to the IAEA, which disseminates the information to all Member States. The IAEA also collects information on incidents from open sources. For incidents that are not reported formally, the IAEA may ask the Point of Contact to confirm the accuracy of this information.

All nuclear materials seized in illicit trafficking are to be covered by safeguards agreements in the State where they were seized. The IAEA undertakes appropriate follow-up actions to this effect.

The IAEA organizes international conferences to foster exchange of information, such as this one and the November 1997 Conference in Vienna on the Physical Protection of Nuclear Material.

During the past four years the IAEA has convened meetings with representatives of international organizations which through their mandate have an interest in

[1] Canada, France, Germany, Italy, Japan, the Russian Federation, the United Kingdom and the United States of America.

ensuring the safe and secure transport and use of nuclear material and other radioactive substances. The IAEA believes that regular meetings of this kind will help enhance co-ordination among the organizations and thereby avoid duplication of efforts.

3.2. Protection of nuclear materials

Nuclear material accountancy and physical protection constitute the first line of defence in ensuring that nuclear materials do not become the subject of unauthorized use leading to illicit trafficking. Although the responsibility for physical protection rests entirely with the State, it is recognized that efforts at the international level are also necessary. Together with Member States, the IAEA develops the international standards for physical protection.

To assist States in assessing their needs for implementing effective physical protection systems at the State and facility levels, the IAEA offers the International Physical Protection Advisory Service (IPPAS) to all States. These peer review missions are carried out by teams of experts from Member States. The results of IPPAS missions, which are kept confidential because of security concerns, identify areas, as applicable, where legal, administrative and technical components of physical protection need to be improved. If national resources are not adequate for making the improvements, the Secretariat may assist the State in generating the necessary support through, e.g., bilateral co-operation programmes or the IAEA's Technical Co-operation Programme.

The Convention on the Physical Protection of Nuclear Material [1] defines international standards for the physical protection of nuclear material during international transport. The IAEA Recommendations on the Physical Protection of Nuclear Material [2] are applicable to nuclear material, in peaceful or military use, storage or domestic transport. The recommendations are not legally binding, but they acquire legal status as references in other, legally binding documents such as bilateral co-operation agreements and export control regimes. The IAEA also develops technical documents and guidelines to facilitate the implementation of the international physical protection standards.

The IAEA conducts, often together with Member States, national and regional courses in physical protection that are adapted to the needs of specific States and regions. The target audience is individuals responsible for administering regulatory systems and for designing and implementing physical protection systems. The training material is available in English, Chinese, Russian and Spanish. These courses or workshops may also address the specific need for physical protection systems in a State or region, current concepts and technology, and programmes for prevention, detection and response to illicit trafficking in nuclear materials and other radioactive sources.

Together with States offering bilateral support to the NIS, the Secretariat has established a Co-ordinated Technical Support Programme (CTSP) designed, inter alia, to avoid duplication of effort, identify needs and disseminate information. Such co-ordinated programmes have been developed for Armenia, Belarus, Georgia, Kazakhstan, Latvia, Lithuania, Ukraine and Uzbekistan, and preparations are being made for such activities in the other NIS.

3.3. Protection of radioactive sources

The IAEA is preparing a Safety Guide on the prevention, detection and response to illicit trafficking in radioactive materials. This publication, which is expected to serve as a basis for national legislation and to provide practical assistance to customs and other law enforcement authorities, is co-sponsored by the IAEA, the WCO and the International Criminal Police Organization (Interpol). The International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources [3], which relate to both the safety and the security of radiation sources, provide the scientific foundation for the Safety Guide.

In May 1998, the IAEA and the WCO signed a Memorandum of Understanding which provides for continued co-operation between the two organizations, including information exchange, joint training and other activities. The IAEA and the WCO have designed, for customs and other officials, a five day 'train the trainers' course on the prevention, detection and response to nuclear smuggling. The course has been given in 1997 and in 1998.

Together with the Austrian and Hungarian customs authorities, the IAEA is involved in a large scale study of border monitoring systems and inspection procedures. The results of the study will be made available to States as an aid in selecting and installing border monitoring systems.

3.4. Legal and regulatory framework

Because the national legal and regulatory framework is crucial to preventing, detecting and responding to illicit trafficking, the IAEA provides, upon request, advice and assistance to Member States on their existing national legislation related to the safe and peaceful uses of nuclear energy. As part of this programme, a Model Law is being developed to provide guidance to States on the elements to be included in national nuclear laws.

3.5. Technical co-operation

Through the IAEA Technical Co-operation Programme, States obtain support in establishing the infrastructures needed to prevent unauthorized use of nuclear material and other radioactive sources, including legislative assistance, technical advice and other support to establish systems for the protection and control of radioactive sources. Under this programme, four significant projects of relevance to the prevention of illicit trafficking in radioactive materials have been established relating to nuclear legislation, protection of radioactive sources and physical protection of nuclear material.

4. OUTLOOK

The IAEA Security of Material Programme will continue to focus on the prevention of illicit trafficking. Nuclear materials must be protected at all times, with improved international standards underpinning national efforts to provide adequate protection. Physical protection personnel at State authorities and at nuclear facilities will continue to require training and opportunities for exchanging views and experience with colleagues from other States.

Efforts to protect other radioactive sources will also continue. During the past year, radioactive sources have been confiscated (by States) that otherwise could have had a serious impact on health and safety. States have, in their correspondence with the IAEA, indicated an increased awareness of the necessity to arrange for systems that will provide secure management of radioactive sources.

There is no room for complacency in the protection of nuclear materials and radioactive sources. The IAEA programme will therefore be designed and implemented as a long term commitment with activities aimed at preventing such unauthorized use of nuclear material and other radioactive sources that could result in illicit trafficking of these materials. When trafficking in these materials nevertheless occurs, the programme offers assistance in characterizing and handling the materials seized.

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THE IAEA DRAFT SAFETY GUIDE — PREVENTING, DETECTING AND RESPONDING TO ILLICIT TRAFFICKING IN RADIOACTIVE MATERIALS

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Abstract

THE IAEA DRAFT SAFETY GUIDE — PREVENTING, DETECTING AND RESPONDING TO ILLICIT TRAFFICKING IN RADIOACTIVE MATERIALS.

The paper describes the details of a new Draft Safety Guide, co-sponsored by WCO and Interpol, which is being prepared within the IAEA programme to combat illicit trafficking in radioactive materials. The Guide is intended to help customs, border police and other law enforcement officers as well as regulatory authorities in Member States to prevent, detect and respond to illicit trafficking. Supporting Technical Manuals will provide concise information on technical details. The first manual lists physical and chemical data of frequently encountered radionuclides and gives necessary safety precautions for the handling of radiation sources no longer in use. Requirements for legal national infrastructures to prevent loss of control of radioactive materials are given in the manual on prevention. Extensive technical information on equipment performance requirements, calibration procedures and testing are contained in the manual on detection. Manuals on response and training will describe procedures for handling incidents with radioactive materials and will contain detailed training protocols for officers involved in such incidents.

1. INTRODUCTION

A major activity within the IAEA Security of Material Programme is the preparation of a Safety Guide on Prevention, Detection and Response to Illicit Trafficking in Nuclear and other Radioactive Materials, and of supplementary Technical Manuals giving technical details. As already mentioned in the first paper of this session, the primary safety function of the IAEA, as stated in its Statute, is to establish "standards of safety for protection of health and minimization of danger to life and property (including such standards for labour conditions), and to provide for the application of these standards". This function is reflected in the IAEA's Safety Fundamentals document [1] which summarizes the basic objectives, concepts and principles that are needed to ensure radiological safety. The main safety standards that have been developed within the framework of these fundamentals are given in the International Basic

Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources [2].

When the safety requirements of these standards are not properly met, unexpected risks and hazards can arise. Such situations can occur as a result of the unauthorized receipt, possession, use, transfer or disposal of radioactive materials. Loss of control of radioactive materials has had serious, even fatal, consequences. For example, radioactive material in radiation therapy units has been unintentionally sold as part of scrap metal [3, 4]; radioactive materials have been found by unsuspecting individuals [5]; radioactive material has been deliberately stolen, causing multiple deaths [6]. Other incidents may have been less serious and less publicized, but, in addition to posing a potential radiation hazard to customs and law enforcement officers and to the general public, all such incidents entail considerable costs from decontamination activities, from the shutdown of production and from the waste of products containing contaminated scrap. Numerous incidents have been reported in which radioactive sources and materials, buried in scrap metal, crossed borders and ended up in the scrap cycle, often as the result of careless or fraudulent disposal [7, 8]. Naturally occurring radioactive materials, mainly radium and thorium accumulated in scale inside pipes and well drilling tools, have been frequently found in scrap metal. The instances of illicit trafficking in radioactive materials that have been detected so far are likely to be just a fraction of the total.

The need for a Safety Guide explicitly directed to the problem of illicit trafficking in nuclear and other radioactive materials was raised by the IAEA Director General in 1994, and proposed measures were agreed by the IAEA Board of Governors in 1995. Such measures as might be taken to prevent, detect and respond to illicit trafficking will be common for all radioactive materials, including nuclear materials. However, nuclear materials are, or should be, subject also to safeguards for nuclear non-proliferation purposes and to physical protection to prevent uncontrolled diversion. The regulations, controls and methods described in this Safety Guide and the supplementary Technical Manuals are intended to help customs officers, border police and other law enforcement officers, as well as regulatory authorities and other relevant bodies in Member States, in their efforts to prevent, detect and respond to illicit trafficking in radioactive materials.

2. SCOPE

The advice in this Safety Guide is intended to provide the basis for a system, within a national infrastructure, that ensures that radioactive materials are securely managed and controlled so that illicit trafficking is inhibited and so that there are processes and procedures in place to detect and respond to any attempted illicit trafficking. The Safety Guide covers aspects of radiation protection, waste management and nuclear safety as well as the regulations concerning law enforcement and border control activities. It refers to all kinds of radioactive materials, including radioactive sources, radioactive wastes and nuclear materials. The technical information in this document offers general guidance to those responsible for the development, construction and selection of monitoring equipment, for the training and qualification of personnel and for other aspects of dealing with illicit trafficking in radioactive materials, such as response measures when illicit trafficking is suspected. Detailed guidance is provided in the supplementary Technical Manuals.

3. PREVENTION OF ILLICIT TRAFFICKING

The section of the Safety Guide on the prevention of illicit trafficking describes the main elements within a national infrastructure required in the areas of radiation protection, nuclear safety and waste management aimed at preventing the loss of control of radioactive materials. Illicit actions covered include unauthorized receipt, possession, use, transfer, import, export and disposal of radioactive materials. The foundation for preventing illicit trafficking is a national regulatory authority, empowered to issue regulations and to grant authorizations for justified practices such as receipt, possession, import, export, use, transfer and disposal. This regulatory authority should also conduct inspections and implement an enforcement policy to correct non-compliance with regulatory requirements.

Detailed requirements are given in the Guide concerning authorization to transfer, store and dispose of radioactive materials. A particularly important part of this section contains regulations on the security of radioactive materials. This includes the requirement for records of accountability and periodic checks of inventories, and notification of loss of control. It further covers requirements for the level of security, depending on the particular practice, the level of hazard and the risk of loss. Apart from measures of physical security, which are generally required for nuclear materials under the Convention for the Physical Protection of Nuclear Material [9], specific elements of physical security and control are also applied to other radioactive materials in use, storage or transport. Such measures should be based on the concept of defence in depth and should be commensurate with the activity and properties of the materials. Controls may start from the existence of a clearly designated and exclusive place for handling and storage, and from controlled access to the place of use or storage, by means of doors and physical barriers or any other appropriate means, to prevent unauthorized access or other means to provide physical security of the area.

4. DETECTION OF ILLICIT TRAFFICKING

Monitoring of gamma radiation is essential for detecting radioactive materials that are being illicitly moved. Neutron detection is necessary for detecting the illicit movement of nuclear materials, particularly shielded materials. Both gamma and neutron monitoring allow non-invasive interrogation of flows of people, goods and transport vehicles crossing checkpoints. The time available for the detection of radioactive materials is necessarily short in this application.

The task of detecting radioactive materials that are being illicitly trafficked has to be undertaken in a radiation environment that has natural and anthropogenic components, which will vary from place to place and from time to time. Any criterion (or 'investigation level') used to decide whether the radiation from any particular shipment indicates the presence of illicitly trafficked radioactive materials has to take this variable background into account.

Some radiation sources or radionuclides are not subject to regulatory control. They may be excluded, the practices that produced them exempted, or they may be specifically cleared. The mechanisms and applications of exclusion, exemption and clearance derive from the Basic Safety Standards [2]. Exposures to radiation that are part of the natural human environment are mostly regarded as unavoidable, and it is usually not practicable to control them through regulation. Recognizing that such exposures are essentially not controllable, the Basic Safety Standards treats them as 'excluded' from the regulatory requirements. If radioactive materials in a given application pose a low radiation risk, a regulatory authority may have exempted the practice of applying such radioactive materials in the defined way from regulatory control. Examples are the application of radionuclides in smoke detectors and luminous dial watches. Finally, if it can be shown that the exposures from release of radioactive materials will be trivial, a regulatory authority may clear them from regulatory control. Such clearance can apply both to materials that are being discarded as waste and to materials intended for further use or recycling. It is implicit to the concept of clearance that materials, once cleared, are subject to no further regulatory restriction or control.

The investigation level of radiation signal that is selected for deciding that a monitored vehicle, passenger or cargo may be transporting radioactive material illicitly is a compromise. On the one hand, it is desired to detect any illicitly trafficked radioactive materials, e.g. sources in shielded containers which may be buried deeply in scrap metal or other non-radioactive goods. On the other hand, it is desired to avoid unnecessary 'nuisance' alarms, rejections and delays at border crossings.

For radionuclides emitting gamma radiation, the Safety Guide recommends as an investigation level a dose rate, measured on the outside of a vehicle, that is within the range 0.1 to 0.5 mSv/h [10, 11]. The final value will be determined on the basis of the results of the Illicit Trafficking Radiation Assessment Programme (ITRAP) pilot study on border monitoring instrumentation being conducted at the Austrian Research Centre, Seibersdorf. Details on the ITRAP Study are given in Ref. [12]. If the measured dose rate is below this value, then it can be assumed that there is no indication of illicitly trafficked radioactive material. For nuclear materials emitting neutrons from spontaneous fission, such as plutonium, the investigation level will correspond to an emission rate of approximately 2×10^4 neutrons per second, equivalent to 300 g of weapon plutonium (6% ^{240}Pu). This amount is a compromise between excessive costs for neutron detecting equipment and the minimum mass required for a nuclear weapon.

There are three basic types of instrument for detecting radioactive materials that may be being moved illicitly: pocket sized instruments, hand held and mobile instruments, and fixed installation instruments.

Pocket sized instruments that are chosen for this application should be easy to use, even by non-specialized staff, and should allow quick, qualitative assessment of suspect materials. They should be battery powered and shock and water resistant and should have low maintenance requirements. Auto-ranging, an alarm function and some indication of the radiation level are further requirements. Instruments using Geiger–Mueller counters as radiation detectors are not sensitive enough for this application.

Hand held instruments are used for localization and identification. They are more bulky than pocket sized instruments but generally have more features. They typically use an inorganic (e.g., sodium iodide) or a plastic scintillator as detector and may include a multichannel analyser for gamma spectroscopy so that the radioactive materials can be identified by their gamma ray energy signature. However, use of these instruments requires more specialized training of the staff than do pocket sized instruments. More complex, mobile systems have been developed, generally with greater sensitivity than hand held instruments. They can be mounted on vehicles, helicopters or vessels and can be used in searching over areas or in detecting weak radiation fields from small amounts of activity or from well shielded radioactive materials at a larger distance.

Fixed installation instruments are designed to be located at border control stations, airports, ports of entry, etc. Monitors should be installed as close as possible to the object to be monitored in order to obtain the greatest practical sensitivity. Alarms and display instruments are usually installed in an area away from the detector and the monitored passageway. Use of these highly automated systems should require no highly specialized training and allows a continuous flow of persons, luggage or vehicles to be monitored with reasonable speed.

In general, the sensitivity of the instrumentation that is required depends on several parameters. Judgement at any particular location is needed to achieve the best compromise between too high a sensitivity, which will result in too many alarms because of naturally radioactive materials, and too low a sensitivity, which will fail to indicate quantities of radioactive material that should be of concern.

In accordance with the Basic Safety Standards [2] and national radiation protection regulations, personnel expecting to encounter radioactive materials in their monitoring should have access to adequate protective equipment and should be familiar with the appropriate radiation protection procedures. These will typically include the use of personal alarm dosimeters for alerting them to radiation hazards in the field and of dosimeters that are suitable for demonstrating compliance with regulations that specify limits for radiation doses.

5. RESPONSE TO ILLICIT TRAFFICKING

In the context of the Safety Guide, a response of some kind is needed when radioactive materials have been detected or information has been obtained that they are not under appropriate authorized control. Irrespective of whether the materials are of domestic or foreign origin, the need for response should be recognized and the response should be carried out by the Member State in which the radioactive materials are found. 'Response' in this context refers to actions taken to regain control of radioactive materials, to implement appropriate radiation protection procedures to mitigate hazards to health and bring the situation under appropriate radiation protection control, to provide any medical treatment needed and to apply any penalties in accordance with national regulations.

Circumstances requiring response include the following:

(1) detection, through radiation monitoring, of the unauthorized or uncontrolled presence or movement of radioactive materials;
(2) a report about radioactive materials having been found in an unauthorized location;
(3) a report about something suspected to contain radioactive materials;
(4) a report about an accident involving, or suspected to involve, radioactive materials;
(5) a report about the detection of instances of non-compliance with the transport regulations;
(6) discrepancies found in an inventory of radioactive materials;
(7) a report about illicit transboundary movement of radioactive materials.

Member States should have a plan ready for response to the detection or suspicion of illicit trafficking in or loss of control of radioactive materials. The plan should be implemented whenever the regulatory authority becomes aware of possible loss of control or illicit trafficking. The type of response depends very much on the particular circumstances, e.g., the type of radioactive materials, where they are located and potential pathways of exposure. The topics covered in the plan should include the following:

(1) whom to notify (customs officials, law enforcement officials, emergency response units, etc.);
(2) what information should be supplied to aid recovery of control;
(3) measurements to be made for detection and analysis;
(4) temporary storage arrangements for any radioactive material that might be found;
(5) arrangements for transport to a final authorized storage or disposal facility;
(6) the type of information needed for alerting and informing the public about lost or illicitly moved radioactive materials.

6. TRAINING

Training in preventing, detecting and responding to loss of control and in the detection of illicit trafficking is essential for customs officers, border control and other law enforcement personnel. Training must be matched in scope and detail to the organizational level, knowledge and roles of the trainees. A typical training syllabus should include information on the following:

(1) the nature and effects of ionizing radiation;
(2) the properties and applications of radioactive materials;
(3) monitoring and detection principles and techniques;
(4) national and international radiation protection, safety and security requirements (including regulations and procedures for personal protection);
(5) the proper response activities if radioactive materials are detected.

Training courses should be repeated regularly to ensure that sufficient familiarity with the equipment and procedures is maintained so that vigilance is not diminished as staff change and so that any needed response can be prompt. Such training should include practical, hands-on exercises and drills.

The World Customs Organization (WCO), in close co-operation with the IAEA, has recently developed a Customs Enforcement Training Module on the smuggling of nuclear and other radioactive materials. Details are presented in Ref. [13]. The overall objective of this module is to provide customs training units with a basis or framework to enable them to design their national training courses. With the assistance of this module, national training courses can be conducted not only for beginners, to provide basic awareness and knowledge, but also for multiagency courses to improve mutual understanding between customs and other relevant agencies. The IAEA–WCO training strategy has been to give priority to the Eastern and Central European region. The first joint IAEA–WCO training course was held in Vienna for Customs Trainers on 2–6 June 1997, and the second course is scheduled for customs and police officers of the same region in September 1998 in co-operation with the IAEA, WCO and Interpol.

7. SUPPORTING TECHNICAL MANUALS

The Draft Safety Guide consists of a basic part containing the essential general information and a set of supporting Technical Manuals, under preparation. Technical details, such as instrument performance requirements, typical radioactive materials encountered and recommended operating procedures in response and training programmes, are provided in separate manuals. At present, manuals on the following subjects are foreseen and under preparation:

(1) Radioactive materials in medicine, industry and research that are typically involved in illicit trafficking;
(2) The regulatory infrastructure and physical measures needed for preventing illicit trafficking;
(3) Performance requirements, calibration and testing of monitoring instrumentation for the detection of illicit trafficking;
(4) Response procedures when illicit trafficking is suspected or detected;
(5) Training programmes for persons involved in the prevention, detection and response to illicit trafficking.

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THE ROLE OF CUSTOMS SERVICES AND THE WORLD CUSTOMS ORGANIZATION'S ENFORCEMENT PROGRAMME TO COMBAT NUCLEAR AND OTHER RADIOACTIVE MATERIALS SMUGGLING

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Abstract

THE ROLE OF CUSTOMS SERVICES AND THE WORLD CUSTOMS ORGANIZATION'S ENFORCEMENT PROGRAMME TO COMBAT NUCLEAR AND OTHER RADIOACTIVE MATERIALS SMUGGLING.

The World Customs Organization (established as the Customs Co-operation Council in 1952) is an independent intergovernmental body with worldwide membership (146) whose enforcement mission could be summarized as "to assist its Members in strengthening their enforcement measures through training and technical programmes designed to combat customs offences", which also include nuclear and other radioactive materials smuggling. One of the best strategies for an effective fight against illicit trafficking in nuclear and other radioactive materials is to stop their illegal movement at the national border before they enter or leave the country. From this point of view, customs services are unique governmental cross-border control agencies which are mostly located at national cross-border checking points. In addition to this local advantage, customs expertise and authority in checking documents, goods, vehicles and passengers deserve special mention. It should also be noted that customs services have great experience in how to combat and respond to transnational crime and criminals. On the other hand, in order to make best use of their experience, they should be furnished with sufficient authority for investigation, appropriate detection equipment and support through relevant training programmes. In line with the request made by Member States, the WCO Secretariat has recently developed an enforcement programme on combating nuclear and other radioactive materials smuggling. This programme is based on awareness raising, development of training materials, designing training programmes, promoting exchange of information and improving co-operation at all levels. The WCO Database, the WCO RILO project and WCO Recommendations are three key tools which enable customs administrations to develop accurate, timely and rapid exchange of information and intelligence. Within the concept of international co-operation, the WCO and the IAEA agreed to sign a Memorandum of Understanding (13 May 1998) for further joint initiatives. The two international organizations are now conducting several joint technical meetings and training programmes and are producing safety publications for law enforcement agencies.

1. INTRODUCTION

1.1. The World Customs Organization (WCO)

The World Customs Organization (established as the Customs Co-operation Council in 1952) is an independent, intergovernmental body with a worldwide membership of 146 customs services. (In June 1994, the Council adopted the working name World Customs Organization (WCO) to reflect more clearly the nature of the organization and its international functions. The convention establishing the organization was not amended, however, so the official name is still Customs Co-operation Council.)

The WCO's mission is to enhance the effectiveness and efficiency of customs administrations in the areas of compliance with trade regulations, protection of society and revenue collection, thereby contributing to the economic and social wellbeing of nations. In order to fulfil this mission, the WCO:

(1) Establishes, maintains, supports and promotes international instruments for the harmonization and uniform application of simplified and effective customs systems and procedures governing the movement of commodities, people and conveyances across customs frontiers;
(2) Reinforces Members' efforts to secure compliance with their legislation, in particular by endeavouring to maximize the level and effectiveness of Members' co-operation with each other and with international agencies in order to combat customs and other transborder offences;
(3) Assists members in their efforts to meet the challenges of the modern business environment and adapt to changing circumstances, by promoting communication and co-operation among Members and with other international organizations, and by fostering human resource development, improvements in the management and working methods of customs administrations and the sharing of best practices.

On the basis of an analysis of input from Members, the WCO Enforcement priority has been identified as "Implementation of a comprehensive programme to help members combat commercial fraud", which includes the WCO Enforcement Programme on Actions to Combat Nuclear and Other Radioactive Materials Smuggling.

1.2. International concerns

There is no doubt that the use of nuclear and other radioactive materials is essential to meet countries' social, economic and medical goals in many ways.

However, when they are not properly handled and managed, these materials represent a considerable risk to people and the environment, and have caused concern for many years.

The potential risk is immense when these materials have been subject to any form of illicit trafficking or smuggling. Even relatively small amounts of radioactive material may cause serious damage to health if people remain in their vicinity or try to manipulate the material without taking the necessary safety and security measures.

Many international and regional organizations such as the IAEA, the WCO, ICPO-Interpol, the EC and some international summits have shown a heightened concern about nuclear proliferation, the continuing possibility of an illegal black market, nuclear terrorism and safety measures for facilities where the radioactive materials are used or stored.

These initiatives at the international level have always included invitations to Member States to review the existing preventive measures and to reinforce them with a view to stopping illicit trafficking in nuclear and other radioactive materials.

Preventing the illegal acquisition of nuclear material such as plutonium and highly enriched uranium has been a top priority and national security concern of some WCO member countries since the 1990s because of the increasing number of attempts to buy and sell nuclear materials throughout the world, particularly in Europe.

Along with the ongoing international initiatives, there has been a slight decrease in the number of radioactive material seizures in the past two years. It is to be noted that some of these attempts have been proven to be nothing more than profit motivated scams involving bogus materials.

However, these positive remarks should not be interpreted as indicating that the illicit movement of nuclear and other radioactive materials has stopped or that there is no illegal market for these materials. The reduction in seizures could be due to the concrete measures taken by various governments or to the employment of very sophisticated smuggling methods by criminal groups. Illicit trafficking in nuclear and other radioactive materials has a tendency to shift from individual cases to organized or transnational crime; it can become linked to other organized crimes such as drugs, stolen cars and firearms smuggling; it has seen an increase in experts' involvement; and it has increased outside Europe.

The international community has also become increasingly aware of an unwanted component in scrap material: radioactive sources. It seems that the threat of radioactive sources in recycled scrap material will continue for the foreseeable future, thus posing special problems for exporting, importing and transit countries.

In sum, the international community has added a new but very sensitive item to its agenda since 1989 while it was trying to solve the existing issues related to the safety and security of nuclear and radioactive materials and their waste.

The international community has committed itself to deal with this new phenomenon and is in favour of stopping illegal trafficking in nuclear and radioactive materials at national borders before these materials leave or enter the country. For this purpose, being in the front line at national borders, customs agencies are expected to take an active part in the implementation of all preventive measures or plans drawn up by national institutions. This approach requires governments to pay attention to the legal, technical and administrative capabilities of customs and other law enforcement agencies taking part in controlling the international flow of people, vehicles and goods.

1.3. Potential threat to customs officers

Nuclear and other radioactive substances fall into Class 7 under the United Nations classification system for dangerous goods and require special procedures and measures in every phase of their management from mining to disposal. They clearly differ from other dangerous goods in their ability to emit radiation. Consequently they pose a hazard to people and property that depends on conditions of shielding, distance and time.

This hazard is greater in accidents involving package rupture or if a package is opened inadvertently or by inexperienced persons. The specific hazards are overexposure of persons due to irradiation and radioactive contamination by direct contact with the material. This contact could be any form of skin contact, ingestion, inhalation or a combination thereof.

Overexposure usually goes unnoticed for some time because radiation cannot be detected by sensory perception, and the deleterious effects do not usually manifest themselves immediately. Even relatively small amounts of radioactive material can therefore cause serious damage.

Given these properties, nuclear and other radioactive substances instil fear in people (including customs officers). However, customs officers are legally responsible for physically checking and monitoring the international flow of passengers, vehicles and goods. Customs officers are therefore under potential risk of irradiation and radioactive contamination because of the possibility of finding unauthorized consignments and improperly packed nuclear and other radioactive material in illicit trafficking during their normal work.

It is clear that this risk will be higher for customs officers when there is insufficient awareness, basic knowledge, proper detection equipment, safety measures and well established response to the discovery of illicit trafficking in radioactive materials.

Because of the nature of these materials, the WCO Secretariat recommends that its Members co-operate closely with their national nuclear regulatory bodies when it is necessary to conduct a physical examination or if there is suspicion or detection of illicit trafficking in nuclear and radioactive materials.

1.4. Role of customs services

Historically and practically, customs have been seen as revenue generating agencies through the collection of duties. However, customs services all around the world are now undertaking two additional tasks: (1) facilitation of international trade and (2) protection of society. These additional tasks are non-fiscal functions and require customs services to strike a balance between facilitation and effective control, which is managed through the application of risk assessment techniques.

Customs services have always played a key role in preventing and detecting illicit transborder movement of goods before they leave or enter the country. This role falls into the category of 'protection of society', and it ranges from combating drugs smuggling to preventing illicit trafficking in nuclear and other radioactive materials.

Customs services have also been crucial agents in designing and implementing national strategies for combating smuggling activities by virtue of their legal, administrative and technical advantages, which can be grouped in eight major categories, described below.

1.4.1. Location of customs offices

Customs services are mostly located at national border checkpoints such as airports and seaports. This physical position enables customs to stop illicit transborder movement of radioactive materials before they leave or enter national territory.

1.4.2. Capability of monitoring international trade

Customs administrations have at their disposal all relevant documents and data on national foreign trade in terms of value, quantity, passengers, exporters, importers, means of transportation, goods and trends in foreign trade. This huge volume of information allows them to support related law enforcement and administrative agencies and can yield target, operational or strategic intelligence for their own needs.

1.4.3. Authority for physical checking

Customs services have the legal power for the physical checking and searching of goods, vehicles and passengers entering or leaving the country. This is, of course, the essential power for customs services. Only physical checks and monitoring can result in the discovery of smuggled goods including nuclear and other radioactive materials.

1.4.4. Seizure and preliminary investigation power

Almost all customs services are legally authorized to detect and seize goods illicitly trafficked and to conduct at least preliminary investigations of smuggling or of attempts to smuggle goods. Through this function, they have gained enormous experience and knowledge on investigation techniques and have established internal and external contact points for the collection of information and intelligence.

1.4.5. Experience in dealing with crime and criminals

As a natural result of being one of the governmental control agencies at the frontiers with the task of protection of society, customs services encounter all kinds of cross-border offence. This provides them with a wide experience on crime and criminals, e.g., frequently smuggled goods, nationalities most often involved, routes taken and concealment methods employed.

1.4.6. Worldwide exchange of information and intelligence network

Through the WCO's guidance, most customs administrations around the world are now able to exchange information and intelligence worldwide on customs offences including radioactive material smuggling. This is usually done through the electronic network created under the Regional Intelligence Liaison Offices (RILO) project, which now includes more than 100 States.

In addition to bilateral agreements and activities carried out under the IAEA–WCO Memorandum of Understanding (see Section 2.5), most customs administrations are contracting parties to one of the WCO legal instruments which create a legal or administrative basis for the international exchange of information and intelligence on customs offences.

1.4.7. Awareness and training

Customs services are continuously being informed on the potential smuggling of radioactive materials and on the associated risks to themselves, society and the environment. In response, most customs administrations are either conducting their own awareness training programmes and employing the necessary detection equipment or are participating in or conducting regional seminars or courses.

1.4.8. Employment of risk assessment techniques

Customs services are advised and encouraged to use targeting and selectivity, based on risk assessment techniques, to assess the probability that goods being processed through customs control have not been legally entered or declared. This modern enforcement technique helps customs services to identify potential or suspected persons, vehicles or goods in advance for further examination. This not only facilitates the international flow of goods but also enables customs services to optimize their limited resources.

2. THE WCO INITIATIVE: ENFORCEMENT PROGRAMME ON ACTION TO COMBAT NUCLEAR AND OTHER RADIOACTIVE MATERIALS SMUGGLING

In 1993 the World Customs Organization launched a programme to assist its Members in the development of a comprehensive action plan to combat nuclear and other radioactive material smuggling.

The objective of this programme is to help Member administrations enhance their capabilities for preventing, detecting and responding to illicit trafficking in nuclear and other radioactive materials. This programme is basically intended to provide the necessary awareness background for initiatives to ensure that nuclear and other radioactive materials are securely monitored and controlled so that illicit trafficking of them is inhibited, and that there are processes and procedures in place to detect and respond to any attempted illicit trafficking.

To attain this overall objective, the WCO action plan is aimed at: heightening of awareness, development of training materials, design of training programmes, exchange of information and development of a database, and promotion of international co-operation.

2.1. Awareness activities

The WCO awareness raising activities can be summarized as follows.

(1) The First Seminar on Dangerous and Toxic Products, held in Brussels on 14 and 15 March 1994.

(2) The Second Seminar on Nuclear Materials, organized by the US Customs service in collaboration with the US Department of Energy, held in Brussels on 31 May 1995.

(3) The First Working Group on the Identification of Nuclear Materials and Dangerous Goods, held in Brussels on 1 and 2 June 1995.

(4) Adoption of a WCO Recommendation concerning Action Against Illicit Cross Border Movement of Nuclear and Hazardous Material (including associated waste), adopted by France (March 1998), Sweden (January 1998) and Finland (May 1998).

(5) On 28 June 1996, Members were asked to describe their experience, resources and needs in a questionnaire; awareness, training, exchange of information and co-operation were their first four priorities.
(6) Issuance of a progress report on WCO Awareness and Training Programme on Nuclear and Hazardous Material (June 1996).
(7) The First IAEA/WCO Technical Committee Meeting, held in Vienna, Austria, from 8 to 12 July 1996.
(8) The Second IAEA/WCO Technical Committee Meeting, held in Vienna, Austria, from 14 to 18 July 1997.
(9) The Third IAEA/WCO Technical Committee Meeting, held in Vienna, Austria from 6 to 10 July 1998.
(10) The next IAEA/WCO Technical Committee Meeting is scheduled for July 1999 in Brussels, Belgium.

2.2. Training material

At the request of its Members, the WCO has developed a comprehensive Customs Enforcement Training Module on the smuggling of nuclear and other radioactive material. This module provides guidelines for customs trainers to develop their own national training programmes.

The module was prepared in close co-operation with the IAEA, and special contributions were made by certain Member countries. In particular, it has been possible to combine the IAEA's experience and knowledge with those of the customs enforcement experts who met at the first and second expert group meetings in Brussels in 1995 and 1996.

As a priority, trainers from customs services in Eastern and Central Europe were trained in 1997 in the use of this module at the national level.

Concerning the development of the WCO training module, the following progress was made:

(1) The First Working Group on the Identification of Nuclear Materials and Dangerous Goods and the WCO Nuclear Awareness Seminar, Brussels, 1–2 June 1995.
(2) The First Expert Group Meeting on Identification of Nuclear and Hazardous Materials, Brussels, October 1995.
(3) The Second Expert Group Meeting on Nuclear and Hazardous Materials, Brussels, 3–5 January 1996.
(4) The first train-the-trainer course in the Eastern and Central Europe region, held in Vienna, 2–6 June 1997.
(5) The Joint WCO/IAEA Expert Group on the WCO Enforcement Training Module on Nuclear Material, Brussels, 22–23 September 1997.

The WCO has received a wide range of training materials in the form of books, leaflets and brochures from certain Members. The IAEA plans to provide a video on the safe transportation of nuclear materials, which will accompany the training module. The WCO Secretariat will also continue its efforts to contact all relevant international and specialized institutions with a view to collecting and distributing useful training materials to WCO Members.

2.3. Training programmes

In line with the request made by its Members, the WCO Secretariat has given priority to designing training programmes for customs at the regional level to improve their enforcement structures and measures taken at the national level. First priority was given to Eastern and Central Europe, and the 'train-the-trainer' course described in item (4), above, was the first result. This programme was financed by the Japanese customs service and the IAEA, supported by the IAEA and the Austrian Research Centre Seibersdorf and hosted by the Austrian customs service. The training was given by 31 trainers and was attended by customs personnel from Albania, Austria, Belarus, Bulgaria, Croatia, Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia and Turkey.

Given the success of the first training course, the possibility of conducting a second course is now being discussed among the IAEA, ICPO-Interpol and the WCO, in a multiagency format with police and customs officers of Eastern and Central European countries. It is to take place in the first week of October 1998.

2.4. Exchange of information and development of a database

Timely, comprehensive and rapid exchange of information and intelligence is the principal element of effective global preventive efforts concerning illicit transborder movement of nuclear materials.

With a view to assisting its Members in this regard, the WCO Secretariat has proceeded in two directions:

(1) Co-operation at the national level: customs services are encouraged to improve co-operation with the national law enforcement agencies and competent nuclear authorities.

(2) Development of a database: the WCO Secretariat has developed a separate database for nuclear and radioactive material smuggling at the WCO headquarters with the support of Members and international organizations concerned. As of June 1998, the total number of confirmed smuggling cases was 234 (see Section 3).

The basic aim of this database is to enable customs services to make their own information analysis and produce strategic, operational and tactical intelligence for their own needs, such as regional and international trends, modus operandi employed by smugglers and routes commonly used.

The steps leading to the database were as follows. On 8 June 1996, Members were informed of the establishment of the WCO database and were requested to send seizure information; on 3 April 1997, certain Members were invited to provide detailed information on seizures recorded in the database; on 17 April 1998, all Members were informed that the updated database was on the WCO Electronic Bulletin Board for downloading and use for their own intelligence purposes. In this regard, the regular exchange of seizure data between the IAEA and the WCO deserves special mention.

This database is accessible to customs services through the WCO Electronic Exchange of Information Network; information is gathered from Members, international organizations and open sources (unconfirmed cases); it is protected with double password; cases are classified as confirmed or unconfirmed.

2.5. International co-operation

One of the pillars of the WCO programme is to co-operate with the international organizations concerned to ensure the broadest communication channels for timely and accurate exchange of information, close co-operation and harmonization of actions to be taken at the international level in this arena. The IAEA, ICPO-Interpol, Europol, the EC and the UN specialized agencies are particularly covered. However, the co-operation between the WCO and the IAEA deserves specific mention because of the progress made in the relevant meetings.

The IAEA/WCO Joint Technical Committee Meetings are held each year. They aim at bringing together nuclear and customs experts of countries where most nuclear and other radioactive materials are seized, in order to review the action taken, share the practical experience and discuss future steps for the effective combating of radioactive material smuggling.

Other co-operation activities are the following:

(1) The Joint WCO/IAEA Expert Group on WCO Enforcement Training Module on Nuclear Material, Brussels, WCO headquarters, 22–23 September 1997.
(2) WCO participation in the IAEA annual interagency meetings.
(3) WCO participation in the IAEA Consultants Service meetings.
(4) Co-sponsorship by the WCO of the International Conference and the IAEA Safety Guidelines for law enforcement agencies.
(5) Continuous support of the development of the IAEA Safety Guides on illicit trafficking to be published for law enforcement agencies.

(6) Support of the implementation of the IAEA Detection Equipment Test Project (ITRAP).
(7) Regular exchange of seizure information on radioactive material smuggling.

This close co-operation reached a point where a Memorandum of Understanding between the two organizations was signed on 13 May 1998, aiming at the establishment of an administrative base for effective co-operation and developing joint projects to enhance international efforts to combat illicit trafficking in nuclear and other radio-active materials.

3. AN OVERVIEW OF RADIOACTIVE MATERIAL SEIZURES

Tables I–IV give an overview of nuclear and other radioactive materials smuggling between 1993 and June 1998 based on the confirmed cases recorded in the WCO database. The total number of the seizure files was 234 as of 17 June 1998.

4. RESULTS

It is widely accepted that customs services around the world have a role to play in preventing and detecting illicit trafficking in nuclear and other radioactive materials, because of their location at national borders as governmental cross-border control agencies.

This role can be maximized by raising awareness, employing risk assessment techniques and deploying detection equipment and by making customs an integral part of the national preventive strategy or action plan.

It is therefore very important to invite Member countries to consider using customs services in combating nuclear and other radioactive material smuggling.

To prevent and detect the illegal movement of nuclear and other radioactive materials at national borders before they enter or leave a country is always interpreted not only as protection of a country's own citizens but also as protection of society worldwide.

However, the following matters are left open for further consideration:

(1) The illicit trafficking of nuclear and other radioactive material needs to be clearly identified as a crime with proper penalties:
  (a) Law adapted at national or international level,
  (b) Harmonization of policies at the national level.
(2) Deployment of detection equipment:
  (a) Selection of appropriate equipment,

TABLE I. SEIZURES BY REGION, 1993–1998

Region	Number of cases	Percentage of cases
Western Europe	71	30.3
Eastern and Central Europe	154	65.8
North America	1	0.4
South America	5	2.1
Central and Southern Africa	1	0.4
Southeast Asia	1	0.4
Pacific Ocean Region	1	0.4

TABLE II. SEIZURES BY COUNTRY, 1993–1998

Country	Number of cases	Percentage of cases
Germany	67	28.6
Russian Federation	52	22.1
Poland	18	7.7
Ukraine	17	7.2
Lithuania	17	7.2
Turkey	14	6.0
Bulgaria	10	4.3
Estonia	8	3.4
Czech Republic	7	3.0
Belarus	6	2.6
Azerbaijan	3	1.3
Italy	3	1.3
New Zealand	1	0.4

TABLE III. SEIZURES BY ELEMENT, 1993–1998

Element	Number of cases	Percentage of cases
Uranium	129	55.1
Caesium	53	22.6
Plutonium	10	4.3
Radium	5	2.1
Americium	3	1.3
Other	34	14.5

TABLE IV. OVERALL SEIZURES, AND SEIZURES OF URANIUM, BY YEAR

Year	Overall seizures	Uranium seizures
1993	56	30
1994	65	42
1995	38	22
1996	37	20
1997	28	11
1998	10	4

(b) Identification of the best location,
(c) Dealing with false alarms.

(3) The need for awareness and training:
(a) Awareness of the potential threats and trends,
(b) Terms used,
(c) Sort and scope of training, including personal safety measures.

(4) The necessity of timely, accurate exchange of information and intelligence:
(a) Legal obstacles,
(b) Permanent or case by case,
(c) Scope of exchange of information,
(d) Sharing of practical experience.

(5) Co-operation between customs and:
(a) Trade and industry,
(b) Other law enforcement agencies,
(c) Nuclear regulatory bodies.

(6) Contaminated scrap material.

(7) Identification and detection:
(a) Identification of materials,
(b) Isolation of suspected/detected materials,
(c) Storage.

As one of the co-sponsors of this International Conference, the WCO hopes this event will help all parties concerned to assess the dimension of the problem we face, understand the technical difficulties we encounter, promote co-operation among the parties concerned and improve the exchange of information and intelligence we seek.

PRESENT ACTIVITIES WITHIN ICPO-INTERPOL TO COMBAT ILLEGAL TRAFFIC IN RADIOACTIVE MATERIALS

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Abstract

PRESENT ACTIVITIES WITHIN ICPO-INTERPOL TO COMBAT ILLEGAL TRAFFIC IN RADIOACTIVE MATERIALS.

The International Criminal Police Organization, also known as Interpol, was created in 1923. The number of Memher States is now 177, and the Interpol General Secretariat (headquarters) is situated in Lyon, France. The purpose of the organization is to ensure and promote the widest possible mutual assistance between all police authorities, within the limits of the laws existing in the various countries, and to establish and develop all institutions likely to contribute effectively to the prevention and suppression of ordinary crimes, including illegal traffic in nuclear and radioactive materials. Each Member State has an Interpol National Central Bureau through which international police co-operation is co-ordinated. In 1995 ICPO-Interpol carried out a study in order to obtain insight into trafficking in radioactive substances and related fraud within eastern and western European countries and North America. The organization is now maintaining a database on seizures and thefts of nuclear and radioactive materials and on individuals involved in this crime, all as reported by Member States. In the future the organization will be involved in a joint training programme with the International Atomic Energy Agency and the World Customs Organization. The paper describes the organization and activities of ICPO-Interpol in relation to the illegal trafficking of radioactive materials.

1. INTRODUCTION

The problem of illegal traffic in nuclear and other radioactive substances is a fairly new phenomenon to law enforcement agencies. The problem was hardly known to the police several years ago, although countries had already begun to combat illegal transborder movement of hazardous industrial waste which contained radioactive substances.

It was in the early 1990s, particularly since the East–West border opened up, that we saw a dramatic increase in illegal traffic in nuclear and other radioactive substances. The reader may recall the series of seizures of nuclear substances in 1994 which drew so much public attention that the problem was treated as a political matter of top priority.

While the situation has calmed down since then, and the sensational press coverage has died out, the problem still needs to be closely monitored from the viewpoint of law enforcement, since the smuggled substances can be used for criminal purposes or may cause serious damage to the public health and security if handled ignorantly.

ICPO-Interpol has paid attention to this problem since the early 1990s and has made efforts to enhance the exchange of information among Member States and to strengthen co-operation with the international organizations concerned. This paper describes the structure of Interpol, Interpol's activities in this area and an analytical study of the problem in Europe.

2. STRUCTURE OF INTERPOL

Interpol, the only global police organization, has 177 Members. Its purpose is to ensure and promote the widest possible mutual assistance between all police authorities, within the limits of the laws existing in the different countries, and to establish and develop all institutions likely to contribute effectively to the prevention and suppression of ordinary crimes.

Interpol is strictly forbidden by its constitution to undertake any intervention or activity of a political, military, religious or racial character.

Each Member State designates an office, normally a part of the national police force, as the Interpol National Central Bureau (NCB). The exchange of information is conducted through the NCBs, which monitor the flow of messages.

Contrary to popular belief, Interpol is not made up of international brigades of investigators travelling around the world investigating cases in different countries. International police co-operation has to depend on co-ordinated action on the part of the Member States' police forces, all of which may supply or request information or services on different occasions.

Experience shows that three major obstacles impede efficient international police co-operation:

(1) different structures of national law enforcement, which often make it very difficult, from the outside, to identify the service competent to deal with a particular matter or to provide information;
(2) language barriers;
(3) differences between the legal systems of Member States.

This is why, in each Interpol Member State, the task of co-operation is assigned to the above mentioned NCB.

The General Secretariat is the permanent administrative and technical body through which Interpol speaks. It is situated in Lyon, France. Approximately 90 police officers from about 40 countries, representing all regions of the world, work there in the Liaison and Criminal Intelligence Division.

The General Secretariat implements decisions taken by the General Assembly, the Executive Committee and other deliberative organs. In order to co-ordinate and facilitate various actions for combating transnational organized crime, the General Secretariat provides the following services to Member States:

(1) A criminal intelligence service, which assists Member States in identifying, arresting and prosecuting internationally active criminals. The General Secretariat maintains its own database, which contains data concerning known criminals as well as case summaries and properties used in criminal cases. The content of the database depends on information provided by Member States. Analytical study of criminal cases by a team of experts is an integral part of the above mentioned service.

(2) A liaison function, which facilitates the exchange of information between Member States. This occurs either through the numerous meetings and conferences which the General Secretariat hosts or attends, or through the efforts of its liaison officers, who are well informed both in respect of their subject matters and on the regions they represent.

(3) A number of training courses, both at a regional and an international level, designed to assist Member States in improving their communication and criminal investigation infrastructures.

(4) A technical support service, which has developed an independent and secure telecommunications network and is upgrading systems in Member States, enabling them to send or receive information quickly and securely. This also includes our Automated Search Facility, which allows the NCBs to consult our database automatically and to transfer photographs and/or fingerprints of known criminals via computer.

The General Secretariat has also developed co-operative relations and has collaborated with a number of intergovernmental or non-governmental international organizations. Our co-operation with the IAEA in this area is one example. Interpol is always ready to take the advice of other organizations in order to enhance international co-operation among law enforcement agencies.

3. INTERPOL'S ACTIVITIES IN THIS AREA

Although the first case of trafficking in radioactive materials was reported in 1989, the General Secretariat recognized a rapid increase in 1991. As most of these cases were reported from the European Member States, the situation there was closely monitored. It seemed that real (as opposed to purported) nuclear and other radioactive substances were illicitly transported mainly from the countries of the former USSR to Central and Eastern European countries. Also reported were a number of fraud cases in which offenders only purported to possess such substances in order to defraud potential buyers.

In January 1993, at the request of Germany, the General Secretariat organized a European working meeting on the subject, the first meeting to discuss law enforcement measures against this type of offence. Delegates from 23 European countries, the USA and Canada actively exchanged information in this forum.

Further to the meeting, the subject was taken over by the Interpol Working Party on Environmental Crime, which had been set up in 1992, because there was no other permanent forum in which to discuss the subject and because the Working Party was already expected to discuss the problem of transborder movement of radioactive waste.

Participants in the first meeting of the Working Party, held in September 1993, considered it necessary to subdivide the group in order to discuss various subjects of environmental crime effectively. It was agreed that the Working Party meetings would comprise the plenary session, a forum to discuss common approaches to environmental crime and subgroup meetings to discuss specific subjects. One subgroup was assigned the subject of illegal traffic in real or purported radioactive or nuclear substances. The Working Party Members met three times and issued a number of recommendations.

One result of these meetings has been the creation of the so-called ECO message, a formatted message that law enforcement officers can fill in easily when they report seizures of radioactive materials or when they request information or assistance from other Member States or the General Secretariat. The Working Party Members recognized that law enforcement officers in general did not have expertise or specific knowledge on these substances and considered it necessary to find the easiest way to report the cases they handled. In this context, they developed a quick reference guide on nuclear and other radioactive materials, which can be consulted by police officers when the materials are offered for sale or seized.

Another work which has been conducted as a result of the recommendations is an analytical study of the subject in Europe. The study was conducted by a crime analysis specialist at the General Secretariat and was aimed at giving an insight into trafficking and fraud involving nuclear and other radioactive substances. The study is discussed in Section 4.

The Working Party Members also recommended that the General Secretariat develop co-operative relations with other concerned international organizations such as the IAEA. The IAEA has organized interagency meetings on several occasions to bring the concerned parties together. Interpol has been an active participant in these meetings together with other organizations such as WCO, Euratom and the EC. The interagency meetings offered Interpol excellent opportunities to make use of their expertise and to obtain specific information as needed.

In 1996 and 1997, Interpol participated in the Technical Committee meetings organized jointly by the IAEA and the WCO to prepare a Safety Guide on Preventing, Detecting and Responding to Illicit Trafficking in Radioactive Materials. These meetings were aimed at helping regulatory authorities and other relevant bodies in our Member States to establish or enhance their capabilities for preventing, detecting or responding to illicit trafficking in radioactive materials. This Guide is now being finalized by the IAEA[1] and will be distributed to our Member States in due course.

The results of our activities were reported to other Member States in two International Conferences on Environmental Crime, a broadened forum organized by the General Secretariat and held in September 1996 and November 1997. The participants in the conferences endorsed the results and encouraged us to continue our work on the subject.

In the future, Interpol will also be involved in training, as the IAEA, the WCO and Interpol are jointly organizing a training course for customs and police officers from East and Central Europe which will take place in Vienna, Austria, at the end of September 1998. This first joint training programme is the result of the excellent co-operation between the IAEA, the WCO and Interpol.

4. ANALYTICAL STUDY IN EUROPE

The analytical study was conducted in 1995 and covers mainly the period 1992 to 1994. In terms of geographical area, it covers Europe in principle. The Interpol in-house database was used to obtain basic information, which was completed by additional data provided by Member States in Europe, the USA and Canada. Open source information from books, reports and press articles were referred to as well.

Although the Member States in the region were in general co-operative, we found it difficult, from time to time, to obtain detailed information on offenders or potential buyers because of the sensitive nature of the cases. It was also extremely difficult to obtain any information related to military forces because of Interpol's non-military nature. Therefore, despite the efforts made by the analyst, the study is not at all exhaustive.

The study covers real seizures, proposals for sale and fraud cases, while the distinction between them was not easily defined. The cases concerning the substance called red mercury were considered fraud, since the substance could not be identified.

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[1] K. DUFTSCHMID, IAEA, Vienna, personal communication, 1998.

A distinction is established between 'illegal traffic in nuclear/radioactive substances', in which the substances themselves have a market value, and 'illegal traffic in radioactive waste', in which the cost of disposal of the substances accounts for the market value. Cases involving 'radioactive waste' were not taken into consideration in the study.

A summary of the results of our (unpublished) study is as follows:

(1) So far as the number of cases is concerned, a rapid increase was recognized from 1992 to 1994. Before 1991, only a few scattered cases were reported.

(2) The smuggled substances seem to originate from the countries of the former USSR, in particular, the Russian Federation, Ukraine and Belarus; in some cases the origin was unknown. The substances seem to have come from nuclear power stations, other nuclear plants, military units, factories or coal mines, but it was rather difficult to identify the real origin of the substances. One case was reported in which the substance seemed to have originated outside of Europe.

(3) Central and Eastern European countries appeared to be the main transit countries. The routes used can be described as northern, central or southern. In cases involving the northern route, the substances were smuggled through Baltic states (Estonia, Lithuania and Latvia), Scandinavian states (Denmark and Sweden) or Finland. In those involving the southern route, the substances transited through Azerbaijan or Armenia to Turkey and then to Central Europe. The central route goes through the former Eastern bloc countries, such as the Czech Republic, Slovakia, Poland, Hungary or Bulgaria. Among these three routes, the central route seemed to be used most frequently, whereas the Southern Route was used in only a few cases.

(4) The destinations seemed to be countries in Western Europe, especially Austria, Germany and Switzerland. Other Western European countries such as France, Belgium, Spain, Netherlands or the UK were rarely, if at all, affected. It seemed that the countries affected, in particular Germany, were seen as countries where potential buyers could be found. The final destination, if any, remained unclear. No established market for buyers has been identified, either.

(5) While uranium, either natural or lightly enriched, was the most commonly smuggled and/or seized substance, plutonium and highly enriched uranium, which can be used in nuclear weapons, were also found and/or seized. It should be noted that a case was reported where nearly 3 kg of highly enriched uranium (87.7% ^{235}U) was seized. Although the quantity and the level of enrichment were not enough for the production of nuclear weapons, this case indicates the dangerous nature of this type of crime. The substances found and/or seized were: ^{239}Pu, uranium (natural, lightly-enriched or highly-enriched), beryllium, ^{134}Cs, ^{137}Cs, ^{57}Co, ^{60}Co, ^{192}Ir, ^{226}R, ^{249}Sr, ^{249}Cf, ^{252}Cf, ^{133}Cs, ^{85}Rb and ^{6}Li.

(6) Special attention was paid in the study to packaging, since the type of packaging and handling of the substances determine the degree of danger they represent for human beings and the environment. Information from Member States indicates that the packaging was insufficient, although no accident or damage by radiation was reported. Examples include a seizure in which the offender transported enriched uranium in his bag for several days; its only protection was a thin lead cover. Some offenders were not aware of the danger of the substances they were transporting and therefore could have irradiated themselves or their surroundings unknowingly.

(7) The offenders were mainly from Eastern Europe, including the countries of the former USSR. The suppliers, when identified, were mainly of Russian origin, while offenders of other nationalities acted as buyers or intermediaries. The real buyers or the end users were not identified. It was possible to recognize one or two organized crime groups, although there was no evidence of the existence of large criminal organizations behind the trafficking.

(8) The study also covered prevention policy and legislation in the countries concerned. Most of the countries took the problem seriously and were trying to take appropriate measures such as adopting special legislation or establishing a special unit. Nevertheless, the Eastern European countries seemed to have encountered difficulties because of the shortage of human and financial resources in their law enforcement agencies. The situation may have improved since the study was conducted in 1995.

Although the study did not make it clear, an analysis of the financial records might be useful in order to identify the networks and interrelations of criminals. If the financial records of the criminals or potential suspects are available, this approach may produce a considerable volume of information on the day to day activities of the targets.

Since the completion of the above study the General Secretariat has continued to compile information on seizures of nuclear and radioactive material on the basis of information received from Member States. The information is by no means complete, because some Member States are still reluctant to share it.

Since 1996 information has been received about more than 100 persons involved in the illegal traffic in nuclear and radioactive materials. This information has been stored in our database together with the case files and is thus available for the law enforcement agencies in their investigations.

Most of the seizures still take place in Europe, mainly Eastern and Central Europe, and very few cases are reported to us from other regions of the world.

From the viewpoint of law enforcement, the situation has calmed down since the mid-1990s. However, more cases of radioactive contaminated waste are now being reported, because many countries have installed equipment to detect radioactive materials in appropriate places.

5. CONCLUSION

Traffic in nuclear and other radioactive substances poses a real danger to people and their environment. A potential threat in terms of criminal use, e.g. terrorism, cannot be denied. Sensational reaction combined with the complexity and the scientific nature of this problem makes it difficult for the public to discern the real threat and to remain objective. It is therefore of great importance to collect as precise information as possible in order to analyse the actual situation and conduct an objective risk assessment.

Interpol's activities in this area have concentrated mainly on the European region. It is therefore particularly interesting at this Conference to hear about the situation in other regions.

Interpol is fully aware that law enforcement agencies cannot achieve the goal on their own. It is important that each country develop and maintain a national prevention system with efficient working relationships between the different authorities with expertise in this area, e.g. the national atomic energy agencies, environmental agencies, the customs and different police forces. In this regard, this Conference offers Interpol an excellent opportunity to exchange views with other parties concerned. Criminals follow no rules. We should take a co-ordinated approach to use our human and financial resources as effectively as possible.

PRESENT ACTIVITIES OF THE EUROPEAN COMMISSION IN THE FIELD OF SAFETY OF RADIATION SOURCES AND SECURITY OF RADIOACTIVE MATERIALS

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Abstract

PRESENT ACTIVITIES OF THE EUROPEAN COMMISSION IN THE FIELD OF SAFETY OF RADIATION SOURCES AND SECURITY OF RADIOACTIVE MATERIALS.

The Euratom Treaty is the legal basis for legislative action of the European Union in the field of radiation protection, covering also the safety of radiation sources and the security of radioactive materials. The Treaty, signed by all European Union Member States, obliges the European Union to issue appropriate legislation in order to protect workers and the general public against the dangers arising from ionizing radiation. The paper provides an overview of European and national legislation, derived directly or indirectly from the Euratom Treaty, in this field.

1. INTRODUCTION

In recent years, the media, radiation protection authorities and law enforcement agencies have increasingly reported about accidents, misuse, unauthorized disposal or illicit traffic connected with radiation sources, radioactive substances, contaminated metal scrap or even special nuclear material.

However, competent government authorities, regulatory bodies in radiation protection, and national and international organizations are well aware of the dangers implicit in the authorized and controlled application or use of sources or substances emitting ionizing radiation in industry and medicine. International organizations and national competent authorities and regulatory bodies active in the radiation protection field have therefore established comprehensive legal instruments, regulations and administrative acts in order to cope with the dangers and to protect the affected workers, the general population and the environment.

Nevertheless, these organizations are now confronted with unlikely situations leading to incidents or accidents sometimes causing health detriments or even deaths. It is therefore much appreciated that this Conference, jointly organized by five national and international organizations, brings together scientists, regulators and administrators to discuss possible countermeasures.

2. RADIATION PROTECTION

2.1. The Euratom Treaty

The Treaty establishing the European Atomic Energy Community, the so-called Euratom Treaty [1], gives to the European Union the normative and executive legal power in the field of peaceful use of nuclear energy.

Chapter III of the Treaty, entitled Health and Safety, delegates the direct and exclusive legal competence in radiation protection related legislative initiatives to the European Union. Articles 30 to 39 provide the relevant obligations for the Union and the Member States in order to fulfil their liabilities. Article 30 stipulates that the Union shall lay down basic safety standards for the protection of the health of workers and the general public against the dangers from ionizing radiation (Section 2.2). In this context, the EU basic safety standards are to express maximum permissible doses compatible with adequate safety, maximum permissible levels of exposure and contamination and the fundamentals governing the health surveillance of workers. Articles 31 and 32 describe the legal pathway for the establishment of any radiation protection legislation, the EU Basic Safety Standards in particular. Article 33 obliges the Member States to lay down appropriate national laws, regulations or administrative actions to ensure compliance with the EU Basic Safety Standards. Furthermore, Member States have to communicate any draft provision applicable, and the Commission may issue recommendations with regard to such provisions.

2.2. The EU Basic Safety Standards

Article 161 of the Euratom Treaty describes the legal instruments available to the Union in order to carry out its tasks. From the beginning in 1959, the Union has chosen the directive as the most appropriate legal instrument for the adoption of the EU Basic Safety Standards. The directive is addressed to the Member States, which are consequently obliged to transpose this European law into national legislation. The directive is binding on the Member States as to the result to be achieved.

The directive is the only legal instrument of the Union which takes into account the different legislative structures of the individual Member States and which leaves them the necessary legislative and administrative freedom for the transposition of European legislative acts.

The centrepiece of the European radiation protection policy is the Basic Safety Standards for the Protection of the Health of Workers and the General Public against the Dangers from Ionizing Radiation [2]. First issued in 1959, the Basic Safety Standards have been regularly adopted and revised, taking into account the most recent scientific developments and findings. With the Como Agreement, it was agreed by Euratom, the International Commission on Radiological Protection (ICRP) and the

International Commission on Radiation Units and Measurements (ICRU) that the EU Basic Safety Standards will mirror the scientific recommendations issued by these two important international organizations in radiation protection.

After the publication of the 1990 Recommendations of the ICRP [3], in application of Article 32 of the Euratom Treaty, the European Commission took the initiative and drafted, in consultation with the group of experts under Article 31, the most recent Basic Safety Standards. On 13 May 1996 the 15 Member States of the European Council unanimously adopted this directive [1], which must be implemented before 13 May 2000; consequently the directive now in force will be inoperative as of this date.

There are major changes in the obligations provided by the new directive. In the context of this International Conference, those articles providing the legal basis for the activities of the Member States and the Commission concerning the safety of radiation sources and security of radioactive material will be highlighted.

The new directive changes the scope of application in two important points. It no longer applies to activities involving a hazard from ionizing radiation. Instead, it now applies to practices, which are human activities increasing radiation exposures, and it applies to interventions, which are activities foreseen to decrease and prevent radiation exposures. In this way, it enlarges the scope and the legal margin of the directive.

The redefinition of the scope of the directive also includes new requirements for reporting and authorization, such as for import and export into and from the Union.

In relation to illicit traffic, this modification of Article 2 is of importance. Import and export are now legally treated in the same way as transport, holding, use, etc. Import and export must undergo the system of prior notification and authorization, even if there is no physical possession of the material in question. In relation to the prevention of illicit practices, this is an important step forward towards harmonization of EU Member States' legislation.

The revision of the system of prior notification and authorization created some confusion in the public because of misinterpretations and misunderstandings between the radiation protection specialists, the mass media and politicians. The Member States' authorities now have two systems of laying down the appropriate regulations to handle the use of radioactive substances.

Reporting of the intention to carry out any practice involving ionizing radiation is compulsory.

Exempted from the system of notification are those practices in which the radioactivity involved is below values given in Annex I of the Directive. Article 3 and Annex I describe the circumstances under which competent authorities may exempt prior notification. The specifications given in Annex I say that under exceptional circumstances, and subject to specified conditions, Member States' authorities may deviate from the values of the quantities and the activity concentrations given in Table A therein.

Also exempted from prior reporting and authorization is the use of electrical equipment which emits ionizing radiation below limits given in Article 3 and practices permitted in accordance with special conditions laid down in national legislation. These are mainly cases involving negligible risks of exposure to human beings.

The next section of the EU Basic Safety Standards deals with clearance of radioactive substances. Disposal, recycling or reuse of materials containing radioactive substances is subject to prior authorization, in particular when these materials originate from authorized practices.

Such materials may be released from the scope of the directive in cases where the quantities of the involved radioactivity are below the clearance levels, which must be established by national authorities in application of the criteria given in Annex I of the directive.

Article 3 also states that those activities involving materials contaminated as a result of authorized releases need not be reported.

Within the context of this Conference, other important changes in the obligation of the directive are the reduction of annual radiation dose limits for workers and the general public. The directive follows the recommendation of the ICRP [4] with respect to setting the annual dose limit for workers to 100 mSv, averaged over five consecutive years. But in view of the different possibilities of interpretation and of managing the averaging over a long period, the directive entitles the Member States to decide on annual dose limits.

In this context, the general principle of justification of practices must be seen in different views. The justification of practices is in the competence of the Member States' authorities, except for those practices directly prohibited by Article 5 of the directive.

The general principle of justification can also be seen in the light of the topics of this Conference. Practices may be not justified when the safety of the sources or the security of radioactive material cannot be guaranteed by the user.

New practices involving radiation sources or radioactive materials must always be seen in the context of the balance between economic and social benefits and the risks of possible health detriments.

One of the major challenges of the Commission's activities is to work towards a uniform adoption of European radiation protection legislation with the view to establishing within the European Union a harmonized and synchronized system of radiation protection for workers and the general public.

2.3. Shipment of radioactive substances

The Council regulation concerning the shipment of radiactive substances [5] supplements the Basic Safety Standards directive and closes gaps between other existing European legislation concerning the transport of dangerous goods.

The regulation seemed to be the most appropriate legal instrument in relation to the problems of shipments within the European Union, because the regulation says explicitly that the authorization, supervision and control of shipments of radioactive substances should not be discriminatory. The regulation specifies that directly existing provisions for shipments under Chapter VII of the Euratom Treaty, entitled Safeguards, are not affected, nor are those under the Convention on the Physical Protection of Nuclear Material [6]. The Union therefore considered that sufficient control is already exercised on nuclear material and radioactive substances likely to play a role in nuclear proliferation. This is notably the case for those provisions requesting advance notification of those States through which the nuclear material is expected to transit.

One major point of the regulation is the mutual notification of the competent authorities involved in shipments of radioactive substances. This was the major gap to be closed, because all the operations and conditions associated with the movement of radioactive materials, such as the design, manufacture, maintenance and preparation of packages and their dispatch, handling, routing, storage during transport and reception or delivery, are dealt with by the European Union legislation on transport [7].

In 1984 and 1989, communications from the Commission on the transport of radioactive materials in the European Union [8, 9], together with reports on that subject from a special working group [10], were established and transmitted to the Council and the Parliament. A third report has been finished recently [11], and on the basis of this the Commission may identify possible actions in the field, taking into account the activities ongoing within the IAEA.

The regulation has to be seen independently, because it deals with radiation protection, which is the subject of Chapter III of the Euratom Treaty, and it must be applied independently from other European legislation.

2.4. Radiation sources

The competence of the European Union in relation to radiation sources is distributed over a number of legal instruments. On one side, European legislation lays down provisions for the production and placing on the market of such sources. On the other side, provisions are issued regulating all activities from first use until final disposal. Above all, these different regulatory steps have to be seen in the light of radiation protection. Therefore, the respective provisions of the Basic Safety Standards have to be adopted by the Member States' authorities in conjunction with the adoption of other European legislation.

2.4.1. Active sources

The manufacturing of active radiation sources is mainly regulated by international standards on electrical equipment. The International Organization for

Standardization (ISO), the International Electrotechnical Commission (IEC) and the European Standardization Commission lay down general standards for electrical equipment subsequently specified by the national standardization organizations such as the Association française de normalisation (AFNOR), the Deutsches Institut für Normung (DIN) or the Österreichische Normungsinstitut (ÖNorm). Within the European Union, these standards are mandatory because of the obligation of the Member States' authorities to comply with the directive on Low Voltage Equipment [12]. This is the result of the earlier mentioned flexibility of the Member States in transposing directives.

The directive on Low Voltage Equipment and the directive on medical devices [13] require the establishment of a quality assurance and control regime during manufacturing, installation and testing of any equipment emitting ionizing radiation. The directives require further quality assurance measures for equipment used in the medical sector, such as acceptance tests, status tests and constancy tests.

For the use of the equipment as mentioned above, prior notification and authorization are compulsory. It is the only competence of the Member States' authorities to lay down requirements and obligations for the operators of such equipment. The national regulations on the use of equipment emitting ionizing radiation are based on the Basic Safety Standards directive or on the Medical Exposure directive [14]. Both directives require the training and education of workers and the presence of a qualified expert in radiation protection.

Furthermore, the directive on the Health and Safety of Workers [15], established under Article 118a of the EEC Treaty, requires that Member States pay particular attention to encouraging improvements, especially in the working environment as regards the health and safety of workers. Member States must set as their objective the harmonization of conditions in this area, but in cases of contradictory dispositions, the Euratom directives are given priority.

2.4.2. Passive sources

For passive sources, manufacturing is also regulated under the provisions of the Basic Safety Standard directive because this is an activity involving radioactive substances.

In respect of the safety of sealed sources, the Member States transposed their obligations into national legislation through the creation of national standards and norms based on standards laid down by international organizations. The same goes for quality assurance.

However, the authorization of activities using sealed radiation sources must follow different priorities. Reports on accidents arising from the use of radiation sources have shown that routine, daily use of radioactive sources has resulted in many cases in careless manipulations and subsequently in accidents. The aspects of physical protection became more important, particularly in relation to illicit traffic. Training and education, in combination with the presence of a qualified expert, is an essential requirement of the Basic Safety Standards directive in order to prevent such unacceptable events.

It is in the competence of the Member States to lay down provisions for the safe manufacturing, handling, use, transport and final disposal of radiation sources. This includes requirements for physical protection and notification procedures in case of loss or theft.

2.5. Radioactive substances

The field of application of radioactive substances in industry, research and medicine is of vast variety. It is extremely difficult to cover the large number of different radioactive substances by single national regulations adopting the Basic Safety Standards directive.

In order to get a clear picture of the situation, the Radiation Protection Division (since February 1997 known as the Radiation Protection Unit) initiated and published in 1993 a study on consumer goods containing radioactive substances [16]. When reviewing the actual situation and observing the developments, it can be seen that Member States' authorities tend to apply the general principle of justification more frequently and more strictly.

Radioactive substances can be separated into two major categories. In one category are substances which are used in different applications for their chemical or physical properties but which also emit ionizing radiation. In the other category are substances enriched with natural or artificial isotopes and which are used because of their radiological properties. In this context, residues from the dismantling of nuclear installations and contaminated metal scrap should be mentioned.

Because of the unsolved problem of the final disposal of radioactive substances, it is the intention of the Commission to take the steps necessary to motivate the Member States' authorities to reduce authorizations for the import, manufacturing, placing on the market and use of the latter category.

The reduction of the exception levels and the concept of clearance as provided by the new Basic Safety Standards directive can be seen as an important step forward in this direction.

2.6. Legal consequences

Article 192 of the Euratom Treaty obliges the Member States to take all appropriate measures, whether general or particular, to ensure fulfilment of the obligations arising from the Treaty or resulting from actions taken by the institutions of the Union. The Member States must facilitate the achievement of the Union's tasks.

Within the EU, there is still a long way to go towards harmonization of the different national legislation laying down the juridical consequences for jeopardizing regulations based on the obligations given by the Basic Safety Standards directive. Similar offences against regulations in the radiation protection area are prosecuted very differently. In some countries, violation is prosecuted as a minor administrative offence and fined between 5 and 50 000 ECU. Other countries punish similar violations by imprisonment between 6 months and 20 years. Ireland even foresees imprisonment for life for causing health detriments.

3. ILLICIT TRAFFIC

3.1. Background

The dissolution of the Soviet Union and of the Eastern Bloc resulted in the fragmentation of centralized control and management structures for radioactive substances and sources and for special nuclear material. The entire Eastern Bloc nuclear industry had been subject to security and safety regulations specific to the existing political systems. These highly centralized systems were based on completely different criteria from those applied in the European Union and on deep interpenetration between military and civil activities.

The stringent controls and physical security rules which were part of these systems have now been considerably relaxed. This situation has become more acute because a number of the new States, in particular the Russian Federation, Ukraine and Kazakhstan, have undertaken an ambitious programme of dismantling nuclear installations and nuclear arsenals, with the result that radioactive materials and sources might move into areas where malicious acts cannot be ruled out. This has been accompanied by a drastic change in the social and economic situation of the population and the societies of these countries.

This combination of elements has stimulated an illicit traffic in radiation sources, radioactive substances and nuclear materials, fraudulently acquired and resold secretly.

The emergence in certain countries, including Russia, of powerful criminal organizations adds to the risks of diversion. Such organizations could take advantage of the situation and establish black market and smuggling channels. Experience shows that this traffic is conducted by organizations rather than by isolated individuals.

This factor could undermine the system of controls and security of States and individuals in the European Union and the rest of the Western world. It calls for an overall response from the European Union and is clearly also in the common interest of the countries of the former Soviet Union and the Central and Eastern European countries.

The joint work that needs to be embarked upon will make it possible to give firm shape to certain aspects of common actions between the European Union and Eastern Europe through partnership and through the Europe Agreement with the

Central and Eastern European countries [17]. Stability in Europe cannot be achieved without such joint approaches and practical co-operation.

The aim of this International Conference is to draw attention to the seriousness of the problem and to suggest some ways in which it can be tackled effectively and systematically, using the various existing legal instruments at the disposition of the Member States and of the European Union.

For obvious geographical reasons, there is a risk that the territory of the Union could increasingly become a venue of this dangerous trade. The dangers inherent in this trade are considerable, and the risk of radiation hazards, which varies according to the radioactive sources and substances involved, exists for those who handle the material and also for individual workers, the general public and the environment. Moreover, the persons guilty of this traffic are sometimes not aware of the real nature and the associated health risks of what they are handling.

An important distinction must be made between the legal frameworks governing the materials in question. Special nuclear materials are subject to 'safeguards' under the provisions of Chapter VII of the Euratom Treaty and the Treaty on the Non-Proliferation of Nuclear Weapons [18].

3.2. Instruments for an European response

It is clear that the situation is ripe for what could be very dangerous trafficking on the territory of the European Union. The present level of safety controls in certain Newly Independent States is quite inadequate, given the quantities and qualities of the dangerous products located on their territory.

It is clear that, in the medium term, the problem can only be solved by an improvement in the economic and political conditions of the countries concerned. In the short term, however, actions focusing on border controls, co-operation between investigating offices, police force co-ordination and controls in the countries in question should produce positive results. The question which therefore arises is what type of strategy the European Union and the Member States could adopt to prevent this worrying problem from escalating. The Commission considers that a response at the Union level would be better suited to the scope of the problem and therefore more effective. The Union already has at its disposal a wide range of instruments which could be used to combat this illicit traffic. This integrated approach must involve the three 'pillars' of the Maastricht Treaty [19], a common foreign and security policy and co-operation in the area of justice and home affairs.

3.3. Co-operation with the countries concerned

Active co-operation with and from the countries concerned is clearly essential if efforts to combat such traffic are to succeed. The Commission therefore takes the view that in order to resolve this problem there is also a need for constructive dialogue with the countries concerned. Given the very high level of expertise of scientists, engineers and authorities in the radiation protection sector, there is considerable mutual benefit in increasing co-operation between industrial operators, the very competent Transuranium Institute of the EU and the national authorities. In addition to this technical assistance and co-operation, the EU can make use of dialogue and co-operation opened up by the Partnership Agreement with the Russian Federation [20] and the Europe Agreement concluded with six Central European countries. Other possibilities for establishing a close dialogue arise in connection with the ongoing negotiations concerning the enlargement of the European Union.

As regards radiation protection, it should be pointed out that, where the international transport of radioactive material is concerned, the Convention on the Physical Protection of Nuclear Material [6] requires its signatories to apply physical protection measures and sanctions. The European Union, the Member States and the Russian Federation, Bulgaria, Hungary, the Czech Republic, Slovenia and Romania are parties to this convention. Supplementary, voluntary guidelines have been adopted by the IAEA. Moreover, in order to guarantee the protection of the public against radiation hazards, there would have to be a firm commitment from the various authorities responsible for radiation protection and the means for increased co-operation with them.

3.4. Customs co-operation

The Member States' customs administrations are the first line of defence at the European Union's external frontiers and will have a decisive role to play in combating this traffic. Their activities can be divided into two main areas. There is a need for more uniform and more effective checks at the external frontiers. In order to achieve more targeted customs controls, the Commission's responsible service is endeavouring to develop appropriate risk analysis techniques. In addition, the Radiation Protection Unit and the Directorate-General for Customs jointly organized an International Seminar on radiation protection aspects of illicit traffic for customs authorities in Vienna in 1995 and still support special training and education for customs officers. Within the framework of the Matthaeus programme [21], the Radiation Protection Unit also supports exchanges of expertise between customs officials of the Member States in the combating of illicit nuclear traffic.

The Customs Information System (CIS), administered by the Commission, is of vital importance in efforts to combat illicit nuclear traffic. The CIS ensures real-time communication between 240 terminals installed in the frontier posts of the Union and supplements the Secure Customs Enforcement Network (SCENT), through which information is exchanged confidentially between the competent authorities in connection with suspected or established cases of illicit nuclear traffic.

3.5. Police co-operation

The Maastricht Treaty foresees, for the purposes of achieving the objectives of the Union, that the Member States will regard a number of areas as matters of common interest. Of these, juridical co-operation in criminal matters, customs co-operation in non-harmonized sectors and police co-operation for the purpose of preventing and combating serious forms of international crime would appear to be the most concerned action to combat illicit nuclear traffic. As regards direct police co-operation, the Commission can only approve the possibility of extending the authority of the future European Police Office, Europol [22], to the traffic in radioactive substances and nuclear material, under the heading of "other serious forms of international crime", with which the Office would be dealing under Article K1 of the Maastricht Treaty.

4. CONCLUSIONS

The safety of radiation sources and the security of radioactive materials are directly connected with serious legal complexity. The current status of the respective legislation gives no reason for major concern. As has been pointed out in this paper, from the point of view of the European Commission there is a need for national and international action in order to keep pace with technical developments. Although there is no need for new legal regulations, regular revision, correct implementation and consequent enforcement of existing laws must all be attended to.

There is a need for supporting, assisting and improving the close co-operation between national and international organizations, government authorities and regulatory bodies. It is necessary to establish, on the broadest basis, common channels for exchange of information, for information systems and for co-operation with law enforcement agencies and customs authorities in the case of illicit traffic. There is one area which should be mentioned especially. As stated above, the human factor plays an important role in preventing accidents and illicit traffic. Therefore, careful and sound education and training should be made available for personnel employed in the nuclear industry, the medical sector, research, regulatory bodies and other authorities involved in the field.

This bundle of proposals for measures will certainly improve and strengthen the application of the existing legal regime in order to respond successfully to the challenge of radiation protection of the workers, the general public and the environment.

The expertise and experience of the IAEA, the WCO, Interpol and other national and international organizations should be applied. I can assure you that the European Commission, and in particular the Nuclear Safety Directorate, will contribute to this end wherever and whenever possible.

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THE REGULATORY CONTROL OF RADIATION SOURCES, INCLUDING SYSTEMS FOR NOTIFICATION, AUTHORIZATION (REGISTRATION AND LICENSING) AND INSPECTION

(Technical Session 1)

Chairperson

G.J. DICUS
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Summaries of Contributed Papers
IAEA-CN-70/16 and 80 were also presented

THE REGULATORY CONTROL OF RADIATION SOURCES, INCLUDING SYSTEMS FOR NOTIFICATION, AUTHORIZATION (REGISTRATION AND LICENSING) AND INSPECTION

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Abstract

THE REGULATORY CONTROL OF RADIATION SOURCES, INCLUDING SYSTEMS FOR *NOTIFICATION, AUTHORIZATION (REGISTRATION AND LICENSING)* AND INSPECTION.

The paper gives a general overview of the main objectives and features of regulatory control of radiation sources. The relevant international framework on guidance for establishing and implementing regulatory control is described. Some critical points in the control system often leading to deficiencies in radiation protection or in the safety of sources are indicated, and some proposals for countermeasures are made. The paper focuses on sealed radioactive sources, whose use is widely spread. The regulatory element of 'clearance' (i.e., releasing material with negligible radioactivity from control) is briefly discussed.

1. INTRODUCTION

1.1. Need for regulatory control

Over time, a considerable body of knowledge has been accumulated in protection and safety matters connected with the use of radiation sources — essentially from the lessons learned in incidents, accidents and other unusual events with sealed and unsealed sources. It has become evident that regulatory control contributes to the protection of workers, the public and the environment against hazards connected with radioactivity, such as uncontrolled exposures, intakes and spread of contamination.

Regulations therefore form an essential part of the protection against ionizing radiation and of the safety of radiation sources.

1.2. Main points to be covered by regulations

To achieve the desired protection and safety objectives regarding sealed or unsealed sources, the regulations must cover (1) defined proper manufacturing,

(2) correct delivery, transport and receipt, (3) appropriate use and (intermediate) storage and (4) proper recycling or disposal after final termination of use.

Permanent control of a source throughout all these steps is one of the most important issues. The protection and safety objectives have been largely achieved if this control is effective during the entire history of a source.

1.3. International guidance framework

Several international organizations, commissions or bodies have created regulations which are harmonized in their principles, have elements that complement each other, i.e., radiation protection system, regulatory aspects and technical requirements, and have proved their effectiveness by the way that many States use them for national legislation and procedures.

In matters of radiation protection and the safety of sources, an exemplary internationally harmonized guidance is therefore available, mainly due to the efforts of:

— The International Commission on Radiological Protection (ICRP) (basic radiation protection philosophy, radiation risk assessment, radiation protection system including dose limits),
— The International Atomic Energy Agency (IAEA) (basic practical regulatory aspects, implementation procedures and data, material for training),
— The International Commission on Radiation Units and Measurements (ICRU) (definition of quantities and units of radiation and radioactivity, measurement procedures and definition of operational quantities),
— The International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) (technical standards for sources and for devices containing sources).

Selected from this international framework, Refs [1–11] give typical examples covering the main points mentioned in Section 1.2.

2. GENERAL BASE OF REGULATORY CONTROL

2.1. General provisions required

The core of all regulatory measures are provisions which (1) state the need for permission to engage in a practice involving radioactive sources, (2) force the person responsible to address the competent authority prior to the beginning of the practice, (3) define the prerequisites with respect to radiation protection and safety of sources which shall be fulfilled by that person and (4) enable the authority to prescribe specific measures for radiation protection and safety and to supervise their fulfillment in an unrestricted manner.

These provisions shall have a binding status to the person responsible and also to the authority to ensure unique and equal effective action. Therefore, they should preferably be of legal character, or at least based on a legal framework.

Levels of permission and extent of proofs to be submitted by the person responsible should be graded according to the risk and complexity of the practice proposed. For this purpose, the regulatory elements of notification, registration and licensing have been developed. A similar grading applies to supervision procedures, namely to the further regulatory element of inspection.

The description of all relevant elements of regulatory control, and practical guidance for establishing and implementing these elements, is presented in detail in IAEA publications, e.g. Refs [5, 6, 12, 13].

2.2. Notification

Notification is the requirement to submit a document to the authority to notify the intention to carry out a practice. It is a basic mechanism that provides information to the authority about a planned action. Notification alone is sufficient for those sources causing a very small exposure (e.g. compared to the dose limits) under normal conditions and having negligible likelihood and magnitude of potential exposure under abnormal conditions.

Typical examples for notification are (1) low activity sources for use in schools [12], where a minimum of control by the competent teacher is provided and (2) approved devices with sealed sources not suitable for exemption.

In situations where regulatory control is in a build-up phase, notification would be a useful first step to identify users and sources prior to initiating an authorization programme [12].

2.3. Registration

Registration is a form to authorize practices. A safety assessment has to be submitted to the authority for evaluation. If the prerequisites are met, the practice is authorized, with conditions or limitations as necessary.

Suitable for authorization by registration are in particular those practices where [12] (1) radiation protection and safety is largely an inherent component of the design of the equipment, (2) operations do not vary significantly and operation problems are small and (3) operating procedures are simple to follow and training requirements are minimal.

Typical examples for registration of radioactive sources are the use of industrial gauges up to medium activity and of radioimmunoassays.

2.4. Licensing

Licensing is the process of granting an authorization for practices involving higher risks or more complex operations. Submission of a detailed description of operations and related exposures and of a safety and risk assessment is required. After evaluation — including appropriate additional checks — the authority issues the licence, which often contain specific conditions or limitations for the operations.

Typical examples of cases requiring licensing of radioactive sources are [12] (1) high activity industrial gauges, (2) industrial radiography, (3) industrial irradiators, (4) radiotherapy and (5) use of non-sealed sources (in nuclear medicine, industry and research).

2.5. Remarks concerning notification, registration and licensing

As the few examples of practices for notification (Section 2.2) show, regulatory control should focus on authorization that increases radiation protection and safety. Authorization gives a powerful position to the authority for determining the proofs to be submitted and for prescribing restrictions and supervision measures. It is an adequate procedure even for low activity sources via the simplified, standardized form of registration. For this reason, Article 4 of the 1996 Radiation Protection Standards Directive of the Council of the European Union (Euratom BSS) declares more practices subject to prior authorization [14] than the 1980 version.

In Germany, the discussion on harmonizing and amending the German Radiation Protection Ordinance according to the Euratom BSS tends to extend the authorization process to all sources with an activity higher than the exemption values (Section 2.6) and to no longer use notification.

The authorization process should concern, in particular, the evaluation of safe storage and related source accounts, as well as appropriate arrangements for recycling or final disposal of sources no longer needed (Section 3.2, item (f)).

2.6. Exemption and clearance values

Closely related to the system of notification and authorization is the definition of which practices shall be subject to regulatory control. A commonly used decision base is formed by

(1) *exemption values* as a criterion for assigning radioactivity levels to regulatory control, i.e., radioactive substances with activity not exceeding the exemption values (e.g., 10 μSv/a [15]) need no regulatory control;

(2) *clearance values* as a criterion for releasing activity formerly assigned to regulatory control from any further regulatory control (the principle is the same as that of Ref. [15]).

Exemption values are a common part of regulations, e.g. identical values are included in the IAEA Basic Safety Standards [6], the IAEA Transport Regulations [3] and the Euratom BSS [14].

It is important to note that clearance values are normally lower than exemption values. Typical for clearance are large amounts of material with such a low activity content that the material is suitable for recycling or disposal. Therefore, in comparison to exemption [16], additional scenarios and exposure pathways have to be calculated.

The IAEA started years ago to systematize clearance procedures and create preliminary clearance values [17, 18]. The Euratom BSS prescribe in general a prior authorization for clearance. If clearance is in compliance with the nationally established clearance values (as far as Euratom values are not available), no authorization need be required.

In Germany, the Commission on Radiation Protection has issued recommendations [19] for clearance procedures, including clearance values for unconditional clearance, for disposal and for scrap metal recycling[1]. It is envisaged to supplement these clearance data to the Radiation Protection Ordinance to be used with the new clearance authorization step according to the Euratom BSS.

When cleared, the material is no longer regarded as radioactive in the sense of regulatory control. Handling and use of cleared material is no longer restricted from the radiation protection point of view. Therefore, clearance shall be granted only according to supervised procedures and proper derived clearance values, preferably based on international recommendations with respect to scrap metal, which is internationally spread.

Exemption values and clearance values should be taken into account by Interpol and the World Customs Organization with respect to their control mechanisms and judgements.

2.7. Inspection

It is evident that a notification and authorization system must be supported by periodic inspections by the authority to verify compliance with regulations and with the conditions and limitations laid down in the authorization process.

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[1] Values identical with those of Ref. [20].

On-site inspection is a necessary and essential part of regulatory control, although some inspection aspects such as regular reports (e.g., results of leakage tests) can be handled by data exchange with the authority office. The frequency and level of on-site inspections depend on the risks and complexity of operations and on the history of previous non-compliance or unusual events.

Additionally, specific inspections may be necessary when misuses or malfunctions (e.g., design or operating deficiencies of a device) are reported from other users or authorities for the same or similar functions.

Specific inspections may also cover the pre-operational phase of a practice (e.g., during the authorization process) to evaluate the extent to which relevant protection or safety measures can be implemented or have been considered.

Specific checklists for each type of practice facilitate a complete but time saving inspection.

The inspection should not be conducted in an 'authoritarian' way. Authority should support appropriate measures by the persons responsible (e.g., the Radiation Protection Officer), and both together should optimize the relevant radiation protection and safety matters. As a result, respect for the authority of responsible persons inside the facility is supported and safety culture encouraged.

With insufficient inspection, the established system of notification and authorization will be restricted to a simple formalism, and eventually regulatory control will become worthless. This consequence should be recognized, particularly where, as in some European states, minimizing the staff of authorities is a trend.

3. SOME CRITICAL POINTS

3.1. Emphasis needed

An established regulatory system alone is no assurance of continuing proper radiation protection and safety. Emphasis should be kept regularly on typical critical points which may cause deficiencies to radiation protection and safety. According to the experience in many states, such critical points are the following:

(1) lack of training of persons engaged and lack of respect of the authority on the part of persons responsible,
(2) drop-off in reliability (interest, dependability) due to routine or overburden of persons engaged,
(3) loss of knowledge and/or care about existing sources, namely when facilities are closed down without prompt dissolving or when responsible persons leave a facility,
(4) lack of possibilities to dispose spent sources,

(5) weak standing of the competent authority (e.g., lack of competence or of qualified staff, insufficient inspections).

Such cases may have severe consequences, such as loss of control of sources, often leading to high exposures, spread of contamination or at least to increased potential exposures. Even strenuous efforts to find lost sources are often without success. Several fatalities due to exposures from sources coming out of control have been reported [21, 22].

The cleaning of contaminated facilities or areas and rejection of contaminated products cause very high expenses. The scrap metal industry, steel mills, foundries and customs services have established control measurements [23].

3.2. Some countermeasures

Unusual events show that the causes of deficiencies are mostly incorrect human conduct that can hardly be avoided completely by rules or supervision. But some regulatory measures may support recognition of incorrect behaviour or the potential of it and enable the authority to act. Considering the critical points mentioned which may lead to loss of control of sources, the following measures are seen as helpful:

(a) Sufficient regular inspections by the authority in the collegial sense mentioned in Section 2.7 are the most effective measures, but they are intensive in personnel, knowledge and costs.
(b) Requiring periodic inventories of sources and prompt reporting of changes due to receipts and shipments (e.g. in Germany, inventory yearly and changes within one month [24]); authority evaluates submitted data, notes missed reporting deadlines and acts if deficiencies are found.
(c) Appropriate wide use of periodic leakage tests (by the user or preferably by an external expert) and prompt submission of results to the authority as a further contribution to the control source inventory.
(d) Periodic checks (radiation protection, safety) of equipment by an external expert (e.g. yearly, as established in Germany by a legal requirement for sources of more than 20 TBq [24]), including proper control of the source inventory and any relevant changes.
(e) Prompt notification of the authority if registrant's or licensee's evaluation suggests losses, unauthorized use or removal of sources. The authority should encourage such notifications as a basis for initiating countermeasures at an early stage to prevent potential exposures and avoid high expenses for search operations. It should be noted that punishment is not the motivation for this notification. This prompt notification must also be required of all authorities

engaged in the control of sources, namely (in addition to the radiation protection authorities) the police and customs authorities.

(f) Avoiding storage of spent sources on the facility's site by offering storage centres which keep these sources for later release, recycling or transfer to final disposal.

4. CONCLUSIONS

Using the international framework of guidance for establishing or amending regulatory control provides the following benefits:

(a) protection and safety regulations will be to the state of the art,
(b) a valuable profit from the lessons learned worldwide is integrated (i.e., the repetition of already analysed regulatory deficiencies, misuses or malfunctions is avoided),
(c) confidence in protection and safety measures is encouraged,
(d) recognition of authorizations and approvals given is supported (the importance of this issue is likely to grow along with international economic co-operation).

On-site inspections are essential for the actual monitoring of compliance but also for reviewing safety culture, optimization and regulatory infrastructure.

These features can be effective only when competent State bodies permanently pay attention to implementation and (as necessary) to improvements.

Consideration should be given to the establishment of a registry of those sources which have the potential to create severe hazards when uncontrolled. Such registries should be built up at least by each authorization authority and preferably should be centralized nationwide. Such registries may support search operations (by facilitating identification and ownership histories of sources) and help to assess deficiencies (lessons learned).

Based on such registries, the IAEA and the Member States might wish to consider building up a registry of sources lost and of sources found whose holders cannot be identified. Some recent finds [25, 26] have shown that investigation needs international assistance.

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SUMMARY OF DISCUSSION

Technical Session 1

Chairperson: **G.J. Dicus** (United States of America)

Rapporteur: **G. Weimer** (Germany)

G.J. DICUS (United States of America) (Chairperson): What, in your opinion, are the absolutely essential elements of a system for the regulatory control of radiation sources?

G. WEIMER (Germany) (Rapporteur): A clear legal basis and a properly established authority with the power to issue licences, to carry out inspections and to prosecute when regulations are violated.

J.A. LOZADA (Venezuela): I was told recently by the purchasing officer of a major corporation which engages in oil exploration in South America that in some countries he had seen sealed radiation sources being used as paperweights. Has the IAEA any information about incidents due to the use of radiation sources in such a manner?

P. ORTIZ LOPEZ (IAEA): No, it has not. If incidents of that kind were to occur, the IAEA would probably be asked by the States where the incidents had occurred to render assistance, perhaps under the terms of the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (the Assistance Convention).

J.A. LOZADA (Venezuela): I read recently, in the Spanish magazine *Interview*, about the disappearance of about 100 nuclear warheads in the 1–1.5 kilotonne range from arsenals in the former Soviet Union. Has the IAEA looked into such reports?

G.J. DICUS (United States of America): We have all read such reports in the media, but none of them has ever been substantiated.

A.J. GONZALEZ (IAEA): The IAEA cannot, and does not, follow up on such media reports. It acts in response to requests from States.

J.U. AHMED (Bangladesh): From some of the presentations already made here, it is clear that in many countries, developed as well as developing, the systems for the regulatory control of radiation sources are defective, despite the fact that organizations such as the IAEA have for decades been issuing technical guidelines for the safety of radiation sources. The reason is essentially that those organizations do not have the power to enforce compliance by individual countries with the technical guidance which they issue. There is therefore a need for an internationally binding legal instrument laying down the obligations of countries as regards the safety of radiation sources, a legal instrument to which all countries would have to become parties in order to be sure of receiving the radiation sources which they require.

SAFETY ASSESSMENT TECHNIQUES APPLIED TO RADIATION SOURCES

Design and Technological Measures, Including Defence in Depth and Good Engineering Practice

(Technical Session 2)

Chairpersons

D.J. BENINSON
Argentina

D. QUÉNIART
France

A summary of Contributed Paper IAEA-CN-70/18 was also presented

PROSPECTIVE RADIATION SAFETY ASSESSMENT
Safety assessment techniques applied to radiation sources

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Abstract

PROSPECTIVE RADIATION SAFETY ASSESSMENT: SAFETY ASSESSMENT TECHNIQUES APPLIED TO RADIATION SOURCES.

There are two techniques applicable to assess potential exposures to radiation sources, deterministic assessment and probabilistic assessment. Deterministic methods estimate the likelihood of accidents with conservative safety margins and ensure that the most severe accident would not result in effects above the acceptable level. Probabilistic assessment methods comprehensively estimate the probability of all predetermined detrimental consequences. Event tree analysis and fault tree analysis are introduced in the paper. Some specialized hazard identification techniques are also introduced. Probabilistic safety analysis (PSA) is considered a useful method for comprehensive assessment. In this context, identification of scenario and assessment of probabilities are emphasized. For more practical application, some consideration of completeness of scenario, applicability of assessment method according to the characteristics of accident and uncertainty of human behaviour and dose estimation will be needed.

1. INTRODUCTION

Potential exposure is exposure that, while not certain to occur, can be anticipated as a result of introducing or modifying a practice and to which a probability of occurrence can be assigned [1]. There are two complementary techniques available to assess the level of protection against potential exposures, known as deterministic assessment and probabilistic assessment. They are both needed to ensure that an adequate level of safety has been achieved and that no major contributors to risk are overlooked [2].

Deterministic methods provide safety in systems where scenarios leading to potential exposures are specified in terms of initiating events and component failures. The acceptance criteria are specified to include conservative safety margins to ensure that the likelihood of accidents with serious consequences is extremely small, although not quantified in probabilistic terms.

Probabilistic assessment methods comprehensively estimate the probability of predetermined detrimental consequences. Therefore, the probabilistic methods are useful to identify weaknesses in the safety systems which might have been overlooked by the deterministic approach. In nuclear safety, the probabilistic assessment methods are usually called probabilistic safety analysis (PSA). PSA methods have been developed and improved for application in nuclear power plants since the 1970s and have been recognized as the best available tools to estimate risks associated with many potential exposure situations.

PSA is usually based on: (a) identification of scenario, (b) assessment of probabilities of the sequence, (c) dose assessment, (d) evaluation of detriment, (e) comparison of the results with the criteria of acceptability and (f) optimization of protection. It is important in step (a) to list all scenarios without exception. Therefore, the comprehensive approach is necessary for the identification of scenario. Steps (a) and (b) are emphasized in this paper. At first, event tree analysis and fault tree analysis are introduced as for the quantitative safety assessment techniques. As the approaches of scenario identification were also developed in the field of chemical process plant safety, some of them are available for radiation safety. Those techniques are introduced briefly. Finally, some considerations in applying those probabilistic safety assessment techniques are described.

2. LOGICAL STRUCTURE OF SCENARIO FOR QUANTITATIVE ANALYSIS

Two models are widely used to present logical structures for quantitative analysis: event trees and fault trees. The logical structure describes the interdependence of the components to permit statistical analysis of the behaviour of the system. An essential idea in the analysis of logical structures is the concept of success or failure of systems.

2.1. Event tree analysis

An event tree analysis is an inductive analysis. It starts with an initiating event and moves progressively through the successive responses of the system, describing the corresponding results in terms of success or failure. As one moves through the tree, probabilities are assigned to the successes or failures, which allows assessment of the overall probability of failure of the system. As an event tree is developed for a scenario, the logical flow from initial event to final consequence may consist of serial or parallel processes or of a combination of the two. Similarly, systems intended to provide protection can be modelled as an aggregate of subsystems, arranged in series or in parallel. These may consist of subsystems of a secondary order. In complex systems there may be a number of initiating events, each of which can be represented by a separate event tree. The combination of these event trees allows an evaluation of the safety of the system.

Event trees are often headed by a left-to-right verbal description of the initiating event and the safety functions which can be requested during the event sequence. The actual tree is drawn beneath this text as a left-to-right line with a bifurcation or fork under each safety function. At each fork, the upward branch represents success of the safety function described in the top line, and the downward branch represents failure. Event trees are thus binary in nature. Figure 1 shows two parts of an event tree drawn in this manner.

2.2. Fault tree analysis

A fault tree begins with an undesirable event. This undesirable event is called 'top event', because it is placed at the top of the fault tree. How the top event could occur is analysed by the fault tree. Such top events are often identified through a separate analysis before the actual fault tree analysis, using techniques such as HAZOP (Hazard and Operability Studies), as described in Section 3. The construction of a fault tree can also be aided by other preliminary analyses such as FMEA (Failure Modes and Effects Analysis), also described in Section 3. Fault trees are essentially the reverse of event trees, in that they contain a single result and point through a deductive analysis to whatever preceding events could have produced this result.

An example of a fault tree is shown in Fig. 2. Graphically, fault trees are headed by a box with a brief verbal description of the top event. The most important categories of top events are logical 'and' gates (half circles) and 'or' gates (rounded arrowheads). The top event box is connected through lines to boxes describing intermediate events. In contrast to event trees, fault trees are multinodal, i.e. one logic gate may well be connec-ted to more than two lower events. At the bottom of the tree, boxes or circles contain descriptions of basic events that require no further development. If a tree extends over more than one page (as in Fig. 2), triangles are used to symbolize transfer points.

2.3. Event tree/fault tree and subscenario/subsystem combinations

For the analysis of simple systems, either event tree or fault tree analysis is usually sufficient. In complicated systems such as nuclear power plants, it may be useful to apply both approaches. The probability of failure must be assigned at each branch of the event tree. In complicated systems, this probability cannot be estimated easily. The use of the fault tree method can help in the estimation of these probabilities.

There are two methods of combination of event tree and fault tree analysis. In one of them, probabilities estimated by small fault trees are applied to branches of a large event tree. This combination is known as the large event tree/small fault tree (LET/SFT) method. The converse method, involving a small event tree and large fault trees (SET/LFT), is also available. Which method is suitable depends on the characteristics of the sequence analysed.

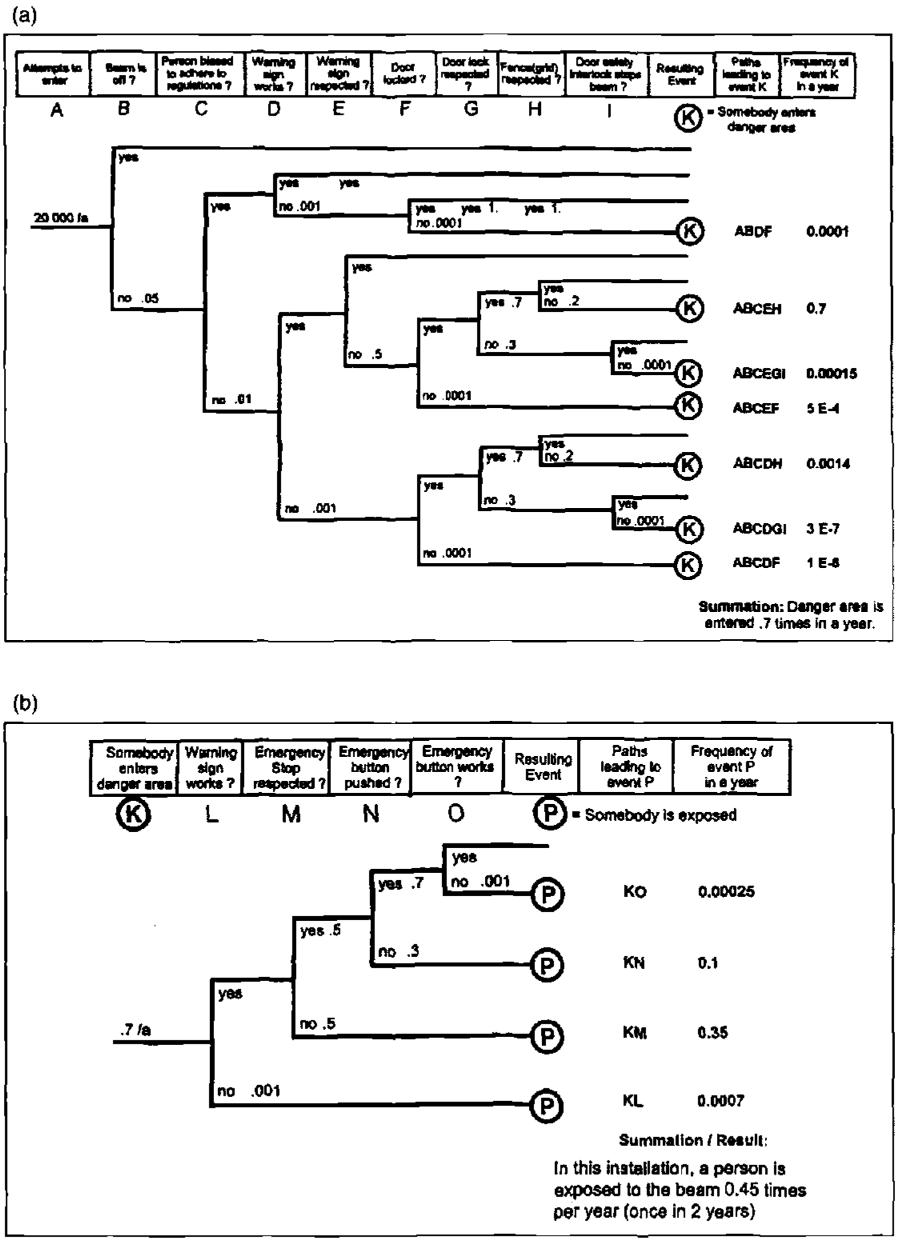
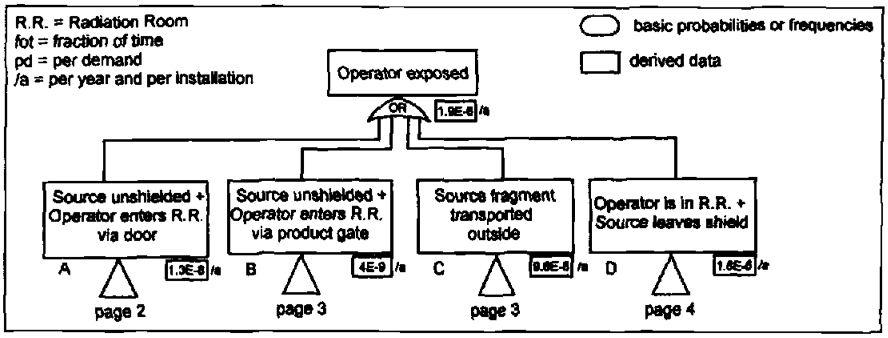


FIG. 1. Fault tree analysis of potential exposure in a modern accelerator [1]. (a) Part 1 of 4; (b) part 2 of 4.

(a)



(b)

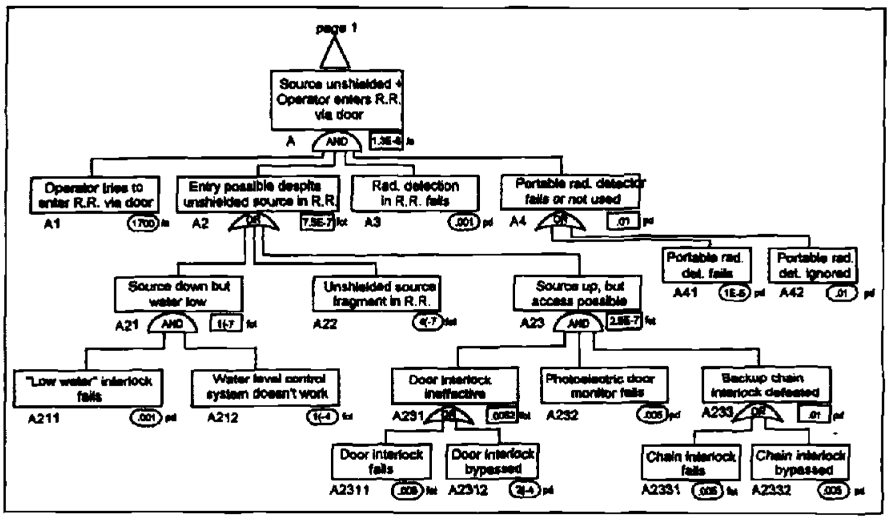


FIG. 2. Event tree analysis of potential exposure in an accelerator [1]. (a) Part 1 of 2; (b) part 2 of 2.

Modelling a scenario of events with logical structures helps assessments of reliability or probability of failure. Definition of subscenarios or subsystems and calculation of their probabilities of failure allow such results to be introduced as parts of more complex sections of the logical structure. With this procedure, calculations relating to a complex event tree or fault tree can be simplified by replacing an assembly of components of the subsystem with an estimated single probability of failure as if it were a single component.

3. HAZARD IDENTIFICATION TECHNIQUES FOR QUALITATIVE ANALYSIS

Material in this section is taken from Ref. [3].

3.1. Hazard and Operability Studies (HAZOP)

HAZOP is a qualitative safety analysis for potential hazard and is investigated by using a piping and instrument diagram (P&ID). The P&ID is represented by the connection of components and pipes and the associated control systems.

The basic procedure of HAZOP is as follows:

(1) Subdivide the P&ID according to the function and condition of the system.
(2) For each divided line or device, assume the malfunction or abnormality. The malfunctions and abnormalities are described as a deviation from design intention. So-called guide words are used for describing the deviation. Examples of guide words are shown in Table I.
(3) Consider all the causes of the deviation and the resulting effects on the system.
(4) Investigate the appropriateness of the detection methods of deviation and of the countermeasures.
(5) Summarize the above investigation into a HAZOP report sheet such as that shown in Table II.

HAZOP is carried out by a group which consists of specialists or staff from various fields. The number of members is usually 5 to 7. The formal HAZOP group meeting is proceeded by free discussions. HAZOP can be applied at various stages, such as at pre-construction design stage, before modifications and under operations.

HAZOP studies not only identify potential hazards and their likely causes but also estimate their severity and risk factor. Corrective recommendations are made for

TABLE I. EXAMPLES OF GUIDE WORDS FOR HAZOP.

Guide word	Explanation
No	Denial of design intention
More, Less	Increase or decrease of amount (such as flow, temperature, pressure, level)
As well as	Existence of additional event
Part of	Accomplishment of only a part of the design intention
Reverse	Occurrence of reverse event to the design intention
Other than	Other event

TABLE II. EXAMPLE OF A RECORD SHEET OF HAZOP (HAZARD AND OPERABILITY STUDY)

Project				Review team	Sheet no.	
Component/device				Chairman: Specialist 1: Specialist 2: Record keeper:	Line no.	
Line	Start point	Intermediate point	End point		PID No.	
					Date	
Guide word	Parameter	Cause	Effect	Countermeasure	Investigation/ examination	Charge

TABLE III. EXAMPLE OF A RECORD SHEET OF FMEA (FAILURE MODES AND EFFECTS ANALYSIS)

Job: Sheet No.: Prepared by:

Unit: Date:

No.	Item	Failure mode	Cause of failure	Possible effects	Countermeasure	Note

making effective safety management decisions that will ultimately improve operability, profitability and safety and that will minimize environmental impact.

3.2. Failure Mode and Effects Analysis (FMEA)

In FMEA, all the ways in which each component of the systems can fail are described. Then the effects of such failure on the whole system are investigated. FMEA deals with component failure, while HAZOP is mainly related to process parameters. The appropriateness of countermeasures for the failure is also considered.

FMEA usually deals with only a single event failure, but various and detailed failure modes are set in order to represent the actual situation. FMEA is usually applied at the design stage before construction and modification, as is HAZOP.

FMEA is also proceeded by a group meeting. An example of an FMEA record sheet is shown in Table III. It takes a lot of time to examine each component in the assessment of a huge system. Therefore, it is important to investigate the failure modes for the basic components previously.

FMEA is basically a qualitative analysis. For a quantitative analysis, a criticality number is introduced. In this case, FMEA is called Failure Modes Effects and Criticality Analysis, or FMECA. Because the criticality number is defined as a comparative index, it is difficult to apply FMECA itself for total risk estimation of potential exposure.

3.3. Other qualitative analysis methods

Three methods, the checklist method, preliminary hazard analysis and what-if analysis, are introduced briefly. Those methods are more primitive than HAZOP and FMEA.

3.3.1. Checklist method

The checklist method is a basic and elementary method for safety analysis. A detailed list of questions, written from knowledge and experience, is used to assess the acceptability or status of the process, system or operation compared to standard design and operating practices.

3.3.2. Preliminary hazard analysis (PHA)

PHA identifies potential hazards at the conceptual stage of a design. The procedure for PHA is almost the same as that for FMEA. But the list failure mode is not so detailed. PHA is usually followed by a more comprehensive analysis at a later date.

3.3.3. What-if analysis

What-if analysis uses a series of 'What if...?' questions to examine a process or operation for the identification of potential hazards and their consequences.

4. SOME CONSIDERATIONS ON PROBABILISTIC SAFETY ASSESSMENT

There are some points to be considered in an application of PSA techniques for the safety assessment of potential exposure.

4.1. Completeness of scenario

In order to list the complete scenario of accident or failure, several comprehensive assessment techniques, such as HAZOP and FMEA (Section 3), are used. Use of those techniques is always preceeded by group discussions of specialists. Therefore, the quality of the assessment results depends on the experience, knowledge and ability of the analysis group. To reduce problems, guidelines for the analysis are prepared, such as paying attention to components one by one or investigating an effect of a failure on auother component. It is important, for an effective analysis, to examine and list the failure mode of each component previously. If the analysis team relies on the previous investigation list too much, however, the result of the analysis may tend to reflect the previous results. It is necessary to have flexibility and a wide outlook.

4.2. Applicability of assessment method according to accident characteristics

The PSA method is useful for the assessment of potential exposure, especially in the analysis of nuclear power plants (NPPs). A series of defensive devices or equipment, defence in depth, is present in NPPs to prevent the expansion and progress of the accident. Therefore, the large event tree/small fault tree (LET/SFT) method is appropriate. On the other hand, the consequence is limited to the core melt in the case of an NPP. A large fault tree can be written down, in which the core melt is designated as the top event. Both LET/SFT and LFT/SET analyses, described in Ref. [3], are applicable in NPP analysis. That can be considered as one of the reasons why PSA methods were developed in the field of nuclear safety.

Usually that the sequence and scenario of analysis vary considerably from one radiation source to another. Therefore, fault tree analysis will be relatively easy to use because of the easiness of connecting or separating a part of the fault tree. Fault tree analysis is also useful to limit the range of analysis.

4.3. Uncertainty of human behaviour and dose estimation

The dose to which a person may exposed in the case of potential exposure is very context specific, as mentioned in ICRP Publication 76 [1]. Even if the probability of occurrence of a scenario is estimated, the dose will depend strongly on human behaviour. If quantitative risk limitation is used for the protection of potential exposure, we should pay attention to its large uncertainty and to the variability of human behaviour. It is important to consider two aspects concerning human factor, the probability of the occurrence of human error and the effect on the severity of accidents of human behaviour.

5. CONCLUSIONS

Two probabilistic safety assessment techniques, event tree and fault tree analysis, have been introduced. The probabilistic assessment methods are useful for the safety analysis of potential exposure because of their comprehensiveness. For more practical application of such techniques, some discussion of the treatment of risk limitation for potential exposure will be needed.

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DESIGN AND TECHNOLOGICAL MEASURES

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Abstract

DESIGN AND TECHNOLOGICAL MEASURES.

The paper discusses the principles of defence in depth and good engineering practice which are requirements of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, IAEA Safety Series No. 115. Defence in depth is illustrated by describing some of the defence layers employed to prevent inadvertent or uncontrolled entry to the radiation room in a typical Category IV irradiator when the radioactive source is in use. Some of the practices used to ensure safety during the design and operation of radiation sources and equipment are also described.

1. INTRODUCTION

The purpose of this session is to discuss some design and technological measures that can be used during the design and manufacture of radiation devices in order to provide some assurance that products being manufactured will perform safely.

For the purposes of the discussion we will focus on Category IV gamma irradiation devices because these devices have the potential for accidents with serious consequences. Category IV [1] irradiators produce very high dose rates in the irradiation mode, so the accidental presence of persons in the irradiation chamber can lead to a lethal dose within seconds or minutes. Precautions against uncontrolled entry must therefore be taken. Contamination can result from corroded or damaged sources, and decontamination can be expensive. These possibilities clearly indicate the need for a high degree of safety and reliability of the facilities. This is clearly recognized in Ref. [2], which describes requirements for defence in depth and good engineering practice.

2. DISCUSSION

The requirements of Ref. [2] are very global and require further clarification if we are to conduct our daily business activities in accordance with them. For this purpose the International Atomic Energy Agency (IAEA) provides publications to give advice for each specific type of device, such as Ref. [1]. This publication provides a very detailed discussion regarding the principles of defence in depth. Here we will discuss how they are applied in practice.

3. APPLICATION OF PRINCIPLES

The application of defence in depth can best be illustrated by describing some of the defence layers employed to prevent inadvertent or uncontrolled entry to the radiation room in a typical Category IV gamma irradiator when the radioactive source is in use.

3.1. Sequential procedure to start an irradiator

Sequentially interlocked controls are designed to ensure that the operator will switch off the machine and take the operating key from the control console to open the door, check the radiation room monitor for proper operation, search to make sure no one is in the radiation room, exit quickly and close the door and start the machine within a pre-set time limit. Any attempt to override the controls or apply them out of sequence will automatically abort the operation and require that the sequence be restarted. The startup sequence generates visible and audible alarm signals to warn anyone in the area that the machine is being started. Emergency pull cables are available in the radiation room and maze passage areas so that anyone in the area can abort the startup by pulling the cable. The radiation room door will always allow anyone to exit by simply turning the inside door knob.

The controls are also designed to prevent access while the source is exposed. Violation of the interlock system or use of the door while the machine is operating will cause the radiation to be automatically terminated.

3.2. Key control

The keys required to operate the irradiator are strictly controlled to ensure that only one key is available for operation at any time. The single key control of the machine ensures that the operator is in control of the machine at all times. The key that is required to operate the source controls is also required in order to gain access at the personnel entry door. The same key is also required in order to initiate the startup procedure by turning a key switch during search and lockup inside the radiation room. This procedure is to ensure that the machine is switched off with the source in its shielded position before the personnel access door can be opened. To ensure that no other key is available during startup, spare keys are locked in a safe place that is under the control of the Radiation Safety Officer.

A portable radiation meter is connected to the operating key by a chain to ensure that the operator carries it when entering the radiation room. A small radioactive test source is located at the entry door to enable the portable radiation survey meter to be tested prior to entry.

3.3. Personnel access control

Lights on the console indicate the position of the source (up, down or in transit). Warning lights above the personnel access door also indicate when the source is exposed or in transit.

The door lock engages automatically when the barrier door is closed and requires electrical power to open it. A limit switch inside the door detects when the door is open or closed. If the door lock bolt is not positively engaged, a strong spring forces the door open so that its position is clearly detected.

To enter the radiation room, the door key switch must be activated using the same key that operates the controls. This switch will only receive power after the operator checks the radiation room area monitor and shows that it is working properly.

A backup access control provides a secondary system to prevent inadvertent entry when the source is exposed. This consists of a series of photosensors or other detectors that detect the entry and provide an alarm via a flashing beacon and audible horn. It also returns the source to safe storage and provides a fault indication on the control console. This system is wired independently from the primary access controls.

Before entry, the operator cuts off the air required to drive the source hoist, preventing the source from being raised while the operator is inside the radiation room.

When the operator has determined that no one is in the area and that conditions are safe to start the machine, the operator activates a safety timer key switch using the control key and exits from the radiation room.

3.4. Timing controls

A timer monitors the machine startup procedure. Once the safety timer key switch in the radiation room has been activated, the operator will have only enough time to walk out through the maze, connect the safety chain, close the door and turn the key in the control console to start the machine. Any undue delay will cause a time fault, which will abort the startup procedure. During this time flashing lights and audible alarms indicate that the machine is about to start operation.

Timers also monitor source travel and product motion.

The backup access control inside the barrier door is a good example of redundancy, diversity and independence, since it relies on photosensors or pressure mats to detect entry; limit switches and a radiation monitor prevent entry under normal circumstances. This system adds substantially to safety during routine entry into the radiation room, and is perhaps more important during entry when faults are being investigated. Had this type of system been installed on machines involved in previous fatal accidents, some of the fatalities might have been avoided, particularly if the operator was uncertain about the source position.

Many existing machines built to earlier safety standards could be made much safer by retrofitting such devices. This is illustrated quite well in the examples of probabilistic safety assessment provided in Ref. [3].

It is important for designers to improve their products continuously, and particularly to improve them after accidents have occurred. One example of this is ensuring that the 'source down' limit switch is not accessible outside the radiation room, since this was a contributor in previous accidents. Another example is to make sure that entry interlocks cannot be tampered with, or 'fooled', as occured in some previous accidents.

Every effort must be made to ensure that equipment operates trouble free and cannot result in the source becoming stuck in the exposed position.

It is equally important to make provisions to safely recover from such accidents without unnecessary radiation exposure. The designer must therefore consider all possible accident scenarios and provide adequate protection, detecting faults and causing the machine to shut down safely.

It is important to design systems or procedures that will assist in recovery from accidents. Emergency access ports are provided in the shield near to where the source is exposed. Equipment and procedures are designed to enable technicians to locate sources from outside the shield and to store them safely in the source storage pool.

Equipment and procedures are also designed to detect leaking sources and isolate them in sealed containers for removal to safe disposal. All of these activities must be considered as part of defence in depth.

3.5. Good engineering practice

There are some guides for the design and manufacture of radiation devices. The American National Standards Institute (ANSI) has produced standards for various categories of irradiators [4, 5]. These were produced some time ago and need to be updated, but they still provide good advice for the design and manufacture of irradiators. Reference [2] also gives good advice and provides additional references to other standards that are useful to designers.

The designs of most radiation sources and equipment are not entirely new, but are instead based on existing proven designs modified to meet the requirements of new applications.

Good engineering practice requires that designers have adequate systems in place to identify the potential hazards present under the new set of circumstances, as well as in the existing design, and that they ensure that machine controls have adequate defence in depth to avoid such hazards during use of the equipment.

One of the tools used to control design projects is a written project plan which describes the planned design and quality assurance activities to be used during manufacture. The plan provides references to all the important inputs required for the design process. Some important things to be included in the planned activities are the following:

(a) Design review activities that provide opportunities to provide input for all disciplines involved in the process.
(b) A review of previous accidents with similar products to check that the new product has provisions to prevent such accidents. Customer complaints related to safety with similar products should also be reviewed.
(c) A formal hazard analysis of the final design to ensure that all anticipated hazards have been considered.
(d) A step to demonstrate safety in the finished product. The final product should have a completed safety checklist after installation, demonstrating that all safety devices have been tested and that they perform according to the design specifications.

One purpose of the plan is to ensure that everyone involved in the design and manufacturing activities adheres to the same requirements. It also allows design activities to be reviewed and performance to be verified in accordance with the initial requirements. It helps to ensure that all necessary inspections and tests are performed during manufacture and assembly of the equipment. It also provides a clear audit trail that allows you to verify that all planned activities have been completed.

Good engineering practices cover much more than design related activities. According to the principle of defence in depth, one must also consider organizational and behavioural activities.

Suppliers of sources and equipment generally adopt a life-cycle approach to their products, maintaining an interest in them from cradle to grave. They usually have programmes in place to monitor the performance of products during their useful life.

Sources and equipment are not always used in the manner that the designer intended. The designer's intended conditions of use are not always clearly stated. Businesses find new applications and new ways to use their existing sources. Dangerous conditions are therefore very often not discovered until much later in product life. It is therefore difficult to put restrictions on use at the time of sale, but it does highlight the need to detect and communicate such situations to other users and regulators.

Field surveillance of sources is used to periodically inspect sources in the field or to return selected samples to production facilities where they can be given proper metallurgical inspection to look for early signs of failure. Failure does not necessarily result from poor design or manufacture; it can also be the result of poor control or storage conditions during use. In either case, it is in everyone's best interest to detect this and take corrective action.

Source suppliers usually audit operating safety systems when installing new sources at a user's facility. Manufacturer's operating instructions for users require that all safety systems be tested at specified intervals. It is very important that tests be done according to these instructions, because any probabilistic analysis done to predict the safety of the equipment is only valid as long as the tests are done at the specified intervals and defective parts are replaced when detected.

Operating and maintenance instructions provided by the supplier should be translated into the local language so that all workers can be properly trained in the operating and maintenance procedures. These instructions should be available before a new facility is ready for transfer to the operating organization. The operating manual should include an introduction advising the users about the potential hazards involved in working with such equipment. It should also stress the need for workers to be properly trained in the principles of radiation protection and in the operation and maintenance of the equipment.

Since suppliers usually perform formal hazard analyses for their products, they are best equipped to advise operators of the responses required for each accident scenario. They can therefore provide users with a model emergency response plan describing actions for all anticipated failures.

4. CONCLUSIONS

In most, if not all, of the fatal accidents that have occurred in Category IV irradiators, human error or lack of understanding have been major contributors. This will be discussed in detail in other sessions of this Conference, but it is worth mentioning here that training has to be considered as an important element of defence in depth. Some of the fatalities occurred when sources became stuck and operators who were not authorized and unskilled for the task attempted to correct the problem. If they had contacted the regulatory authority and the equipment supplier before taking action, the recovery actions might have been different and less unfortunate for the victims.

When operators encounter unusual circumstances involving potentially dangerous corrective actions, they should always contact the supplier who has experience with such situations, even if it is only to obtain a second opinion. The supplier would be able to 'talk them through' the necessary procedure, giving advice at each step and avoiding unnecessary risks. The lessons learned from previous accidents point out quite clearly the benefits that may be obtained from improved training and improved communications between operators, suppliers and regulators. We all need to turn these lessons into constructive practices that will help to reduce the risk of future accidents.

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SUMMARY OF DISCUSSION

Technical Session 2

Chairpersons:	**D.G. Beninson** (Argentina) **D. Quéniart** (France)
Rapporteurs:	**N. Sugiura** (Japan) **R.G. McKinnon** (Canada)

A.J. GONZALEZ (IAEA): In the discussion at the end of Technical Session 1, J.U. Ahmed called for an internationally binding legal instrument to which all countries would become parties. However, such an instrument would, as far as I can see, bind governments (with their regulatory authorities), but not the manufacturers of radiation sources. When accidents with radiation sources occur, it is usually the regulatory authorities who are blamed. There should be a way of ensuring that the manufacturers of the sources bear their share of the responsibility.

D.J. BENINSON (Argentina *(Chairperson)*): The regulatory authorities in different countries should be capable of checking whether the radiation sources being acquired by users in those countries are safe. If they are not capable of doing that, there are two options: to assume that the radiation sources are safe or to ban the acquisition of radiation sources. With the first option, one takes the risks which are due to faulty radiation sources; with the second option, one takes the risks which are due to a lack of radiation therapy and other facilities.

R.E. CUNNINGHAM (United States of America): Even when regulatory authorities have determined that radiation sources are safe, the users sometimes manage to bypass the safety features or do other things which give rise to accidents. Consequently, I think that, rather than carrying out quantitative analyses of radiation source safety, one should carry out Preliminary Safety Analyses of relative risks, with the involvement of prospective users as well as of regulatory authorities.

J.U. AHMED (Bangladesh): I think some international mechanism must be devised for making manufacturers liable for the safety of the radiation sources manufactured by them.

D.J. BENINSON (Argentina *(Chairperson)*): When talking of the liability of radiation source manufacturers, one should bear in mind that irradiation equipment is sometimes badly maintained and that the procedures for operating it are sometimes not adhered to.

R.G. McKINNON (Canada *(Rapporteur)*): In that connection, I should like to recall a few facts about the radiation accidents which occurred in El Salvador and at Soreq, in Israel. When the irradiation equipment involved in the El Salvador accident was purchased, there was a regulatory authority in El Salvador. At the time of the accident, after years of civil war, there was not. As a result, the condition of the equipment had been allowed to deteriorate and the operators were bypassing safety features in order to keep the equipment working. At Soreq, the operators bypassed the room monitor because, owing to poor maintenance, it did not function reliably — and they did not contact the manufacturer in order to obtain assistance. A manufacturer interested in selling radiation sources in a particular country should, if there is no regulatory authority in that country, contact the IAEA.

J.U. AHMED (Bangladesh): What about the incident where, in Mexico, a ^{60}Co teletherapy source found its way into scrap metal which was melted down and used in the manufacture of furniture parts?

R.G. McKINNON (Canada *(Rapporteur)*): I cannot imagine what the manufacturer of the source could have done in order to prevent the occurrence of that incident.

J.R. CROFT (United Kingdom): My experience of helping the IAEA to investigate radiation accidents is that the radiation source manufacturers are generally keen to learn lessons from the accidents. In all the radiation accidents investigated by the IAEA with my help, there were contributory factors connected with workers, management and regulatory authorities. My conclusion is that the manufacturer has a responsibility, but so have the regulatory authority, the management and the workers.

MANAGERIAL MEASURES, INCLUDING SAFETY CULTURE, HUMAN FACTORS, QUALITY ASSURANCE, QUALIFIED EXPERTS, TRAINING AND EDUCATION

(Technical Session 3)

Chairperson

D. DRÁBOVÁ
Czech Republic

Summaries of Contributed Papers
IAEA-CN-70/58 and 93 were also presented

MANAGERIAL MEASURES TO ASSURE THE SAFETY OF RADIATION SOURCES

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Abstract

MANAGERIAL MEASURES TO ASSURE THE SAFETY OF RADIATION SOURCES.

Although much can be done through design, engineering and other means to prevent accidents and misuse of radiation sources, the most important players in the safety area are the person who interacts with the source and those responsible for that person. The paper sets out the structure of managerial measures that, if fully implemented, should ensure that sources are used correctly, in accordance with defined procedures, by persons who understand what they are doing and even — to some extent — why they are doing it. The managerial measures covered range from the development of that intangible but recognizable entity, a safety culture, to the need for reliable systems of regulatory control, the clear and systematic procedures of quality assurance, and focus to a substantial extent on the correct application of education and training.

1. INTRODUCTION

In the preamble to the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources [1] (the BSS), managerial aspects of safety are given a prominent position, and three aspects are emphasized:

Basic principles

"...the legal person authorized to engage in a practice involving a source of radiation should bear the primary responsibility for protection and safety; a safety culture should be inculcated that governs the attitudes and behaviour in relation to protection and safety of all individuals and organizations dealing with sources of radiation; ... and protection and safety should be ensured by sound management and good engineering, quality assurance, training and qualification of personnel, comprehensive safety measures and a sound attention to lessons learned from experience and research" [2].

National infrastructures

> "National infrastructures must provide for adequate arrangements to be made by those responsible for the education and training of specialists in radiation protection and safety, as well as for the exchange of information among specialists" [3].

The Regulatory Authority

> "Full and proper implementation of the Standards requires that a Regulatory Authority be established by the Government to regulate the introduction and conduct of any practice involving sources of radiation."
>
> ....
>
> "The general functions of the Regulatory Authority include the following: the assessment of applications for permission to conduct practices that entail or could entail exposure to radiation, the authorization of such practices and of the sources associated with them, subject to certain specified conditions; the conduct of periodic inspections to verify compliance with the conditions; and the enforcement of any necessary actions to ensure compliance with the regulations and Standards."
>
> ....
>
> "An additional responsibility of the Regulatory Authority is to require all parties involved to develop a safety culture that includes: individual and collective commitment to safety on the part of workers, management and regulators; accountability of all individuals for protection and safety, including individuals at senior management level; and measures to encourage a questioning and learning attitude and to discourage complacency with respect to safety" [4].

In this paper, those aspects of managerial measures necessary to implement the requirements of the BSS are discussed in turn, with particular emphasis on documents published or under development by the IAEA.

2. LESSONS LEARNED

A powerful method for identifying those aspects of the management that are crucial for safety is the analysis of accidents that have occurred, in order to identify the causes and to extract the lessons learned. The IAEA has, at the request of Member States, investigated a number of the more serious accidents [5–10]. It has also brought together the findings from these and from a large number of other accidents to compile reports on the lessons learned. In this paper, attention is concentrated on analysis of accidents in the industrial area, especially on reports dealing with industrial radiography [11] and irradiation facilities [12] and the management aspects of the lessons learned.

The application of industrial radiography grew rapidly after the 1940s. The dose rates that prevail close to a radiographic source or a device may be high enough to cause overexposure of human extremities in a matter of seconds, which may result in the loss of a limb. Whole body exposures resulting in a fatality are rare, but they have occurred when sources have been mishandled or have been in the possession of members of the public. Industrial radiography accounts for approximately half of all reported accidents in nuclear related industry, and this is true in both developed and developing countries.

Another application with a high growth rate is irradiation using high energy gamma photons and electron beams. There are between 700 and 800 such facilities in operation worldwide, and they are to be found in almost all IAEA Member States. The most common uses of these facilities are to sterilize medical and pharmaceutical products, to preserve foodstuffs, to synthesize polymers and to eradicate insects by use of the sterile insect technique. There is a substantial potential that accidents involving these facilities will result in serious injuries or fatalities because of the very high dose rates produced by the sources.

2.1. Causes of accidents in industrial radiography [11]

2.1.1. *Inadequate regulatory control*

A primary cause of industrial radiography accidents is inadequate regulatory control. This may be due to an ineffective regulatory authority, or it may be that no radiation protection infrastructure has been established. Effective regulatory control by a system of authorizations is essential to establish standards for the possession, use and disposal of radioactive materials and for the possession and use of X ray generating machines. These authorizations are intended to ensure that personnel are trained, that proper equipment in good working condition is used and that written procedures, incorporating radiation protection and safety considerations, are in place. Where there is inadequate regulatory control, it often happens that a lax approach to safety and a lack of safety culture are allowed to develop.

2.1.2. *Failure to follow operational procedures*

Failure to follow operational procedures is a primary or contributory cause in the majority of accidents. This problem is seen across the entire cross-section of workers, from the most senior and well trained, who may become complacent, to the less experienced and untrained.

2.1.3. *Inadequate training*

The second most common cause of reported accidents is inadequacy of training, which includes ineffective initial and refresher training programmes. It is a particular characteristic of industrial radiography, which often is carried out by small commercial companies, that unqualified personnel such as radiographic assistants are permitted to work without supervision.

2.1.4. *Human error*

Even if equipment is operating properly and effective operating procedures are established, the safe operation of radiographic equipment relies heavily on the radiographer's judgement and response. The probability of human error increases during work under adverse and stressful conditions, such as of fatigue caused by night work, low light and high noise environments, production pressures and physical exertion. The probability of human error may also increase with substance use, misuse or abuse.

2.1.5. *Wilful violation*

Training, equipment design and implementation of effective operating procedures cannot stop an individual from deliberately violating safety procedures. The probability of such deliberate acts increases when workers are subjected to stressful conditions due to fatigue, economic factors, production pressures or physical exertion. Wilful violations are more likely to occur in operating organizations where there is no strong safety culture.

2.2. Causes of accidents in industrial irradiation facilities [12]

2.2.1. *Tolerance of equipment malfunction*

In several of the accidents reported in Ref. [12], product jams appeared to have been frequent and to have been tolerated by personnel and management. Thus, challenges to the safety systems were also frequent, and operating personnel had adopted a policy of dealing with the consequences of a problem (clearing jammed transport systems) rather than correcting its cause (product container or transport system design and maintenance).

2.2.2. *Failure or bypassing of interlocks*

Control systems at the entry point to the irradiation chamber are of particular importance. The design of irradiation facilities is such that control of access relies heavily on the use of interlocked systems. Serious consequences result from personnel access through openings that were not interlocked because entry through small openings or over pits was considered unlikely. In some instances the interlock controls were not designed to be sequential, so that any attempt to override or apply them out of sequence would abort the intended operation and require that the sequence be restarted. Use of a radiation monitor to alert personnel, or of an interlock to prevent access when high radiation doses were possible, was crucial. However, in all these accidents such a system had not been installed, or was not working, or was easily bypassed by methods known to the operating personnel.

2.2.3. *Human error and inadequate training*

In every accident, workers and operating personnel performed inappropriate actions, given the information that was available to them and on the instructions that had been provided. In a few accidents, the personnel involved were simply not adequately trained to understand the hazards. In other accidents, operators who were knowledgeable about radiation and its risks made bad judgements on the actual condition of the sources. Operators were so focused on routine operations and on correcting minor problems that even the potentially severe consequences of radiation exposure from high activity sources did not induce them to exercise the appropriate caution. Some of these inappropriate actions were relatively long standing practices and should have been detected and corrected by the management of the operating facility.

3. SAFETY CULTURE

It is not easy to define precisely what is meant by 'safety culture', although the International Nuclear Safety Advisory Group (INSAG) refers in this connection to the assembly of characteristics and attitudes in organizations and individuals which establish that, as an overriding priority, protection and safety issues receive the attention warranted by their significance [13]. Nonetheless, the BSS are quite clear as to the results that a good safety culture will achieve:

> "A safety culture shall be fostered and maintained to encourage a questioning and learning attitude to protection and safety and to discourage complacency, which shall ensure that:
>
> (a) policies and procedures be established that identify protection and safety as being of the highest priority;
> (b) problems affecting protection and safety be promptly identified and corrected in a manner commensurate with their importance;

(c) the responsibilities of each individual, including those at senior management levels, for protection and safety be clearly identified and each individual be suitably trained and qualified;
(d) clear lines of authority for decisions on protection and safety be defined; and
(e) organizational arrangements and lines of communications be effected that result in an appropriate flow of information on protection and safety at and between the various levels in the organization of the registrant or licensee" [14].

The development of a good safety culture can only be achieved if the attitudes and behaviour of both the managers and the employees of an organization are conditioned in line with the requirements set out above.

In many serious accidents, deliberately or through inattention, managers allowed safety systems to degrade significantly and workers to improvise procedures or continue operations when engineered safety systems failed. Workers may have believed that management encouraged deviations from procedures in order to perform jobs more quickly — this belief being based, in part, on the evidence of management apparently turning a blind eye to any improvised methods. Management pressures may have been real, or management may not have noticed the improvisation. In other situations that did not result in accidents, managers deliberately bypassed radiation interlocks and substituted administrative controls to avoid a shutdown to repair a defective radiation monitor. In this way, violations of procedures, rather than the laid down procedures, became the normal methods of working. Not surprisingly, these violations of rules eventually led to accidents.

Failure of management to train staff in procedures and in the operation and purpose of safety equipment can cause workers to make serious errors. Even when training is provided, it should prepare workers to deal with rare but potential events and should not focus on production, with a few routine requirements for safety included.

For their part, it is necessary that workers have confidence that the act of uncovering a safety defect will be viewed positively and not negatively by their managers. This means that an operator who suspends operations to correct the failure of a required safety system should expect praise, not criticism.

In a working environment in which the management and workers are co-operating to achieve safety, the result is greater than the sum of the parts. In this area, synergism is a reality, and what is recognized as a good safety culture is the result of that synergy. Conversely, failures in any one aspect have repercussions in other areas, so the breakdown of a safety culture can be rapid and dramatic.

3.1. Human factors

The BSS require that:

"Provision shall be made for reducing as far as practicable the contribution of human error to accidents and other events that could give rise to exposures, by ensuring that:

(a) all personnel on whom protection and safety depend be appropriately trained and qualified so that they understand their responsibilities and perform their duties with appropriate judgement and according to defined procedures;
(b) sound ergonomic principles be followed as appropriate in designing equipment and operating procedures, so as to facilitate the safe operation or use of equipment, to minimize the possibility that operating errors will lead to accidents, and to reduce the possibility of misinterpreting indications of normal and abnormal conditions; and
(c) appropriate equipment, safety systems and procedural requirements be provided and other necessary provisions be made:
(i) to reduce, as far as practicable, the possibility that human error will lead to inadvertent or unintentional exposure of any person;
(ii) to provide means for detecting human errors and for correcting or compensating for them; and
(iii) to facilitate intervention in the event of failure of safety systems or of other protective measures" [15].

Human reliability has been defined as the probability of successful performance of only those human activities necessary for a reliable system. Human errors, sometimes called 'human failure events', reduce human reliability. In the more formal analyses of human reliability and human errors, consideration of performance shaping factors is important. External performance shaping factors include the entire work environment, the equipment design, the kind of procedures that have been specified and the style of instructions given. All of these factors influence the probability of human error resulting from failure in attention, failure to remember crucial instructions, lack of recognition of a potentially dangerous situation or the application of incomplete or inaccurate knowledge. In addition, it is possible to identify internal factors which are likely to give rise to the failures mentioned above, such as distraction; mental or physical stress; high workload; changes in work routines, situations or plans; inadequacies in procedures, training or leadership; poor human–machine interface; or poor communications.

Human error is commonly considered to include unsafe actions and omission of required actions. It does not include malevolent behaviour intended to produce a harmful effect, although being alert to such behaviour is an important aspect of management supervision, especially in situations where such behaviour may give rise to a significant hazard. An exceptional type of unsafe action involves mistaken intentions or deliberate rule breaking. In these situations, people do not commit a human error in the everyday sense of the term; rather, they circumvent a safety rule or make a choice in order to reach the goal they believe is correct at the time. Such an action is distinctly different in its cause from other kinds of unsafe action.

Through a risk assessment of a given device, the different kinds of human error or equipment failure that can result in unsafe outcomes can be identified before these errors or failures occur in practice. Techniques for such assessments have been described by the International Commission on Radiological Protection [16]. The management and operators of the installation may then plan the steps they would take if such an error or failure occurred or can decide whether some simple change in design or operating practice could remove the potential hazard before an individual was harmed. In addition, by using risk assessment techniques, management may be able to explore whether changes in operation (such as staffing changes) will have an effect on safety.

Investigation of event sequences shows that certain significant patterns of behaviour seem to play a role in potential exposure that is not always recognized in traditional risk assessments. Perhaps the most important of these behaviour patterns are circumventions, as described above. For example, it may become common for staff to ignore radiation alarms if the alarms are prone to false signals. This phenomenon of ignoring warning signals is important in its contribution to the erosion of safety.

In order to avoid such human errors, management needs to ensure that individuals have the knowledge and skills necessary to perform their assigned tasks and responsibilities. In addition to knowledge, skills, procedures and rules, training needs to emphasize that engineered systems can fail. Workers must understand that every warning or alarm is to be believed until an expert determines whether the alarm is real or false. Practice exercises and drills that stress these lessons may be particularly effective. Instructions about safety control systems and warning signs need to be available in the workers' native language. The supervisor needs to identify performance failures and to take appropriate action to reduce the likelihood of repetitions. Traditionally, 'human error' has focused on direct control of, or influence on, equipment immediately before the accident. This narrow view, restricted to 'operator error', provides only a partial approach to accident prevention. A successful approach to reducing human error should look at all stages of operation and should take into account management and organizational issues.

3.2. Supervision

A key individual in the management–worker chain of interaction is the supervisor. Whenever supervisors failed to make rules understood or to take action when rules were violated, accidents eventually happened. Effective management provides comprehensive safety training to supervisors and holds the supervisor accountable for worker observance of the local rules and procedures. The supervisor is responsible for making the local rules and procedures and the protective measures and safety provisions known to those workers to whom they apply and to other persons who may be affected by them. The supervisor needs to monitor worker compliance with rules and to take corrective actions (training, improving procedures, clarifying rules or taking disciplinary action, as appropriate) when deviations occur.

To provide adequate supervision of radiation safety and training, licensees or registrants will normally need to designate a qualified expert to serve as Radiation Protection Officer. The Radiation Protection Officer often has the primary responsibility for providing training to workers on the health risks arising from their occupational exposure and on the significance of their actions for radiation protection and safety.

4. REGULATORY ASPECTS

Full and proper implementation of the BSS requires that an independent regulatory authority be established by the Government, through legislation, to regulate the introduction and conduct of any practice involving sources of radiation. It is essential that the responsibilities of the regulatory authority be kept distinct from those of any other party, so that the regulators can preserve their independence of judgement and decision as safety authorities. For this purpose, there should be a clear separation of functions and responsibilities of the regulatory authority from those of other Government departments and agencies having responsibility for the development and promotion of regulated practices. There should also be a clear separation or independence of the regulatory authority from those subject to regulation, e.g. registrants, licensees and manufacturers of radiation sources.

Radiation safety of sources should be established and maintained through a regulatory programme consisting of the following:

(a) regulations which set forth requirements and standards for protection and safety, and related administrative requirements;
(b) a system of notification and authorization (registration or licensing) for control over possession and use of radiation sources;
(c) provisions for establishing exclusions and granting exemptions from regulatory requirements;
(d) compliance monitoring, including inspection, to assess the status of safety and compliance with regulatory requirements;
(e) enforcement to compel compliance with regulatory requirements;
(f) investigation of accidents and management of emergencies;
(g) dissemination of information on protection and safety.

The BSS apply the terms 'notification, and authorization by registration or licensing' broadly to indicate an appropriate type of control based upon the level of risk or complexity associated with practices, notification (not discussed below) being applied to the lowest order of risk or complexity and licensing to the highest.

4.1. Registration

Registration can be a relatively simple and efficient authorization mechanism if certain criteria for its use can be met. The general criteria which can be used to assess the suitability of a practice as a candidate for registration are that safety can largely be ensured by the design of the facility and equipment, the operating procedures are straightforward and do not vary much between users, there is a history of few safety problems and the safety training requirements are minimal.

4.2. Licensing

Licensing is required for all practices not otherwise designated by the regulatory authority as suitable for the simpler processes of notification or registration. In particular, licensing should be required for the higher risk or more complex practices, including those in which the protection depends largely on human performance, as, for example, in industrial radiography. The licensing process requires that each person proposing to use sources within a practice submit an application containing detailed information related to the proposed use of the source and the radiation protection and source safety provisions, as well as an assessment of the nature, magnitude and likelihood of the exposures attributed to the source. The regulatory authority then evaluates the application to determine that the applicant, and the manner in which the sources are to be used, are likely to comply with applicable regulations and requirements. When issued, the licence grants authority to use sources for specific purposes under conditions and other requirements specified in the licence.

In general, licensing is a more resource intensive process than is registration, because it requires a case by case evaluation of each proposed use within a practice. In some instances, the process may include prelicensing and preoperational inspections by the regulatory authority to ensure that all relevant protection and safety precautions are satisfactorily taken into account.

One of the important specifications in an authorization is the clear identification of personnel who have key responsibilities for protection and safety and of those who could substantially affect protection and safety by virtue of tasks involving operation or manipulation of sources. The objective is to ensure that only appropriately qualified personnel fill such positions. The simplest way to accomplish this is to specify, in the authorization, the names of persons who are qualified to fill such positions. If staff turnover is high, as is often the case in industrial radiography, the authorization can specify the qualification credentials, i.e., training, experience and professional certifications, required of any person who fills a certain position. When a new staff member is added in accordance with the qualification requirements, the regulatory authority often requires notification of the change of personnel.

5. QUALITY ASSURANCE

In respect of quality assurance, the requirement of the BSS is brief:

"Quality assurance programmes shall be established that provide, as appropriate:

(a) adequate assurance that the specified requirements relating to protection and safety are satisfied; and
(b) quality control mechanisms and procedures for reviewing and assessing the overall effectiveness of protection and safety measures" [17].

In several accidents involving accelerators, X ray generators and sealed sources, significant deviations from local rules and other requirements occurred when management failed to review operations for compliance with local rules or conditions of use. Repairs and replacements were frequently made without assessing the consequences, and modified operating procedures were not validated. In general, quality assurance programmes at facilities where serious accidents occurred were weak or did not exist.

For simple practices with low to moderate risk, adequate confidence may be achieved by periodic review of the use of the source by using a checklist of the conditions of use provided by the manufacturer, the requirements of the regulatory authority, recom-mendations from lessons learned and special conditions resulting from a specific safety assessment. As the complexity and risk increases, more formality is necessary to achieve the level of confidence required. The manufacturers of sources and safety equipment, and licensees or registrants with complex operations, need quality assurance programmes meeting appropriate international standards such as those of the ISO 9000 series.

Significant deviations from local rules may occur if management does not have a programme to assure that requirements are satisfied.

6. PROFESSIONAL COMPETENCE

In recognizing the importance of having the people in key positions working within their professional competence, the BSS contain two basic requirements, one of a general nature and the other specifically relating to qualified experts:

"Provision shall be made for reducing as far as practicable the contribution of human error to accidents and other events that could give rise to exposures, by ensuring that ... all personnel on whom protection and safety depend be appropriately trained and qualified so that they understand their responsibilities and perform their duties with appropriate judgement and according to defined procedures" [18].

"Qualified experts shall be identified and made available for providing advice on the observance of the Standards" [19].

Professional expertise will be needed to observe the requirements of the BSS in all aspects of a safety programme. Engineers and radiation scientists design facilities and equipment, experts in radiation protection and safety develop operating procedures, radiation scientists and perhaps human factors specialists design and present training. All these activities need some level of expertise, and experts may be needed initially and for ongoing assessment of designs, operations and training.

The registrant or licensee that uses a radiation source needs the input of the supplier or manufacturer — principally manuals — for the design of facilities and operations. For simple practices suitable for registration, the supplier's input, combined with an effective management system to maintain control and accountability for sources, might be all the expert advice required.

In more complex situations requiring a licence, the licensee or registrant will need staff with the necessary expertise or will make use of independent consulting engineers, physicists and other scientific and technical experts in such areas as structural support and shielding, properties of materials, the operation of safety systems, the operation of environmental control systems (temperature, humidity, etc.), fire protection and security controls. For complex operations, the registrant or licensee may need qualified experts for the systems relied upon for safety (e.g., entrance interlocks; shielding for walls, labyrinths or doors; fume hoods; air supply or water treatment systems).

In the BSS, specific mention is made of a Radiation Protection Officer. The regulatory authority may require that licensees and registrants designate a Radiation Protection Officer. The expertise of such a designated individual may vary from that of a supervisor who has read and understands the conditions of use of a simple gauging device to that of an individual with in-depth knowledge of the basic principles of radiation protection and safety of sources, dosimetry, calibration and use of radiation monitors, shielding and the properties of different radiations.

Over the past decade, various attempts have been made to compare the mechanisms for recognition of professional competence and their bases in different countries. A major review was carried out within the European Community, with the intention of enabling experts to move freely between States and have their expertise recognized. The specific purpose of the survey was to identify and review the training programmes and methods of recognition used. The results of the study were published in 1992 in a discussion document [20]. In a similar exercise, the International Radiation Protection Association (IRPA) established a task group to review the professional training and certification schemes of its Member societies. The results were reviewed by the Executive Council during the 8th IRPA Congress in Montreal in 1992 and again at the 9th IRPA Congress in Vienna in 1996. The general conclusions of all the reviews were that although the procedures adopted in each country may well be appropriate for that country, the vast differences in formality, legal requirements, recognition and training methods make the production of unified international professional recognition criteria not possible for the present. IRPA does, however, still believe in the gradual harmonization of professional standards of competence and is encouraging an approach to this through more use of professional training and development programmes attached to meetings of various types and by using, where possible, international standards and criteria as their bases.

7. EDUCATION AND TRAINING

Education and training are of primary importance for achieving competence in an area of work. Persons who are to be involved in the organization and implementation of work with radiation sources should have an adequate level of understanding of the effects of ionizing radiation and of radiation protection concepts and should be acquainted with the safe use of radiation sources.

The national regulatory authority is responsible for establishing regulations and guidance for the establishment of the minimum training requirements and for certifying the qualifications of personnel. Training can be classified into two types: the first is relevant to the responsibility of the registrant or licensee, and the second must be completed by a qualification or a formal certification, in some cases provided by the regulatory authority.

7.1. Role of registrants or licensees

Registrants or licensees have important responsibilities in respect of training. In particular, they have to ensure that new workers are appropriately trained before they are placed in work where radiation safety is a factor. This initial training should be supplemented by on the job training and refresher training to maintain knowledge and awareness. The training should not just concentrate on normal operations, but should include training in emergency procedures, with periodic exercises to test such procedures.

7.2. Responsibilities of workers

Workers also share the responsibility for safety related training. They have to accept and implement the training they are given for their own protection, for the protection of their work colleagues and for the protection of the public.

7.3. Expertise and training required

For the simplest practices (such as the use of gauges or baggage X ray units), no special expertise is required. General ability to read the instructions, which should be available in a language in which the operator is fluent, and to understand the manufacturer's operating instructions and general precautions will be sufficient. The supervisor will need to be familiar with the instructions and conditions of use to ensure that they are followed and met.

For most uses of sealed sources and X ray generators, and certainly for even the simplest accelerators, some specialized training will be required for safe operation. The licensee or registrant needs to provide equipment specific training related to basic radiation protection and safety principles, operating procedures, local rules and emergency procedures for standardized equipment and uses. Uses which require operators to interpret radiation measurements, to take operational or precautionary actions based on measurements or source status, to set exposure times or to be prepared to take initial emergency response action always require specific training. For all but the most complex operations, the training can normally be provided locally by the Radiation Protection Officer or other qualified expert.

For the most complex practices (e.g., industrial gamma or electron irradiators, teletherapy with sources or accelerators, remote afterloading brachytherapy and research accelerators), the licensee or registrant will usually need to provide equipment specific training by a qualified expert (possibly the designer or manufacturer) knowledgeable about the operation of the equipment. Training needs should be determined by studying the highest risk scenarios identified in the safety assessment. For a research accelerator, training should be presented by qualified experts with detailed knowledge of the specific operational and safety features of the accelerator.

7.4. Training needs and organization in a country

Depending on the complexity of applications of ionizing radiation in a particular country, training needs can range from simple instructions on what to do and how and when to do it, to more sophisticated approaches. To meet all of the requirements for attaining and maintaining personnel competence, the value of establishing and implementing a strategy for national workforce development should be considered;

such a strategy should emphasize not only technical knowledge and skills but also specific attitudes towards safety.

The use of an integrated strategy for training includes the establishment of training requirements, identification of needs and building competency, and it offers, through monitoring of all phases and improvements provided by feedback, more consistency, efficiency and management control.

An overview of an integrated strategy for training on radiation safety is given in Fig. 1. The system consists of a number of interrelated phases: establishment of training requirements and procedures, definition of objectives, analysis of jobs and training needs, design of training programmes, development of training activities, implementation of training and evaluation of training effectiveness.

The objective of the analysis phase is to identify the job requirements, the competence of the existing personnel and their needs for training, and the need for

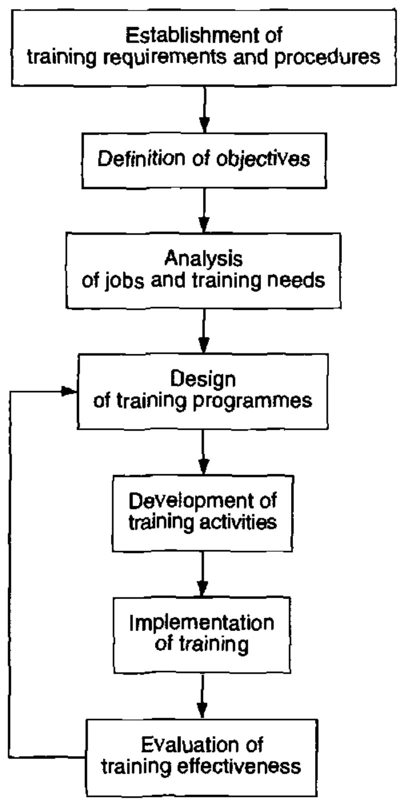

FIG. 1. Overview of an integrated strategy for training on radiation safety.

training of new personnel. The result of this analysis will give a clear idea of the status of the workforce, both whether there are enough personnel to carry out specific tasks and whether the existing personnel have the qualifications and competence required for each practice. This analysis also serves as input for the formulation of training objectives.

It is the objective of the design phase to convert this information into a national training programme. Once such a programme has been established, the country will assess its capabilities and will decide whether the programme can be carried out with its own resources or needs to be complemented with external resources (through bilateral or multilateral agreements or with the assistance of international organizations such as the IAEA).

If, after the assessment, it is found that the programme can be carried out in the country, the development phase will comprise the setting up of arrangements for all the necessary training activities so that the training objectives can be achieved. The developed training programme will be implemented during the implementation phase, by training centres, by professional or technical organizations and employers in the form of training courses, by on the job training, by development of training techniques and training material and by exchange of information at seminars or workshops.

The evaluation phase will include the assessment of country developed training programmes as well as of training given abroad or by third parties. The results are used as feedback to improve the design of the training programmes.

8. CONCLUSIONS

It is more difficult to check that the management requirements of the BSS are being complied with than to check some of the technical requirements. Nonetheless, the effect on radiation safety of these management aspects is arguably greater, in that an alert and well trained workforce will often be able to deal safely with equipment failures or a developing problem, whereas even a minor problem can escalate into a major accident in an organization with a poor safety culture. The development and maintenance of a good safety culture requires the positive commitment and involvement of all those involved, including the national regulatory authority, the management as represented by the licensee, the workers themselves, the professionals such as qualified experts, and those responsible for education and training. Failure in any one area can seriously undermine good efforts in others. The management measures described in this paper are a complete system and should be implemented fully to achieve safety in work with radiation sources.

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SUMMARY OF DISCUSSION

Technical Session 3

Chairperson: **D. Drábová** (Czech Republic)

Rapporteur: **G.A.M. Webb** (IAEA)

L.A. JOVA SED (Cuba): I think there is a need for somewhat more explicit guidance on how to implement the quality assurance requirements spelled out in the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (the BSS). Does the Rapporteur, G.A.M. Webb, agree?

G.A.M. WEBB (IAEA) *(Rapporteur)*: Yes, I do; on the radiation safety side there is nothing about quality assurance as elaborate as the material developed under the IAEA's Nuclear Safety Standards (NUSS) programme. I would hope, however, that such guidance could be given in just a few additional documents.

J.R. CROFT (United Kingdom): One way we have developed of improving radiation safety is to provide major clients of industrial radiography companies — for example, companies in the petrochemical industry — with checklists of what to look for when radiographers are working on their premises and with guidance on the conduct of safety audits. I take the opportunity to mention two messages regarding quality assurance which deserve to be widely disseminated: good quality assurance leads to more efficient (and more profitable) operations, and the economic consequences of not preventing accidents can be very high.

A.M. Al-ARFAJ (Saudi Arabia): In paper IAEA-CN-70/58, it is stated that since 1995 about 50 sealed sources have been found annually in the USA by members of the public. Where are the sources found?

J.M. KARHNAK (United States of America): In all sorts of places. Apart from scrapyards, they are found — for example — along roadsides and in city streets.

A.M. Al-ARFAJ (Saudi Arabia): Are the owners of the sources which have been found held liable for injury or damage caused by the sources or for the costs of disposing of them safely?

J.M. KARHNAK (United States of America): If a source has a serial number on it, one can trace the person originally licensed to possess the source, who will be held responsible for the costs associated with it — provided that person has not gone out of business. In one case last year, the original owner of a source found in a scrapyard was made liable for the costs of — inter alia — cleaning up the scrapyard.

The question of penalties for losing radiation sources is handled in the USA by the Nuclear Regulatory Commission — not the US Environmental Protection Agency (EPA).

K. DUFTSCHMID (IAEA): In his oral presentation (paper IAEA-CN-70/58), J.M. Karhnak (of the US EPA) spoke about recent meetings between representatives of the EPA and of the US steel industry. In that connection, I should like to know whether — with the international requirement that steel be "free of all radioactivity" — some concept was developed regarding clearance procedures for steel and metal scrap. If so, is the concept based on activity concentration, on dose rate at a certain distance from the product — or on what?

J.M. KARHNAK (United States of America): The purpose of those meetings was to compare the ways in which the two sides determine how various radionuclides react with steel — remain in the steel, find their way into the slag, etc. There was also discussion of exactly what is meant by 'clearance', 'exemption' and so on, but no conclusions were reached, except that those terms will have to be examined further in order to ensure that we use them consistently. Steel companies in the USA are being asked by some customers to certify that their product is radioactively 'clean', and some steel companies are asking scrap suppliers to do likewise.

J.R. CROFT (United Kingdom): In the United Kingdom, metals recycling companies are asking for financial help in meeting the costs of the safe disposal of radiation sources which they find in material taken over by them. The responsible governmental departments considering the problem are anxious not to write a 'blank cheque' and thereby encourage some users of radiation sources to dispose of them illegally and unsafely. How is the situation in the USA?

J.M. KARHNAK (United States of America): The situation in the USA is similar. In that connection I would mention that the US EPA is co-operating with the individual States in the establishment of a radiation source disposal programme. The idea is that, under the programme, sources will initially (as an incentive) be accepted free of charge for disposal. Later a small charge will be made — albeit smaller than what would otherwise be charged for the safe disposal of radiation sources. It is hoped that, once it gets going, the programme will be self-financing.

A.J. GONZALEZ (IAEA): Programmes like the EPA programme described by J.M. Karhnak may well help to solve future problems relating to 'orphaned' sources, but probably not past problems. Nevertheless, I hope that the EPA will share with the international radiation safety community the experience it gains through running the programme.

J.M. KARHNAK (United States of America): The EPA would be pleased to work with the IAEA in adapting the programme for worldwide use.

A.J. GONZALEZ (IAEA): An important issue in this connection is that of international clearance levels. There is a consensus — certainly in Europe — regarding exemption levels, but not clearance levels. One reason for this is the fact that different people understand different things by 'clearance', which has numerous dictionary definitions and is difficult to translate from English into other languages (it is translated into French as 'libération' and into Spanish as 'decontrol').

G.A.M. WEBB (IAEA) *(Rapporteur)*: The Radiation Safety Section and the Waste Safety Section of the IAEA's Division of Radiation and Waste Safety are, in the course of developing a safety guide, trying to establish agreed definitions of 'clearance' and 'exemption' — and also of 'exclusion' and 'authorization'.

J.M. KARHNAK (United States of America): I would add that the question of the meaning of 'clearance' and 'exemption' in relation to scrap metal was discussed last week in Luxembourg at an informal meeting attended by representatives of the EPA, the IAEA and the Commission of the European Communities.

J.U. AHMED (Bangladesh): An international problem which needs to be addressed is that of exposures to radiation from sources in industrial radiography equipment brought into countries — especially developing countries — by foreign companies for their own use without notification of the competent national authorities. Often such companies employ untrained workers to operate the equipment, but the competent national authorities do not know about the existence of the equipment until an accident occurs.

A.J. GONZALEZ (IAEA): In my opinion, this problem could become particularly serious in the case of radiation sources in borehole logging equipment being used by companies in the oil industry. Many such companies have more economic and political power than most developing countries, certainly more than the regulatory authorities in most developing countries, and, in my opinion, the only way to ensure that those companies exercise due care when borehole logging in developing countries is to persuade the advanced countries where they are registered to take appropriate action.

J.A. LOZADA (Venezuela): As regards the Regulatory Authority Information System (RAIS) described by P. Ortiz López (paper IAEA-CN-70/93), does the IAEA intend to add to the five existing modules a module on training?

P. ORTIZ LOPEZ (IAEA): Not at present. We are keeping RAIS as simple as possible — the existing five modules cover just what is essential for planning the establishment and running of a regulatory authority. Training is important, of course, and the IAEA is preparing training materials — but not directly in connection with RAIS.

A.M. Al-ARFAJ (Saudi Arabia): Is RAIS available in languages other than English?

K. MRABIT (IAEA): The IAEA Secretariat hopes that in due course it will be available in Arabic, Chinese, French, Russian and Spanish and — with the help of other organizations — various other languages.

P.E. METCALF (South Africa): With regard to Module 5 (Performance Indicators) of RAIS, I should like to emphasize how important it is that the safety assessment process be an integral part of the safety management programme.

LEARNING FROM OPERATIONAL EXPERIENCE

(Technical Session 4)

Chairperson

P.E. METCALF
South Africa

Summaries of Contributed Papers
IAEA-CN-70/4 and 23 were also presented

LEARNING FROM OPERATIONAL EXPERIENCE
Safety of radiation sources in the United States of America in the twentieth century

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Abstract

LEARNING FROM OPERATIONAL EXPERIENCE: SAFETY OF RADIATION SOURCES IN THE UNITED STATES OF AMERICA IN THE TWENTIETH CENTURY.

In 1958, the United States Atomic Energy Commission (USAEC) staff proposed extending the general licence concept to include measuring, gauging and controlling devices. Since then, more than 1.8 million devices containing radioactive sources have been distributed under general licences. These devices are typically used with minimal regulatory oversight. In recent years, there have been an increasing number of reports of radioactive sources and devices appearing in the public domain as a result of inadequate control and disposal of these items. As a result of concerns over these developments, there have been calls for increased regulatory oversight of the users of these sources and devices. Ironically, this is not a new problem. In the 1920s, reports of radium sources entering the public domain in an uncontrolled manner began to appear in the press and in the literature. Additionally, gold jewellery became contaminated by radon daughter products from improper recycling of depleted gold radon seeds. Such contamination occurred as early as 1910. Radium sources are not subject to the Atomic Energy Act, as amended, and for many years radium was distributed and used without government regulatory oversight for safety. In the United States of America in the 1950s, concern over the radiation hazards associated with the improper use, control and disposal of radium led to increased regulatory oversight, primarily by the States but with significant assistance from the US Public Health Service. While this was happening, the USAEC in 1958 approved a rule change to allow distribution of radioactive devices under general licence. This group of users is not routinely inspected and does not otherwise have periodic contacts with the USAEC. In time, problems in this group with control, accountability and disposal emerged, a situation similar to that found with radium users prior to their being regulated. The conclusion to be drawn from this is that periodic contacts by regulators with users of radioactive sources is needed to remind users of their responsibilities to account for, control and properly dispose of their radioactive sources.

1. INTRODUCTION

Failure to properly control, account for and dispose of radioactive sources and devices can lead to their entering the public domain in an uncontrolled manner. Lost and unwanted sources in the public domain can cause radiation safety problems such as radiation exposures of the public and radioactive contamination. Preventing radioactive sources from entering the public domain in an uncontrolled manner has become an international challenge to authorities responsible for regulating the safe use and disposal of radioactive sources [1]. The problem, however, has historical antecedents dating to the earliest days of radium use in the twentieth century.

2. EARLY USE OF RADIUM IN THE UNITED STATES OF AMERICA

The use of radium sources in the United States of America predates the US Atomic Energy Act, as amended. Further, radium sources are not covered by the Act and thus are not subject to regulation by the US Nuclear Regulatory Commission (USNRC). The potential medical benefits of radium were recognized shortly after its discovery in 1898 and resulted in a demand for radium sources [2]. Information on the extent of early use of radium in the USA is scant. In 1932, the US Bureau of Mines estimated that there were 710 medical radium users in the USA, using a total of 124.7 g of radium [3]. Use of radium expanded during World War II, mainly as a result of using radium for industrial radiography; a total of 200 g of radium was used for this purpose [4]. Another 190 g was used during the war in the manufacture of luminous paint [5]. In 1964, the United States Public Health Service (USPHS) concluded that radium use had probably peaked in the immediate post–World War II years and estimated that there were 4500 radium users in the USA, using a total of between 300 and 700 g of radium as identifiable sources [4]. The majority of these, 3500, were medical users. Thereafter, use declined, mainly as a result of other radioactive materials becoming available and the increased regulatory oversight of radium by the States, which caused many users to discontinue use of radium. In 1975, there were 3600 radium users in the USA [6]. The number of radium users is certainly less today. Even at its probable peak after World War II of 5000 to 6000 users, this group was much smaller than the number of US licensees now using by-product, source and special nuclear materials, i.e., an estimated 22 000 specific licensees and 135 000 general licensees.

The extraction of radium from ores was difficult and (in the early part of the century) was expensive. In 1923, radium cost US \$120 000 g^{-1} [2]. Thus, when radium sources were lost or stolen, avoiding the cost of replacing the sources became a strong incentive to search for and recover the radium.

3. RADIUM INCIDENTS

In 1968, the USPHS published a summary of known radium incidents in the USA, based upon a review of the literature and the New York Times for the period

1913–1964 [7]. A total of 396 incidents was tabulated, which included 261 losses and 25 thefts. The remaining incidents involved contamination, overexposures and miscellaneous events. The vast majority of the 396 incidents, 331 or 84%, involved medical sources. The recovery rates were 71% (170 of 240 cases) for lost medical sources, 53% (9 of 17) for lost non-medical sources, 60% (15 of 25) for thefts and 50% (2 of 4) for transportation losses. The earliest incidents for which dates are known occurred in 1911–1920, totalling 9 losses. Losses and thefts steadily increased, peaking in 1961–1967. The USPHS felt that this increase reflected the increasing use of radium up to the 1950s and the greater availability of reports of incidents within the most recent years covered by their survey. The greater availability of reports probably reflected compliance with newly issued State requirements for reporting losses and thefts of radioactive materials not covered by the Atomic Energy Act, as amended.

Many radium incidents, however, probably escaped public scrutiny. For example, consultants acting in their private capacity to search for lost or stolen radium sources often did not publish or report their work. In the case of State radiation control programmes which responded when losses and thefts of radium sources occurred and to requests for assistance in disposing of unwanted radium, their written reports frequently went straight to the files. Fortunately, some individuals involved in searches for lost and radium sources left public records of their experiences.

In 1914, after graduation from Purdue University, A.L. Miller accepted an offer to work for the Standard Chemical Company, in Pittsburgh, PA, which was then the largest producer of radium. There he specialized in calibrating radium sources by use of an electroscope [8]. Since he was familiar with operation of electroscopes, he was frequently called upon to search for lost radium sources using that instrument. In 1923, he wrote about seven cases [9]. His most intriguing story involved 150 mg of radium lost by a hospital. As was often the case, the radium found its way into the hospital's coal fired incinerator, where Miller found evidence of contamination but not the ashes which would have contained the radium sources. Upon inquiry, he learned that incinerator ashes were sold to a nearby contractor, who had used them as aggregate when making concrete that was poured to make a sidewalk. Miller found the sidewalk and confirmed that the radium was embedded in it. Since the radium could not be easily recovered, however, the sidewalk was left in place and the search was terminated. Unfortunately, Miller did not say where that sidewalk was poured. At the time, the radiation hazards of the embedded radium were not considered. This case was later investigated by another radium searcher, R.B. Taft, who contacted the insurance company that covered the hospital's loss but found that the company's records of the incident had been destroyed [10].

So, somewhere, probably in the eastern United States of America, there is, or was, a sidewalk in which is embedded 150 mg of radium.

Taft was a physician who frequently was called upon to search for lost radium. He initially wrote of his experiences, which began in 1933, in a paper presented to the

American Roentgen Ray Society in 1935, and subsequently recounted his experiences in a book, Radium — Lost and Found [10, 11]. Taft's tools for searching for radium included willemite ore (which scintillated when exposed to radiation), electroscopes and early Geiger–Müller (GM) detectors. Taft reported 187 incidents, some of which he was personally involved in and others which were reported to him. Most incidents involved lost or stolen radium sources, but some also involved contamination.

A number of cases involved lost medical radium sources that became mixed with hospital wastes that were disposed of at land disposal sites. A frequent practice of the time was to raise swine at these sites. Taft reported that on one occasion when searchers visited such a site to find a lost radium source, they found indications from their electroscope that the radium was nearby but could not pinpoint it. They noticed that a swine herd had walked by. The herd was captured and they confirmed that one pig was radioactive. It was slaughtered and the radium source was recovered.

In Philadelphia, PA, F. Hartman, a radium sales representative, left a written record in the form of personal notes of his searches for lost and stolen radioactive sources [12]. Hartman's notes cover 120 cases from 1930 to 1958. Like Taft, he used willemite ore as well as ZnS, electroscopes and GM detectors. The 120 cases represented a total of 4.259 g of lost or stolen radium. Of this, he was able to recover 3.806 g, or 89%, an amazing percentage considering the primitive nature of his radiation detection devices and a tribute to his thoroughness and tenacity. Also amazing were his 'repeat customers', one of whom lost radium on eight different occasions!

Another category of incidents involved transportation. An intriguing example is the manner in which Standard Chemical Company transferred partially refined radium from its plant in Canonsburg, PA, south of Pittsburgh, to its laboratory in Pittsburgh for final refinement. This was accomplished by carrying the radium on passenger trams operating between the two cities [13]. In 1959, Miller provided details of this practice [8]. The radium was packaged in corked glass bottles that were placed into bailed galvanized steel cans. These were carried by two messengers riding the trams to the Pittsburgh facility. Miller's account implied that one of the two messengers who regularly made this trip, an individual by the name of "Tommie" Thomas, was also the head of the department in Canonsburg that performed the initial fractional crystallization of the radium from the chloride solutions. Nothing is mentioned about protective shielding, and probably there was none. As much as "a couple hundred mg" were carried at one time. On the basis of known tram transit times between the two sites, the annual dose to Thompson from this activity alone could have been as much as 1 Sv (100 rem) in Standard Chemical Company's peak production year, 1920, when 18.5 g was produced. Nearby passengers and operating crews, of course, would also have been exposed.

Another incident, involving the US Post Office, was reported by the Associated Press in 1921 [14]. In this case, a patient being treated with radium on an outpatient basis misunderstood the directions given to him and returned home with the radium still applied to him. At home, he removed the radium and put it away. The physician then advertised for the US $3500 source and the patient, upon reading the notice, placed the source in an envelope and returned it *by postal service*. Given that the then current price was US $120 000 g^{-1}, the quantity of radium mailed was thus about 29 mg.

4. CONTAMINATED GOLD JEWELLERY

The metal recycling industries are faced with the challenge of preventing radioactive sources which are lost, stolen or improperly disposed of becoming mixed with metal scrap or, failing that, detecting the sources before the scrap metal is processed or melted to make new products [15, 16]. Interestingly, this problem has historical antecedents dating as early as 1910.

'Seeds' containing radon were developed as an alternative to the use of radium sources for medical implants [17]. The most common technique involved pumping radon generated from a radium salt solution into a thin gold tube that was then cut and sealed into short segments (seeds). After calibrations, the seeds were shipped to hospitals and clinics for implantation. Compared to radium, the radon seed technology was more versatile and, because of the radiation characteristics of the radon daughters, the seeds could be implanted permanently [18].

Lacking the tissue imaging technologies available today, therapists had to make their best estimate of the size of a tumour to determine the number of seeds that were needed. Since estimates were normally on the high side, some of the ordered seeds were often unused. Excess seeds could be returned to the supplier for credit, but some physicians kept the seeds and later sold them to gold recyclers. When these seeds were melted, the metallic radon daughters ^{210}Pb, ^{210}Bi and ^{210}Po (or Ra DEF in the radium decay chain nomenclature) became intermixed with the gold. Jewellery made from such gold became a source of radiation exposure, especially if worn close to the skin. By the 1960s, reports of radiation injuries from wearing such jewellery appeared in the literature [19]. In 1981, the New York State Department of Health mounted a special campaign to find such jewellery and remove it from circulation [20]. About 160 000 items were screened, resulting in the collection of 133 radioactive items and the identification of another 22 pieces whose owners declined to surrender them. Most of the items were made or acquired in the 1930s and 1940s, but one item, a plain gold ring, dated back to 1910.

The last US radon generating plant was operated by the Radium Chemical Company at its Queens, NY, site using apparatus designed by G. Failla [21]. It ceased operation in 1981, thus ending the possibility of new radon seeds entering the gold recycling stream. However, in 1982, when the Radium Chemical Company was ordered to inventory its depleted gold seeds, it could not account for them, and there was no anecdotal evidence of their showing up anywhere [21]. One cannot help but speculate that the inventory had been disposed of to the gold recycling market.

The foregoing underscores the point that the known data on losses, thefts and unwanted or improperly disposed of radium sources are but the proverbial tip of the iceberg. The true picture will never be known.

5. GOVERNMENT OVERSIGHT OF RADIUM USAGE

Although information on losses, thefts and other safety problems with radium was fragmentary, there were sufficient reports in the literature to raise public and legislative concerns which led to government oversight of radium users [4, 10, 11, 22–24]. By the 1960s, many States were developing, or had developed, regulatory control programmes for radium. The USPHS provided direct assistance to the States in the forms of monetary grants and loans of personnel to develop their radiation control programmes.

By this time, many radium sources were no longer wanted and their owners could not, or were unwilling to, pay for disposal. Unwanted radium sources were found stored in unexpected places such as bank vaults [25]. In response, the USPHS began a radium disposal project in 1965, under which persons in possession of unwanted radium could transfer the sources to the USPHS [18]. In most cases, State radiation control programme inspectors acted as transfer agents who shipped the sources to the Southeastern Regional Radiological Health Laboratory in Montgomery, AL, where they were stored. This laboratory, originally operated by the US Food and Drug Administration's Bureau of Radiological Health, is now a facility of the US Environmental Protection Agency (USEPA). In 1983, the accumulated inventory of 140 g of radium was transferred to and disposed of at the Hanford, WA, low level radioactive waste disposal site.

Subsequently, other large amounts of radium were disposed of. In 1989, 120 g of radium was removed from the former Radium Chemical Co. plant site in Queens, NY, and disposed of at the Beatty, NV, low level radioactive waste disposal site [21]. In the 1990s, several States mounted campaigns to locate, recover and dispose of radium sources. A total of 4.2 g was collected and disposed of by Oklahoma and Ohio [26]. The Conference of Radiation Control Program Directors (CRCPD) estimates that radium disposals amounted to 12 g y^{-1} in the 1970s, 10 g y^{-1} in the 1980s and 8 g y^{-1} in the 1990s [27].

6. THE USAEC GENERAL LICENCE PROGRAM

In 1958, at about the same time that the USPHS began assisting States in developing regulatory initiatives to improve control, accountability and disposal of radium sources, staff of another Federal agency, the United States Atomic Energy Commission (USAEC), proposed extending the general licence concept to "measuring, gauging and controlling devices" containing radioactive materials covered by the Atomic Energy Act of 1954, as amended [28]. USAEC staff noted that "[a]bout 1000 users would be affected". This proposed change was approved in 1959 by the Commission. Ironically, the rule change eventually led to control, accountability and disposal problems with this group of radioactive sources that, in retrospect, are similar to those that were found with radium sources.

The general licence concept enables persons with minimal training in radiation safety to possess and use licensed devices with minimal risk to the users or to the public while the devices are in use. Robust design and manufacturing criteria that are applied to the devices enable this unique approach. Persons using such devices do not need to apply for a specific licence, but possess and use the devices under the general licence and its conditions, which are provided in the regulations. Inherent in the concept was the notion that general licensees will exert appropriate control and accountability of the devices while they possess them and will properly dispose of them when they are no longer needed.

Because the requirements for robust design of generally licensed devices provide assurance that these can be used safely, there is no routine inspection programme or other regulatory mechanism for contacting most general licensees periodically. Most general licensees are exempted from user fees. As a result, most of the Members of this group of licensees, at present consisting of about 135 000 persons using 1.8 million devices, rarely have contact with the regulatory agencies. In the absence of such contacts, some general licensees' programmes to control, account for and properly dispose of the devices deteriorate. As time passes, warning labels and signs on generally licensed devices often become obliterated as a result of exposure to adverse environments and improper maintenance. Also, personnel knowledgeable about the devices retire, are discharged or otherwise leave the licensee's plant. The predictable consequence of these developments is that generally licensed sources are entering the public domain in an uncontrolled manner, most frequently by being discarded with scrap metal. Some specifically licensed devices are also mistakenly discarded with metal scrap, but the number of devices under specific licences is smaller, and their users are subject to routine regulatory contacts as a result of fee charges and routine inspections.

The similarity of these general licensees to the pre-1960s radium users is this: neither group was universally subject to periodic contacts by regulators to remind them of the need to maintain control and accountability of their sources, to use them safely and to properly dispose of them when no longer needed. A significant difference, however, is the size of the two groups. As noted, the number of radium users probably peaked in the 1950s at about 5000 to 6000, a fraction of the total United States general licensee population using radioactive devices, which grew from 1000 in 1958 to 135 000 forty years later.

As early as 1981, the States expressed concern to the USNRC about the general licence programme [29]. In 1986, an outside panel of experts that reviewed the USNRC licensing and inspection programme for fuel cycle and radioactive materials facilities recommended that the USNRC give higher priority to an ongoing review of general licence policies and procedures because of problems with devices being abandoned or disposed of in unauthorized ways and with malfunctions and lack of accountability [30]. In the 1990s, the scrap metal recycling industries expressed concern as well, reflecting their experiences with licensed radioactive sources and devices becoming mixed with scrap metals destined for recycling, and developed informational and guidance references [31, 32]. A 1996 report by a joint USNRC–Agreement State Working Group expressed similar concerns and recommended changes in the USNRC general licence programme [33]. The Working Group also discussed another problem, namely orphan sources. These are sources or radioactive devices that are found in the public domain, most often by metal recyclers. When these are reported, the finders are often asked to take control of and secure the source or device temporarily, thus removing the potential hazard to the public. This is done because provisions to accept or arrange transfer of licensed radioactive material are not generally available to the regulatory agencies unless there is an immediate threat to the puhlic health and safety. If the owner of the source or its manufacturer can he identified, arrangements are usually made to return the source or obtain payment for its disposal. On the other hand, if the owner or the manufacturer cannot be identified or is no longer in existence, the source is considered to be an 'orphan source', and the unlucky finder may be held responsible for its long term security and eventual disposal. Obviously, this is unfair and probably serves as a disincentive to some persons to report discoveries of radioactive sources. The Working Group recommended that this problem be addressed.

In 1998, forty years after the expansion of the USAEC general licence programme, the Commission directed USNRC staff to make changes in the general licence programme to improve control and accountability of general licensed devices and to take steps to assure proper disposal of unwanted licensed sources [34]. Additionally, the States, through the CRCPD and with financial support from the USEPA, established a committee on unwanted radioactive materials which will attempt to tackle the problem of orphan sources.

7. CONCLUSIONS

An important lesson to be learned from the operational experience with radium users is that periodic contacts by regulators with users of radioactive sources serve as reminders to these of the need to maintain control and accountability of the sources, to properly dispose of the sources when they are no longer needed and otherwise to provide for their safe use. This lesson has been reinforced by the experience following the rule change by the USAEC to extend the general licence programme to include users of radioactive devices. Again, the lack of periodic contacts by regulators with this group of users led to control, accountability and disposal problems. Periodic contact by regulators with users of radioactive materials is an essential element of a regulatory programme.

Given this historical perspective, perhaps another lesson is that when dealing with radiological protection issues, we should not ignore the knowledge learned from past experiences. Otherwise, as George Santayana wrote, "Those who cannot remember the past are condemned to repeat it" [35].

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SUMMARY OF DISCUSSION

Technical Session 4

Chairperson: **P. Metcalf** (South Africa)

Rapporteur: **J. Lubenau** (United States of America)

K. COY (Germany): With regard to the industrial radiography accidents in India listed by A. Kumar (paper IAEA-CN-70/4), it is stated that in the case of the January 1994 accident "exposure to hand could be much higher". What were the calculated finger doses, and what happened to the person in question?

A. KUMAR (India): The calculated finger doses were of the order of 200 R. The person was laid off from radiation work.

K. COY (Germany): In the paper on losses and finds of radioactive materials in Germany (paper IAEA-CN-70/23), it is stated that a major cause of finds is "failure to properly dispose of radioactive materials during or after bankruptcy ...". Such failure is often due to the fact that the official receiver in a bankruptcy case — a lawyer who knows little or nothing about radiation safety — has laid off the person(s) responsible for the radiation source(s). What can one do about this problem?

I. BARTH (Germany): It is a question of someone in the bankrupt company having a sense of responsibility and informing the local supervisory authorities that there are still radiation sources at a given site. For the future, regulatory authorities could, before authorizing an activity, require that the applicant make arrangements at the time of purchase of the source for — say — its return to the supplier.

R.E. CUNNINGHAM (United States of America): If a product is found to be radioactively contaminated and the origin of the contamination is not obvious, one should — even if the contamination level is low — carry out investigations at the production plant, not least in order to protect the people working there. It may be suitable to clear a radioactively contaminated product for one use but not for another — for example, radioactively contaminated steel for bridge building but not for the manufacture of bicycles. This brings us back to the question of 'clearance' discussed in Technical Session 3.

J.M. KARHNAK (United States of America): I believe that any system for the clearance of radioactively contaminated products must be simple enough to be understood by the public, which may have difficulty in accepting the incorporation of radio-nuclides into — say — the structure of a bridge where they will have decayed appreciably by the time that the bridge is dismantled and its structural materials recycled.

A.J. GONZALEZ (IAEA): The clearance system should be as simple as possible, but we scientific and technical people should not 'filter' our advice in order to make it understandable and palatable to the public. In the first place, what is the 'public'? Is it my Aunt Maria or is it a Nobel laureate who knows as little about ionizing radiation as she does? In the second place, any advice we give will be 'filtered' by politicians who think they have their finger on the public pulse — and we should prevent our advice from being 'filtered' twice. We should say things as simply as possible, but we should say what we think is right.

L.A. JOVA SED (Cuba): As regards Learning from Operational Experience (the title of this Technical Session), for countries which are just beginning to establish radiation safety infrastructures it is not simply a matter of statistics or emergency preparedness; it is also a matter of retrospective safety analysis, and such countries should be shown what they can do in that respect.

P.E. METCALF (South Africa *(Chairperson)*: I agree with you completely.

A.J. GONZALEZ (IAEA): In his overview, J. Lubenau said that the US Nuclear Regulatory Commission (USNRC) has directed its staff to make changes in the general licence programme in order to improve the control of and accountability for generally licensed radioactive devices. I imagine that the changes are resulting in more work for regulators, who will need more human and financial resources, and I wonder what the situation will be in poorer countries with similar general licence programmes, if their regulators receive such directions; the regulators will probably be overwhelmed. The only solution I see to the problem is to divide radioactive devices into those which are and those which are not of real radiation significance.

J. LUBENAU (United States of America) *(Rapporteur)*: We at the USNRC were initially overwhelmed, as it was difficult to convince those in authority that such problems must be addressed and that sufficient resources must be devoted to resolving them. The USNRC is currently performing a risk assessment of radioactive materials uses, with a view to reconsidering which uses should be subject to a specific licence, which may be subject to a general licence and which may be exempted from licensing requirements. It is likely that, as a result of the risk assessment, some uses will move from their present category to another one.

P.E. METCALF (South Africa (*Chairperson*): The costs of regulatory control of radioactive devices is clearly quite high, even for developed countries. For developing countries such costs must represent a big problem, as A.J. González was no doubt suggesting.

A.J. GONZALEZ (IAEA): In connection with the radiological accident in Tbilisi, Georgia, which is described in paper IAEA-CN-70/90, I would mention that a few weeks ago three radiation sources — apparently once belonging to the Soviet military — were found at a site about 250 km from Tbilisi. One of the sources is very powerful — some 2000 Ci. This points to what could be a major problem in countries of the former Soviet Union, and I was wondering whether such abandoned sources could be detected by means of systematic aerial surveys. I believe aerial surveys have been carried out in eastern Germany for this purpose.

G. WEIMER (Germany): Aerial surveys have been carried out in eastern Germany for that purpose, but they have not been very effective because most of the abandoned radiation sources (at former Soviet military sites) are shielded (still in their containers) and/or are beta emitters. The sources have been found as a result of on-site searches of buildings, scrap heaps and so on.

J. LUBENAU (United States of America) *(Rapporteur)*: Aerial radiation monitoring has been used successfully in, for example, detecting scattered ^{60}Co pellets on roads in Mexico and a lost nuclear gauge in Alabama.

P.E. METCALF (South Africa *(Chairperson)*: Perhaps the IAEA could establish a service for helping countries to find 'orphaned' sources.

A.J. GONZALEZ (IAEA): That is very much a question of money. I should like to see some European Union and other Western countries providing financial support for efforts to find 'orphaned' sources in countries of the former Soviet Union.

C.J. HUYSKENS (Netherlands): Given the high costs of disposing of radiation sources safely after their useful lifetime, which often discourage users from ensuring that the sources used by them are disposed of safely, I think there is a need for national and international arrangements that will encourage users to surrender — for controlled disposal — the sources no longer required by them.

G.A.M. WEBB (IAEA): Such arrangements — which, I agree, are necessary — would have to be different for new radiation sources just being purchased and old sources just being discovered. In the case of new sources, there should be provision (perhaps linked with a deposit paid at the time of purchase) for the return of the source to the manufacturer. In the case of old sources, there should be national and regional centres authorized to receive and store sources at no cost to the persons surrendering them.

A. HOORELBEKE (France): In France, we have had for almost ten years a system for keeping a check on radiation sources from the moment they are put on the market. The main features of the system are the following:

— No distributor may sell a source without first obtaining from the manufacturer a commitment to ultimately take back the source for recycling or storage and without providing a surety (in the early days of the system, a bank guarantee — later, either a deposit of moneys with the Agence nationale pour la gestion des déchets radioactifs (National Radioactive Waste Management Agency)) or membership in the association of suppliers, which has set up mutual guarantee arrangements to cover the costs of looking for the source if it should disappear.

— No potential user may purchase a source unless it is accompanied by a guarantee that it will be taken back; the guarantee form must be signed by the supplier and certified by the Commission interministerielle des radioéléments artificiels (Interministerial Commission for Artificial Radioelements).

— With only a few exceptions, no source may be used for more than ten years.

Thanks to this system, more than 80% of the radiation sources being used in France are less than ten years old and covered by take-back guarantees. The system could undoubtedly be improved, but it does seem to be effective in ensuring that radiation sources do not end up in scrapyards or suffer a similar fate.

C. MILU (Romania): Two things which, in my opinion, would help to reduce the problem of 'orphaned' sources are (1) the inclusion in each licence of a clear statement regarding procedures for the disposal of the source and (2) (as stated in paper IAEA-CN-70/37) the development of an international database and reporting system for old sources — especially ^{60}Co sources which have been used in teletherapy.

L.A. JOVA SED (Cuba): Often, the supplier of a radiation source is not the manufacturer — and has gone out of business by the time the user of the source wishes to return it. What can be done about the resulting problems?

P.E. METCALF (South Africa) *(Chairperson)*: A system like the French system just described by Ms. Hoorelbeke would probably cater for such situations.

A.J. GONZALEZ (IAEA): The existence of the French system is very encou-raging, but it is a national system — not an international one. What we ultimately need is an international system whereby governments assume responsibility for the radiation source manufacturers and suppliers operating within their national territories. Unfortunately, in the negotiations on the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the 'Joint Convention'), a number of countries, including France, opposed the idea of governments assuming international obligations in respect of radiation sources. Perhaps the most one can do as far as existing radiation sources are concerned is, as suggested by G.A.M. Webb, to establish national and regional centres authorized to receive and store them at no cost to the persons surrendering them.

P. ORTIZ LOPEZ (IAEA): The fact that, often, the supplier of a radiation source is not the manufacturer, just referred to by L.A. Jova Sed, gives rise not only to disposal problems but also to maintenance problems. There is a need for an international approach to the export of equipment containing radiation sources so as to ensure the safety of the equipment through proper maintenance.

J.U. AHMED (Bangladesh): In my view, each country should have a central body with the powers and the facilities necessary for the control of all the radiation sources in that country — sources no longer in use, sources currently in use and sources not yet acquired. Without strong centralized control, various other bodies (among which there may well be rivalries) are likely to set up their own control systems. As regards sources no longer in use, the IAEA should promote the establishment of an exhaustive inventory, with a view to their safe storage or disposal.

As regards sources currently in use in different countries, each country should establish a complete inventory and draw up a plan for their safe management at the end of their useful life. The IAEA could play an important role in this connection. As regards sources not yet acquired, there should be an international mechanism whereby manufacturers or suppliers hire out radiation sources to the users, rather than selling them outright, and assume full responsibility for routine maintenance, for the replacement of source capsules when necessary and for the management of the sources at the end of their useful life.

G.A.M. WEBB (IAEA): In this connection, I would recall that the Model Project of the IAEA for upgrading the radiation protection infrastructures in over 50 of its Member States — described by J. Qian in Briefing Session 2 — has entailed the establishment of complete inventories of the radiation sources in those countries, with details of where they are and who is responsible for them. Also, I would point out that the IAEA is not a supranational authority with powers of enforcement; it acts at the request of its Member States. Consequently, its role with regard to international measures to ensure the safety of radiation sources is at present necessarily very circumscribed.

A.J. GONZALEZ (IAEA): That is true. The IAEA can at present only promote and facilitate the application of such measures. The real initiative must come from States, which I should like to see entering into international legal commitments among themselves as regards the effective operation of national regulatory control systems.

P.E. METCALF (South Africa) *(Chairperson)*: I would mention in this connection that, by becoming parties to the Joint Convention, countries undertake to draw up inventories of the radiation sources within their territories and to manage the spent sources safely. The responsibility is a national one.

J.U. AHMED (Bangladesh): It is precisely because the IAEA is not a supranational authority with powers of enforcement that I believe we need an international legal instrument by means of which countries can commit themselves to operating effective regulatory control systems.

P.E. METCALF (South Africa) *(Chairperson)*: Such instruments are difficult to develop and implement, but perhaps something will emerge with time.

J.A. LOZADA (Venezuela): We have found that suppliers of radiation sources often refuse to take them back at the end of their useful life despite the fact that the purchase contract contains a take-back clause; a common reason given for the refusal is that the source shielding has been damaged and the user is returning it in some other kind of container.

P.E. METCALF (South Africa) *(Chairperson)*: Sometimes suppliers are willing to take back spent sources, but are prevented from doing so by national legislation. This is something which would perhaps have to be covered in an international legal instrument.

A.M. AL-ARFAJ (Saudi Arabia): Is it possible to transfer a radiation source which is no longer being used in one country to a user in another country (rather than disposing of it)?

P.E. METCALF (South Africa) *(Chairperson)*: That is a question of different countries' national legislation relating to what may be exported and imported. Also, much depends on how knowledgeable the regulatory authorities in different countries are about what is being exported and imported.

A.M. AL-ARFAJ (Saudi Arabia): In some countries, the regulatory authority is not empowered to control the radiation sources being used in the military sector. Can anyone suggest a solution to this problem?

P.E. METCALF (South Africa) (*Chairperson*): Again, that is a question of the national legislation in different countries. Often, the military authorities have their own regulatory control system for radiation sources.

K. SCHNUER (European Commission): In some countries belonging to the European Union, the military regulations relating to radiation protection are subordinate to civil law.

R. VENOT (France): Could one use the International Nuclear Event Scale (INES) developed by the IAEA and the Nuclear Energy Agency of the OECD as a tool for the rapid communication — between States, the IAEA, Interpol, the World Customs Organization, etc. — of information about events involving radiation sources?

A.J. GONZALEZ (IAEA): I don't think so. INES was developed for communicating with the media, where most people know little about ionizing radiation and simply want quick — even if imprecise — answers to their questions; it is not a technical scale suitable for communications among technical people. Perhaps something like the Incident Reporting System (IRS) operated by the IAEA in close co-operation with the Nuclear Energy Agency of the OECD would be more suitable. An important aspect of the IRS is that it provides for the technical analysis of the root causes of incidents.

INTERNATIONAL CO-OPERATION, INCLUDING REPORTING SYSTEMS AND DATABASES

(Technical Session 5)

Chairpersons

S. MAGNÚSSON
Iceland

A summary of Contributed Paper IAEA-CN-70/94 was also presented

SUMMARY OF DISCUSSION

Technical Session 5

Chairperson: **S.M. Magnússon** (Iceland)

Rapporteur: **K.E. Schnuer** (European Commission)

K. COY (Germany): I should like to ask the Rapporteur whether he knows of any cases where, as a result of the reduction in the permitted annual dose to 20 mSv, companies have moved away from the European Union area to other parts of the world.

K. SCHNUER (European Commission) *(Rapporteur)*: I know of a company manufacturing radiation sources and one manufacturing electric light bulbs (for which thorium is used) that are planning to transfer their production operations to countries outside the European Union area for that reason.

W.C. CLIFF (United States of America): Are international databases such as the IAEA Secretariat's Illicit Trafficking Database going to be made available via the Internet?

A.J. GONZALEZ (IAEA): I hope that the various safety related databases — and other safety related material — of the IAEA Secretariat will be available via the Internet once certain legal problems have been resolved.

J.R. CROFT (United Kingdom): In the United Kingdom we now have an Ionising Radiation Incident Database (IRID) funded jointly by the National Radiological Protection Board (NRPB), the Health and Safety Executive (HSE) and the Environment Agency (EA). It already contains reports on over a hundred incidents, including 'near misses' from which lessons can be learned. The data and descriptions in IRID have been edited so that organizations and individuals cannot be identified, and the HSE and the EA have given an undertaking not to use IRID when taking enforcement action. The material in IRID is formatted in such a way that it can be used for training purposes. In my opinion, it would be useful if databases like IRID fed into the IAEA Secretariat's International Reporting System of Unusual Radiation Events (RADEV) once it becomes operational.

K. SCHNUER (European Commission) *(Rapporteur)*: With regard to what was just said by A. González and J.R. Croft, there is a legal problem about introducing information about a radiation accident into a database while the accident is still the subject of court proceedings. Normally, the judge will allow only very general, superficial information to be released.

P. ORTIZ LOPEZ (IAEA): From where does IRID obtain reports on 'near misses', when there is so much reluctance among users of radiation sources to issue such reports?

J.R. CROFT (United Kingdom): So far, all the reports in IRID are from the NRPB, the HSE and the EA, the last two of which are regulatory bodies and do not get to know about 'near misses', because there is no legal requirement to report to them on such events. The NRPB, however, does not have regulatory enforcement functions; it learns about 'near misses' when acting as radiation protection adviser to some 900 radiation users. It is hoped that professional bodies and individuals such as university radiation protection officers and hospital physicists will soon start reporting to IRID; they, too, will probably provide information about 'near misses'.

L. CAMPER (United States of America): The US Nuclear Regulatory Commission (USNRC) is developing an automated registration system for the control of generally licensed devices and should in three to four years' time be in a position to share its findings relating to lost sources.

P. ORTIZ LOPEZ (IAEA): I am sure that its findings will be very useful, and I hope that they will include photographs of lost sources. When RADEV becomes operational, the lessons learned from unusual radiation events will be fed back into training programmes — as in the case of lessons learned through the Incident Reporting System operated by the IAEA.

VERIFICATION OF COMPLIANCE, MONITORING OF COMPLIANCE

Assessment of the Effectiveness of National Programmes for the Safety of Sources, Including Development of Performance Indicators

(Technical Session 6)

Chairpersons

E.C.S. AMARAL
Brazil

ZIQIANG PAN
China

A summary of Contributed Paper IAEA-CN-70/49 was also presented

RETROSPECTIVE SAFETY ASSESSMENT
Verification of compliance with radiation protection requirements

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Abstract

RETROSPECTIVE SAFETY ASSESSMENT: VERIFICATION OF COMPLIANCE WITH RADIATION PROTECTION REQUIREMENTS.

The verification of compliance with radiation protection requirements in a given country is implemented by its regulatory authority in order to determine if sources are used according to the requirements established by regulations and the conditions reflected in the licence, registration or authorization granted to the user. The paper summarizes the principal elements of any programme for the verification of compliance. Inspections are the most important of these elements; the types, aims and frequencies of inspections and the preparations needed for them are discussed. Special attention is paid to occupational monitoring and surveillance of workplaces. The main difficulties of the national regulatory authorities at their earliest stages of development are discussed. Also discussed is the way in which periodic reports, user reports on abnormal situations and the systematic assessment of enforcement actions and the revalidation of authorization can help the regulatory authority to verify compliance. The paper emphasizes the difficulties of regulatory authorities in developing countries in verifying compliance, and in particular difficulties relating to the authority given by the government, the financial resources made available and the qualification of personnel.

1. INTRODUCTION

The full and correct application of legislation and regulations in radiation protection demands that governments establish a regulatory authority in charge of regulating, approving and controlling the introduction and performance of any practice that entails the use of radiation sources. This regulatory authority should be invested with suitable powers and should be endowed with sufficient resources for effective fulfilment of its functions.

The type of regulatory system adopted by each country will depend on the extent, complexity and safety issues connected with the practices and the sources used and on the country's tradition regarding regulations. The mechanisms used to ensure compliance with regulatory functions can vary. There are authorities which are completely autonomous and others that delegate certain functions, such as inspection or assessment to official, public or private institutions. A regulatory authority may also be autonomous concerning specialized knowledge or it can resort to the services of outside experts and advisory committees. But always, in any case, systematization, final assessment and decision making are the prerogative of the regulatory authority.

As a rule, the functions of the regulatory authority include (1) assessment of requests for authorization of practices that imply or could imply exposure to radiation; (2) the granting of authorization to such practices and to the sources in connection with them under certain specific conditions; and (3) the performance of periodic inspections in order to verify compliance with such conditions and with the radiation protection regulations in force and to verify the safe operation of the sources and the application of all necessary measures so as to guarantee compliance with the conditions or limitations reflected in the authorization and in the regulations and the standard requirements. Not less important are the surveillance or radiological control, assessment, verification and inspection of the sources, the establishment of plans for response to accidents that imply radiation exposure and the implementation of emergency plans as necessary.

2. VERIFICATION OF COMPLIANCE

The verification of compliance is implemented by the regulatory authority in order to determine if sources are used according to the requirements established by regulations and by the conditions reflected in the licence, registration or authorization granted to the user. The verification of compliance gives the confidence that radiological safety requirements have been met or gives the opportunity of demanding corrective measures in case of non-compliance with these requirements. The most important elements for verification of compliance are (1) in situ inspections, (2) radiological safety assessment, (3) notification of incidents and accidents, (4) reports of registrants and licensees and (5) the systematic assessment of licensees and registrants.

Verification of compliance is essential to any regulatory programme, irrespective of the degree of development achieved in that programme. Usually, in developed countries verification is performed by making use of all available methods; the technological culture and the safety culture created contribute greatly to the success of this undertaking. However, in most developing countries, in which there is a lack of a high safety culture, all available methods of verification are not applied, and those that are applied are only partially used.

3. IN SITU INSPECTION

One of the most effective elements of the verification of compliance is in situ inspection, which is also the main way for establishing personal contact between the users and the regulatory authority's personnel (inspectors). A great part of the regulatory authority's resources should be dedicated to this activity, because it plays a very important role during and after registration or licensing.

All registrants or licensees and other users of radiation sources, whether or not they have notified the regulatory authority of their possession of radiation sources, should allow duly authorized regulatory authority representatives to inspect their facilities to:

(1) be sure that the equipment, facilities, systems, buildings and operational procedures correspond with the regulations in force and with the conditions of the registration or licence;
(2) be sure that the radiation sources correspond with the authorized ones;
(3) check the validity and currency of documents related to operation, records, instructions and warning signals;
(4) verify that the operating personnel are authorized and that they have the required qualifications;
(5) find previously unidentified problems and deficiencies;
(6) verify corrective measures resulting from previous inspections.

Developing countries, no matter what the stage of implementation of regulatory programmes for protection against ionizing radiation (organization, implementation or operational) in which they find themselves, often appear negligent in failing to demand compliance with radiation protection requirements. This includes the most elemental requirements, concerning notification, registration and licensing for private practice. This problem is even worse with respect to verification of compliance, and in particular with respect to inspections. In some countries, especially during the organization and implementation stages, when the legislation is not complete and the regulatory authority does not have full authority in the broad sense of the word, 'respect' for private practice is more obvious.

In small countries, where the users of radiation sources are professional, financial or social entities (for example, in medical or industrial practice), this unequal treatment is accentuated. Quite often, those entities have a great influence on the governments of such countries, and this substantially hinders the work of the regulatory authorities. It is also true that, unfortunately, in the majority of these countries, the post of head of the regulatory authority is a political position, and its appointment depends on many factors, such as the identity of the governing party, political influences and personal relationships. These realities greatly influence the

TABLE I. POSSIBLE FREQUENCY OF INSPECTION FOR VERIFYING THE FACILITIES ACCORDING TO THE RISK OF THE PRACTICE
Adapted by the author from information in Ref. [1]

Practice	Risk	Frequency (months)
Industrial gammagraphy (radiography)		
Stationary	Medium	12–24
Movable	High	12
X ray fluorescence	Low	24–36
Activation analysis	Medium	12–24
Level gauges	Medium	12–24
Teletherapy	High	12
Brachytherapy	High	12
Industrial irradiators	High	12
Nuclear medicine		
Therapy	High	12
Diagnosis	Medium	12–24
Diagnostic X rays	Low	24–36

efficiency of national regulatory programmes aimed at guaranteeing radiological safety and strongly influence in situ inspections. Requirements for radiation protection and safety should be equally applied to all practices and sources, whether State or privately owned, and to all persons, whether legal or natural. All these parties deserve the same respect and consideration with regard to radiological protection issues.

For this reason, it is important that the national legislation defining the functions and obligations of the regulatory authority be of the highest possible legal status and that it provide for all the necessary authorities to take the actions necessary in case of non-compliance. In some countries, advantage has been taken in this regard of the personal relations of the head of the regulatory authority with the government bodies which — in one way or another — have a bearing on the adoption of such legislation.

The inspections, aimed at assessing the status of the verification of compliance with the regulatory requirements and the safety of an authorized practice or operation, should be based on the direct observations of work activities, interviews with occupationally exposed workers (and others related to the practice, such as auxiliary personnel), independent measurements of radiation and contamination levels and the review of procedures and records. If portable sources or equipment are involved in the practice or operation, inspections should be carried out where and when the activity goes on. The review or inspection process can be enriched by exchanges of experiences among inspectors.

The regulatory authority should have an inspection plan. The priority and frequency of inspections will be influenced by the risk and complexity of the practice and by whether the operation is conducted under a notification, registration or licence. Table I [1] shows a proposal for frequency of inspection based on the risk of the practice.

In general, a good pre-operational safety assessment for the registration or licensing can reduce the frequency and priority of later compliance inspections. Both potential accident consequences and the type and frequency of violations detected by the regulatory authority during other inspections and other information received have a great influence on inspection frequency and priority. In order to establish a priority system, it is also necessary to compile and analyse data on performance within practices.

In addition to all the above mentioned technical aspects, in establishing the frequency of inspections the actual resources of the regulatory authority to contact inspections should taken into account. The material and financial resources of most regulatory authorities in developing countries are scarce. In many cases, there is a lack of the necessary and/or adequately calibrated measurement equipment, and there is also a lack of transport. Undoubtedly, these aspects have a negative influence on the frequency and quality of the inspections. These aspects also influence the authority, seriousness and respectability of the inspectors, who are sometimes not able to carry out previously announced inspections or are unable to verify the fulfilment of provisions in cases of previously detected transgressions which require further verification. A partial solution to such problems lies in strict planning and control of the available resources and the correspondence of those resources with the duties of the regulatory authority; hence the importance of relying on a frequency of inspections in correspondence with the risks of the practices, the history of the facilities and other aspects.

The inspectors, besides determining compliance with the regulatory requirements, should state their opinion on operational safety. In general, inspectors' perspectives on safety can be complemented with the use of performance indicators. In this case, this term is used to indicate a group of circumstances that can help to identify safety aspects which may have been degraded. Information suitable as performance indicators for practices with ionizing radiation generally takes the form of subjective warnings of degraded performance. They are thus negative performance indicators, and they are usually associated with institutional management.

TABLE II. MOST COMMON PERFORMANCE INDICATORS

1	Loss or lack of commitment of the institution's management to the radiological safety programme
2	Little attention from the officer or the person in charge of radiation protection to the radiological safety programme; or the officer is very busy with other tasks.
3	Not many persons are trained to carry out an effective radiation protection programme, or an excessive work responsibility.
4	The aspects related to the radiation protection programme are not discussed by persons responsible for this, indicated by the institution.
5	Failure of the quality assurance system to detect problems related to radiological safety.
6	Not much success in the continuation of approved procedures.
7	Users are not familiar with the safety measures or conditions for the authorization.
8	Production activities have priority over the radiological safety programme.
9	Not much success in the implementation of corrective actions.
10	Frequent repetition of small problems, maybe as a result of not being capable of solving the main problems.
11	Deficient updating of records.
12	Evidence of financial instability of the authorized institution.
13	Frequent changes of personnel.
14	Impossibility of implementing on time all the tasks that the radiation protection programme requires.
15	Loss of documentation.
16	Failure in the assessment of effectiveness of the training performed.
17	Not much interest in radiation protection on the part of the labour force.
18	Excess of radioactive wastes accumulated.
19	Lack of training for radiological emergencies.
20	Inadequate radiological surveillance.
21	Poor control of radiation sources.

Although performance indicators are not quite regulatory infringements, infringements usually appear together with performance indicators. Performance indicators may be used as a basis for informing users about aspects which should be improved and to establish the frequency of inspections for a particular user. Table II shows some performance indicators which may be used for this purpose.

The inspections may be announced or unannounced. The advantage of an unannounced inspection is that it provides an opportunity to see the facility operating under its usual conditions. The disadvantages are that part of the facility may not be operating or key personnel may not be available. Knowledge of the practice should help to optimize the timing and duration of unannounced inspections (for example, in a nuclear medicine area, at the moment of reception of radionuclides). It is obvious that the two types of inspection should be combined in order to have a more realistic view of practice and source safety conditions during normal operation. But in order to do this, it is required that the legislation suitably empower the regulatory authority and that the invested authority be used accordingly. However, nowadays unannounced inspections are rarely conducted, particularly in private practice.

The regulatory authority should insist on the preparation of inspections from their first stages with the objective of creating suitable habits in inspectors, as this is an essential aspect for their efficacy and success. The inspector should review the documents sent by the applicant or user to support his request for authorization, i.e. safety assessment and data of related staff, as well as previous inspection reports, detected infringements, enforcement actions applied, aspects pending solution and (something very important) the terms or restrictions for granting authorization.

In a first inspection, the inspector should tour the facility to become familiar with its general layout and operation, paying special attention to organization and general housekeeping. Although these are not radiation protection requirements, they may be an indicator of how the user's radiation safety programme is conducted. Radiation sources, facilities and operation procedures should be inspected in detail to determine whether they conform with those described in the documents submitted by the applicant or user and with the limitations and terms expressed in the authorization. The inspector should verify that the current staff conforms with the staff described in the submitted documentation, still in force, which is in the hands of the regulatory authority. The inspector should also devote sufficient time to thoroughly review records. These records should be up to date and should reflect the real situation within the facility. The records should be confirmed by independent monitoring by the inspector.

Interviews with key workers of the facility, from the operational up to management levels, will permit the inspector to collect information which helps in assessing the status of protection and the safety of practice and sources, as well as the level of safety culture existing in the facility.

Many regulatory authorities, especially in developing countries, are resource limited, and especially so in terms of an insufficient number of staff, or staff with insufficient skills in relation with radiation protection knowledge and operational experience. In these countries this fact is more evident because of the low saleries of these officials, which influences their selection and contracting. Often, when the regulatory authority succeds in contracting and training some specialists, they are later hired by a private company, where they are better paid.

Lack of experience and skills is particularly troublesome for regulatory authorities with small regulatory programmes. In such situations, the quality of inspections can be affected by the existing proportion of performance and prescriptive regulations incorporated into the regulatory programme. For many types of practices, the inspection programme can be based on the use of personnel with basic training in radiation protection and knowledge of practices, who conduct inspections according to the requirements of prescriptive regulations. The use of outside experts can supplement and enhance the available skill level of the regulatory authority. The temporary use of consultants with high professional qualifications and practical experience in particular subjects (e.g. medical physics or mechanical engineering) is a cost effective way to enhance the technical level of inspections and assessments of the competent authority. This approach is rarely practised by developing countries, sometimes because of insufficient financial resources. In any case, if it is decided to resort to outside experts, the following aspects should be taken into account:

(1) The personnel of the regulatory authority should have sufficient technical knowledge to identify the problems and to determine when it will be economically effective to request the assistance of experts or consultants.
(2) As a general principle, the consultants can only advise. The regulatory authority is responsible for evaluating this consulting service and for determining how these recommendations should be applied.
(3) Ideally, the experts or consultants should be free of conflicts of interest so that they are able to provide impartial advice.

The use of inspection manuals or checklists can aid the regulatory authority by helping less skilled staff to conduct inspections. The inspection manual can consist of simple checklists, or it can give the inspector advice on criteria for acceptable and unacceptable performance. These manuals aid inspection efficiency and provide a measure of quality assurance for the regulatory authority. In addition, these inspection manuals unify the assessment criteria for inspections, helping in some way to minimize the differences that may exist in the instruction and training of the various inspectors. This is especially important in countries where, owing to geographical, political or technical conditions, there are subsidiary or territorial branches of the regulatory authority. These manuals, systematically updated with nationally or internationally acquired practical experience, allow the regulatory authorities in developing countries to complete, in a relatively short period of time, the training of new personnel and in some way to compensate the exodus of qualified specialists to other activities, without substantially affecting the quality of inspection programmes. Inspection manuals and the corresponding inspection reports elaborated by regulatory authorities are also a way of avoiding possible cases of favouritism by inspectors and of making their corruption more difficult.

Inspection manuals should be used only as a guide; they cannot substitute for the professionalism and the curiosity of the inspector to reach the essence of the problems concerning safety and radiation protection. The inspector's report should reflect all issues involving operational safety or source safety, whether or not these aspects are reflected in the inspection manual.

4. QUALITY AUDITS

The licensees and registrants can and should verify compliance with radiation protection requirements. In modern radiation protection, the implementation of quality assurance programmes has become an exigency of good practice. Those registrants and licensees which have implemented quality assurance systems should carry out internal or external audits, contracting (in the latter case) competent institutions in radiation protection issues.

These audits should detect and emphasize those activities or processes which do not comply with the established processes and regulatory requirements. Thus, audits can help registrants and licensees to assess and maintain their radiation protection programmes in accordance with radiation protection requirements and with established and approved conditions in the corresponding authorization (licence or registration), and at the same time to maintain a safety culture, avoiding or minimizing possible violations that lead to enforcement actions by the corresponding authority.

On the other hand, internal or external audits can have different degrees of confidentiality, which enables the licensee to take the actions necessary to eradicate violations.

5. RADIOLOGICAL SURVEILLANCE (MONITORING)

In order to verify compliance with the requirements prescribed by the Radiation Protection Standards and by legislation in force concerning this field, radiological surveillance activities and measurement of the established necessary parameters should be implemented. Radiological surveillance requires equipment and sometimes laboratories adapted for each measurement and circumstance. Procedures for carrying out radiological surveillance, as well as for monitoring equipment and systems, should be established.

It is necessary to differentiate two cases: the first, when the users or registrants or licensees have the responsibility of establishing radiological surveillance programmes according to the risks associated with the practice, and the second, independent radiological surveillance carried out by inspectors from the regulatory authority and whose results should be compared with the results obtained by the users.

In the case of occupational exposure, registrants and licensees should guarantee individual radiological surveillance (when appropriate) and surveillance in workplaces. For individual radiological surveillance (personal dosimetry), registrants and licensees should ensure that suitable arrangements with appropriate services are co-ordinated; those services should be preferably accredited by a quality assurance programme and authorized or acknowledged by the regulatory authority. In those cases in which there are internal radioactive contamination risks, radiological surveillance should be organized, insofar as it is necessary, in order to demonstrate the efficiency of the protection provided and to evaluate the intake of radioactive substances, or committed dose, as appropriate.

It is necessary to dwell upon some crucial aspects. In many developing countries, where radiation protection programmes are in the organizational and implementation stages, there have been some efforts aimed at devoting the Regulatory authority's human and material resources to guaranteeing some radiation protection services, such as individual radiological surveillance. In these countries, in the first stage (implementation stage) of the programme, the maximum efforts and resources should be devoted to the elaboration and approval of the necessary legislation; to the implementation of notification, registration and licensing systems; and to begin to conduct inspections and to demand compliance with the legislation in force. The regulatory authority should demand that licensees and registrants guarantee individual radiological surveillance of their workers and should establish criteria for accreditation or approval of laboratories or companies willing to offer these services, regardless of whether they are at home or abroad. In order to render their services in the country in question, these laboratories should comply with certain requirements and should obtain the approval or accreditation of the regulatory authority of the country where such services are intended to be rendered. By so doing, the regulatory authorities would free resources to devote them to main activities. If, in the operational stage of the national programme, the regulatory authority has the necessary resources to install and use its own laboratories, it would be able to do so without neglecting the achieved levels of radiation protection requirements and verification of compliance. It should not be forgotten that, as a general rule, the installation of a modern personal dosimetry laboratory costs hundreds of thousands of US dollars, depending on the quantity of users; retaining qualified personnel is also very expensive. In many countries these services have been based on sophisticated and rather expensive equipment for reading thermoluminescent dosimeters, which the regulatory authority (and sometimes the country) has neither the infrastructure nor the resources to repair or maintain, jeopardizing individual radiological surveillance programmes.

In this respect, it is necessary to dwell upon the low importance that is being given to the establishment of investigation levels by the regulatory authority, as well as to demanding that the regulatory authority be informed, according to what is established in each country, of cases in which these levels are exceeded, the investigation conducted and the measures taken to optimize the radiation exposure. The results of the individual radiological surveillance and its systematization by practices is a tool that the regulatory authority should use as a basis to prove compliance with the requirements, to plan their inspections and to recommend optimization measures for radiological protection. Regrettably, not all regulatory authorities pay the necessary attention to this aspect, and they do not demand that users send information on the results of personal dosimetry to them or take measures to guarantee that these results are adequately recorded and preserved for the period of time established by each country.

The nature and frequency of radiological surveillance in workplaces should allow (1) the assessment of existing radiological conditions in all workplaces; (2) the assessment of exposure in controlled zones and in the supervised zones; and (3) the classification review of these zones. The frequency also depends on the levels of environmental equivalent dose and on the concentration of activity, taking into account previous fluctuations and the probability and magnitude of potential exposures. The same requirements used to verify compliance with procedures can help to detect potential abnormal situations and, thereby, to prevent or reduce the consequences of radiological accidents.

Many accidents that have occurred during operation with radiation sources in irradiators (workers entering the room where the sources are in irradiation position), in industrial radiography (sources that do not return to the shielded container) or in brachytherapy (sources that remain implanted in patients) could have been avoided with radiological surveillance carried out with a calibrated dosimeter or radiometer in good condition. Examples are the accidents in San Salvador, Soreq and Pennsylvania, where the radiation monitors were out of service, not functioning correctly or considered to be unreliable. In some of these cases the measurements demanded for safe operation were not made. Another situation that demonstrates the need for systematic performance of radiological surveillance is the loss or theft of sources. These facts are sometimes discovered long after they have occurred because of the lack of systematic control.

In the case of public exposure, registrants and licensees, if appropriate, should establish and implement a radiological surveillance plan capable of ensuring that requirements prescribed by procedures are complied with regarding (a) public exposure to sources of external irradiation, and assessment of such exposures; (b) disposal of radioactive substances to the environment and requirements set by the regulatory authority to grant authorization to carry out such disposals, and that the alleged conditions for establishing authorized clearance levels continue being valid and sufficient to allow estimating the exposures caused to critical groups.

The regulatory authorities of developing countries do not pay much attention to this last aspect. For example, in medical practice, which is one of the most widespread (if not the most), radiological surveillance in public waiting rooms is rarely demanded or verified. There is practically no control over nuclear medicine modules (for diagnosis or therapy) regarding radiological surveillance of effluents. The argument that they are short half-life isotopes is common, or that all is 'under control' without any evidence or record of the corresponding verification or controls, especially in cases in which ^{131}I is used for therapeutic purposes. In the most fortunate cases, the regulatory authority has authorized a clearance level; but often this has never been verified, nor are there records of such dumping.

In the case of medical exposure, special attention should be paid to radiological surveillance in the cases of therapy with unsealed sources and brachytherapy, particularly with patients that are discharged with implanted radioactive sources. In this regard, it would be an omission not to refer to the reference (guidance) levels, conceived as levels that are a reasonable sign of the dose in the case of patients of medium corporal size. These levels should indicate what can be obtained with a good current practice and not what should be considered to be an optimal result. It would be very useful for patients' protection if regulatory authorities, from the beginning, established the relevant co-ordination with the corresponding authorities or national relevant professional bodies in order to define and establish reference levels. Those countries that for one reason or another cannot establish their own reference levels could use those recommended in Ref. [2] until their own are established.

In all the cases mentioned here, for radiological surveillance and for verification that the requirements have been fulfilled, the registrants and licensees as well as the regulatory authority should make use of the appropriate equipment and establish calibration procedures. All equipment should be properly kept and tested and should be calibrated after purchase or repair and at given appropriate intervals, established by the regulatory authority, using as a reference patterns traceable to national or international patterns. The non-existence in a country of a secondary (or at least tertiary) laboratory for dosimetric calibration should not be an excuse for the regulatory authority not to establish and demand compliance with this requirement. In most cases, international calibration prices are lower than equipment costs. It is the regulatory authority's duty to establish criteria for approval or accreditation of these laboratories — regardless of the country in which they are located — so that they can render these services in the country where the equipment is used, as well as to establish co-ordination with national customs offices so that the equipment is not withheld longer than needed because of customs formalities, as has happened in some countries. The regulatory authority should be an example on this issue; its equipment should be systematically checked and the corresponding dosimetric calibrations validated. In cases of differences between the results of radiological surveillance carried out by the registrant or licensee and those obtained by the inspector from the regulatory authority, the latter must be acknowledged as valid, and this can only be possible if the equipment is in good technical condition and has been appropriately calibrated.

Records are essential not only to demonstrate compliance with requirements but also as part of quality assurance programmes to assess the efficiency of radiation protection and safety programmes. Records are also the written evidence of the correct functioning of maintenance and checking systems. For quality assurance and monitoring compliance with requirements and regulations, records of measurements, evaluations, operations, inventories, calibration and controls should be prepared and kept updated. These should be available to the regulatory authorities, and in some cases, as discussed in Section 7, they are part of the information that the regulatory authority should systematically request from registrants and licensees. Finally, the regulatory authority should set or demand that necessary arrangements be made in order to keep some of these records for long periods of time, although the registrants and licensees may no longer be working, as in the case of personal dosimetry.

6. REPORTS ON INCIDENTS AND ACCIDENTS

The regulatory authorities should give registrants and license holders the responsibility of quickly notifying them in all cases in which a situation requiring protective action might arise or is foreseen to arise, or in any other abnormal situation. In all cases in which an abnormal situation might arise, there should be an investigation to identify the causes and to determine how to prevent a similar situation from happening. Many accidents with ionizing radiation sources are limited to the workplace. This type of event is generally investigated by the users, and the results of the investigation, which must embrace the causes, consequences and corrective measures, should be communicated to the regulatory authority in the shortest possible time. In cases of more severe accidents, generally the regulatory authority, together with other governmental authorities, performs an investigation independent from the one performed by the user. Usually the investigations carried out by the authorities in charge of investigating severe accidents have two aims which are not completely independent from one another: first, to determine the causes, and second, to establish the responsibilities and duties as a result of the consequences.

Considering the features of developing countries in which the application of radiation sources in medical treatments is one of the most widespread practices, it is worth mentioning accidental medical exposures. It shall be recalled that such exposures include:

(1) all therapeutic treatment which has been administered by mistake to a patient or to a tissue, or the incorrect use of a radiopharmaceutical product or dose or dose fractionation that differs considerably from the values prescribed by the physician or that may provoke acute secondary effects;

TABLE III. MINIMAL INFORMATION TO BE SUBMITTED PERIODICALLY BY THE LICENCE HOLDERS TO THE REGULATORY AUTHORITY

1	The facility's reference data.
2	Data on the facility's operating personnel, including the summing up of their radiological control (dosimetry and medical surveillance).
3	Data on sources and radioactive equipment.
4	Data about the verification and control of radiological safety and protection systems and radioactive sources.
5	Incidents and accidents that have taken place during the year, briefly describing when and how they happened, staff involved, received doses, significant data of the consequences and adopted measures.
6	Values surpassing the investigation levels, results of investigation and adopted measures.
7	Results of radiological surveillance of workplaces and the environment.
8	Retrospective assessment of the facility's safety and practice from the information received on abnormal situations in similar facilities.
9	Any other information demanded by specific requisites for granting authorization or any other explanation that is considered to be convenient.

(2) all exposure for diagnostic purposes which is considerably higher than the foreseen exposure or that may result in doses that repeatedly and considerably surpass the established guidance levels;

(3) all equipment failure, error, accident, mishap or other abnormal event which may cause a patient to be exposed to a dose considerably different to the one foreseen.

The regulatory authorities shall establish that the cognizant officials notify them about these events and send them, as soon as possible, a written report detailing the causes of the incident, evaluation of doses, the necessary corrective measures and the measures taken.

In many countries, information on incidents and accidents is not regulated; and if it is, it is not demanded; and if it is demanded, it is not processed and the experiences are not shared with others. Therefore, this valuable source of information to carry out the different safety assessments or analysis is not being efficiently used. Unfortunately, in most cases, only accidents causing a serious impact on human health and on the environment become nationally or internationally known.

This situation is even more critical regarding accidents in medical exposure, a practice that, because of the justification of its introduction, has had little attention given to its optimization. There are thousands of X ray users for diagnostic purposes, and their control is expensive and difficult. There are fewer radiotherapy and nuclear medicine users, and it is perhaps with these practices that the work of the regulatory authorities should begin, considering their potential risks. Regulatory authorities should make the necessary arrangements with sanitary authorities with the aim of establishing the needed procedures for the registration of those practices.

7. PERIODIC REPORTS

Registrants and licence holders should ensure that information on both normal and abnormal operations which is significant for protection or safety be disseminated or supplied, as appropriate, to the regulatory authority and to other interested parties, provided that this has been previously specified by the regulatory authority itself. This information, as shown in Table III, may refer, for example, to the doses associated with the prescribed activities, maintenance data, description of events or corrective measures. This report can generally be elaborated once a year, the holder being required to submit it within the first quarter after the corresponding year of the annual report. The truthfulness and usefulness of this periodic information, which should be sent to the regulatory authority, will depend upon the quality and updating of the records collected and supplied by the registrants and licensees. They have the primary responsibilities for systematically evaluating and taking the corresponding measures according to the results of such evaluations, without having to expect instructions from the regulatory authority.

The holders must always bear in mind that they should conduct investigations as specified by the regulatory authority whenever a value or a working parameter related to protection or safety surpasses the pertinent investigation level or reference level or is not within the boundary limits of the stipulated working regime. This investigation should be conducted as soon as possible; the regulatory authority should be notified and should be sent, within the set period, a brief report on the investigation implemented and the measures taken.

In many countries, the regulatory authorities do not pay attention to this aspect, perhaps because they may be loaded down with other responsibilities. But this information, presented in a concise and systematic way, might facilitate the work of the regulatory authority. It is an essential component of retrospective safety assessment, and it helps to exactly define inspection plans and to give priority to facilities that have greater problems. It is necessary to draw attention here to a potential risk for the regulatory authority. When deciding to demand periodic reports or reports on abnormal situations, the regulatory authority should be prepared to react in some way or other to all kinds of abnormal variation of the essential parameters of the facility, either by participating in the most serious cases, or by an unscheduled inspection, a letter, a phone call, etc. What must not occur is that although the holder reports a variation of the normal, characteristic levels of the facility, the regulatory authority does not take action. This affects the credibility and prestige of the regulatory authority and can lead the holder to attach less importance to the potential situation created, which in the most serious cases might provoke accidents.

In addition to the periodic information, registrants and licensees must notify the regulatory authority about their intention to introduce modifications in any practice or source for which they have been authorized, and should not make any changes of that kind unless special authorization has been granted to them by the regulatory authority. Among these reports we may mention notifications for the definitive closing down of the operating facility; the substitution of sealed radioactive sources; the transfer of radioactive equipment, etc. These notifications or reports should be prepared before implementing the requested operation and are associated to an assessment by the regulatory authority, so as to be able to give an affirmative or negative answer to such a request.

8. ENFORCEMENT AND SANCTIONS

Enforcement actions are taken by the regulatory authority to correct non-compliance with regulatory requirements. A strong and effective enforcement programme is a key component of the regulatory infrastructure for assuring success in meeting regulatory objectives.

When informal instructions are given, for example orally, by an inspector, the instruction should be followed in writing, and a written reply required of the user confirming that corrective action has been accomplished, unless it involves a very minor infraction that can be corrected in the inspector's presence. Communications between the regulatory authority and the users should always be clear, timely, unambiguous and well documented.

Documentation in enforcement actions or sanctions is of vital importance. It should include a description of the infraction made and other conditions that endanger protection and safety; deficiencies or findings encountered during the inspection; sanctions or other measures, to correct unsatisfactory conditions; user's responses to those measures including corrective actions; and the assessment of acceptance or not of the response by the regulatory authority.

In some countries, besides the above mentioned measures, financial sanctions are applied, in some cases to institutions, and in other cases to the responsible individuals.

The regulatory authority should consider and assess any potential and additional effects to the already existing ones due to the detected infraction that may determine the enforcement action or sanction that is to be applied. These corrective measures might provoke a situation with a more negative impact upon the economy and on health and security issues than the benefit that can be gained from the measure itself. An example is the damage to patients that would arise from the closing down of a radiotherapy unit as a result of a sanction by the regulatory authority. Therefore, all the above mentioned factors require a highly professional and honest staff, with high technical capability and expertise, within the regulatory authority. The regulatory authority's staff should be capable of assessing the threat to health and safety of the infraction of regulations and of applying at each time the most suitable measure. Likewise, the personnel should be capable of analysing all the information gathered in this field, both at a national and an international level, to state clearly the enforcement policy established by competent authorities. This should serve as a source for feedback of information on safety assessment practices.

9. SAFETY ASSESSMENT

In order to prevent potential exposures from becoming real exposures and to mitigate the consequences of exposures that may occur, registrants or licensees should constantly concern themselves about the safety of a given scenario. A systematic approach is required to avoid overlooking possible events. A detailed, step by step review of the use of radiation sources is needed. The reviewers should consider and find responses to the potential events in each of the stages: design, construction, operation, permanent closing down, etc.

A safety assessment should include, as stipulated in Ref. [2], a systematic critical analysis of the following:

(1) the nature and magnitude of potential exposures and the likelihood of their occurrence;
(2) the limits and technical conditions for operation of the source;
(3) the ways in which structures, systems, components and procedures related to protection and safety, singly or in combination, lead to potential exposures, and the consequences of such failures;
(4) the ways in which changes in the environment may affect protection or safety;
(5) the ways in which operating procedures related to protection or safety might be erroneous, and the consequences of such errors;
(6) the protection and safety implications of any proposed modifications.

A safety assessment should not be restricted to a prospective analysis before putting the sources into operation; a systematic retrospective assessment is required to prevent potential exposures.

The two most commonly used techniques to assess the level of protection achieved against potential exposures are the following: the first and older technique is referred to as the deterministic assessment method, used for safety assessment in places where accident scenarios have been identified from a review of operational experience. The second and newer technique is referred to as the probabilistic assessment method, used to identify weaknesses that otherwise might have been overlooked, i.e., to discover vulnerabilities for which there is no prior evidence from events. Both the probabilistic and the deterministic methods are subject to limitations and uncertainties. One of the most serious problems for many practices in which ionizing radiation sources are used is that there are too few statistical failure data to allow the assignment of probabilities. Feedback information supplied by designers, registrants and licensees is therefore vital.

On this issue, it is suggested that adequate mechanisms be established in order to obtain the necessary feedback of information between designers, suppliers, registrants and licence holders, the regulatory authority and all those who might need information, on the use, maintenance, operating experience, dismantling and disposal of sources, and on any particular normal or abnormal operating conditions that might be important for the protection of individuals or the safety of the source, doses associated with prescribed activities, description of events and corrective measures.

Whenever an accident occurs during a practice, the prospective safety analysis performed should be reviewed. The regulatory authority should accordingly create the necessary systems to inform the registrants and licensees about the accidents and lessons learned from those practices, both within the country and elsewhere. In addition, the regulatory authority should demand and confirm that registrants or licensees, using the provided information, perform a reassessment of the previously made analysis in order to determine if the new information indicates changes or improvements that need to be made. Such a reassessment may be limited, if necessary, to the circumstances of the accident and to aspects of operation which may be affected.

Unfortunately, countries that are just starting with the implementation of regulatory programmes, and others that have been implementing theirs for several years, do not pay sufficient attention to learning from past experience; only developed countries do this. Although this is difficult to demand and guarantee at the implementation stage, at the operational stage feedback should be obtained on all those aspects which might influence the safety of the practices, and the regulatory authority plays a major role here. In most cases this can be done without making reference to the names of the licensees involved; what really matters is the acquired experience and, later, the requirement by the regulatory authority that the licensees report on the results of the retrospective assessments, especially in those practices involving a higher risk. Such information might be a part of the periodic information that licensees periodically send to the regulatory authority (Table III).

Some of the most serious accidents that have occurred during operations with sources in irradiator facilities or during the making of industrial radiographs have common factors that contribute to the occurrence of an accident, such as non-compliance with monitoring; the violation or blocking of security systems; lack of redundancy or spare equipment; and failure in the source connection systems during operation. Usually designers, manufacturers and suppliers perform an initial safety assessment, but in these cases the users did not check the initial safety assessment to evaluate the potential consequences of the modifications of procedures, equipment or maintenance schemes. For instance, the irradiator accident in Soreq, Israel, was caused by the same initial events and human errors that had previously occurred in El Salvador. The accident that took place in Goiânia, Brazil, with radiotherapy equipment no longer in use, presented very similar features compared to the one that occurred in Juárez, Mexico. All this indicates that authorities do not pay the required attention either to retrospective analysis or to the implementation of modifications based on lessons learned from accidents that have taken place elsewhere, and to the fact that information about such accidents has been widely disseminated could have resulted in a reduction of the number of accidents that have occurred. This past experience should be kept in mind by all countries, but mainly by those that are now beginning to take the first steps in this field, so that it is implemented as a work regulation.

Another important aspect to be considered in the preliminary safety assessment performed are the potential radiation hazards during the decommissioning of the facility. In the case of sealed sources, key considerations should be the amount and location of radioactive sources in the facility as well as unexpected conditions that might arise during its decommissioning. In the case of unsealed sources, special attention should be given to the type and amount of possible contamination.

10. REVALIDATION OF AUTHORIZATIONS

Establishing fixed durations of validity for registrants and licensees is another tool of the regulatory authority to ensure compliance with the requirements and to reassess the safety of the facilities, radioactive sources, equipment, systems, training of the staff, etc. The advantage of demanding revalidation after a predetermined period of time is that it allows an updating of assessments and information. If a record or licence is granted without a deadline, revalidation could be made by means of a periodic review of its status and documentation. However, deadlines force a reassessment. In these circumstances, the review and the documents with the results of the assessment are commonly part of the renewal process, and they are the basis upon which the regulatory authority can make adjustments in the registration or licence, after the assessment of valid requirements, changes in the user's requirements and radiological surveillance measures and deficiencies encountered by the regulatory authority during its inspection programme.

Revalidating registrations and licences is, in addition, a reminder for the users that they have to comply with mandatory regulations. This may be particularly important when inspections are less frequent because of the limited resources of the regulatory authority.

The frequency of revalidation is influenced by various factors, among which are inspection frequency, safety records from different parameters within a practice, the user's stability of operation and the regulatory changes that might affect practices. The validity term of licences in those countries that establish deadlines ranges between 5 and 10 years, depending mainly on the risks from the practices. In my opinion, considering the technological development and demands of radiation protection for Category A practices (Table I), this term should not last longer than 5 years.

11. CONCLUSIONS

The preparation and adoption of legislation and the corresponding regulations regarding radiation protection are the basis for the effective development of a regulatory programme on radiological safety. The infrastructure is completed with a professionally trained and independent regulatory authority. The establishment of a system for notification, registration and licensing, if efficiently used, should allow the registration and control of ionizing radiation sources which are in the country, or that are intended to be introduced into the country. Operational safety analyses and assessments previous to the granting of the corresponding authorizations (registrations and licences) enable not only the assessment of source safety and operation, but the establishment of certain limitations in accordance with the conditions created at the facility.

All this system or programme will no longer fulfil the objectives for which it was created and will lose its effectiveness if an efficient and functional system is not implemented for the verification of compliance with the requirements established by the national legislation in force and by the corresponding authorization granted. Countries having nuclear power programmes, which are aware of the importance that the verification of compliance has for radiological and nuclear safety, have been able to develop to a lesser or a higher degree the different elements which form part of it. Many more obstacles must be removed before these concepts and this work culture can be adopted by countries that do not have nuclear power programmes. Regardless of political issues, radiation protection in these countries competes with many other financial, technological and health needs that overwhelm most of their governments. Unfortunately only in critical situations, and generally only after serious accidents with very harmful effects for health and the environment have occurred, do the infrastructures become aware of these problems and begin to take appropriate measures.

On occasions these sporadic achievements have been practically invalidated when, because of political changes in a country and related to the restructuring of the State apparatus, there have been changes within the regulatory authorities or the resources they had at their disposal have been substantially reduced. These processes generally have resulted in the migration of qualified personnel, with the resulting weakening of regulatory authorities that in many cases were beginning to take their first steps to being acknowledged and gaining authority in the country. Under these conditions of insecurity, and without a clear political will, it is very difficult to guarantee not only notification, registration and the granting of licences, but the verification of compliance with radiation protection requisites.

It is also true that in other countries having some level of development in their infrastructures of radiation protection the different elements here above stated for the verification of compliance of radiation protection are not used in all their scope and possibilities: inspections and auditing; radiological surveillance and monitoring; incident, accident and periodic reports; retrospective assessments; enforcement actions or sanctions; and periodic review of licences and registrations. In situ inspections are mostly given special attention and resources. These inspections, which are occasionally only technical, are often directed at particular equipment and are not entirely aimed at radiological safety in practice, and their results are neither assessed nor systematized.

If the regulatory authorities do not give proper attention to verification of compliance, they will not have efficient regulatory programmes, and the efforts devoted to registration and the granting of licences may be wasted.

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ASSESSMENT OF THE EFFECTIVENESS OF NATIONAL PROGRAMMES FOR THE SAFETY OF SOURCES, INCLUDING DEVELOPMENT OF PERFORMANCE INDICATORS

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Abstract

ASSESSMENT OF THE EFFECTIVENESS OF NATIONAL PROGRAMMES FOR THE SAFETY OF SOURCES, INCLUDING DEVELOPMENT OF PERFORMANCE INDICATORS.

Most developed and emerging nations have implemented national programmes containing key elements such as regulations, authorization, inspection and enforcement processes designed to protect public health and safety in connection with the uses of radiation sources. These programmes have generally been successful. However, the degree to which these programmes have undergone an assessment of their effectiveness as determined through the use of logical and measurable performance indicators is not as clear. The International Atomic Energy Agency and the US Nuclear Regulatory Commission have taken steps to provide guidance or to implement programmes designed to employ performance indicators relative to licensees' radiation safety programmes and to the conduct of national regulatory programmes. Regulatory executives are increasingly under pressure to manage their programmes to achieve desired outcomes cost effectively. While substantial progress has been made in developing systematic approaches to aid regulatory authority executives in assessing their programmes through the use of peer reviews and objective performance indicators, much work remains to be done in this arena. Assessment of national programmes through the use of performance indicators should receive increasing attention in the future. Focused efforts to share findings and disseminate information to all regulatory authorities responsible for protecting public health and safety relative to the uses of radiation safety are warranted.

1. INTRODUCTION

Throughout the world, in medicine, industry, research and teaching, the use of radiation sources and radioactive materials is widespread and generally increasing. The need to ensure the safety and control of these materials is well established and well understood. The majority of developed and emerging nations have established comprehensive national programmes designed to ensure proper control of radiation sources and to ensure the prevention of accidents and the mitigation of consequences when such accidents take place. As a result, the overall safety record for utilizing these materials has generally been satisfactory. However, there have been some serious accidents, including fatalities. Regulatory authorities therefore persist in their efforts to improve their radiation safety programmes, with an increasing emphasis upon assessing the effectiveness of these programmes.

During the past fifty years, a great deal of effort has been expended by governments, regulatory authorities, academia, international organizations and professional societies to define the critical components of radiation safety programmes and the essential elements of national radiation regulatory programmes designed to protect public health and safety in connection with the use of radioactive materials. As a result, a substantial amount of literature, professional presentations and carefully developed regulatory programmes have emerged, most of which have served to improve the public's confidence in the use of radioactive materials. However, the degree to which regulatory authorities have applied logical or measurable approaches to the use of performance indicators in assessing the success of their regulatory programmes is not obvious within the literature. This paper provides a brief overview of efforts to develop safety criteria, to improve and increase the accountability of radiation sources and to establish criteria for national regulatory programmes and methods to identify performance indicators designed to evaluate the effectiveness of regulatory efforts. The listing is certainly not all-inclusive, and it attempts to identify only those documents or regulatory activities that seem readily to lend themselves to the application of performance indicators for national programmes or that specifically address performance indicators within an overall process. The paper places an emphasis on activities of the International Atomic Energy Agency (IAEA) and the US Nuclear Regulatory Commission (NRC). This emphasis results from the scarcity of literature on the relation between the development of radiation safety regulatory programmes, especially national programmes, and efforts to assess their effectiveness. It is assumed that a number of other organizations or countries are focusing attention on this important issue. In time, additional information will therefore emerge and should be compiled so as to allow access and use by regulatory authorities working towards improving the overall effectiveness of their programmes.

2. THE INTERNATIONAL ATOMIC ENERGY AGENCY

The IAEA has played a major role in developing radiation safety standards, developing critical elements for radiation safety programmes, developing critical elements for national programmes designed to protect public health and safety, and investigating major accidents and disseminating information about them.

The top level publication in the IAEA Safety Series is Radiation Protection and the Safety of Radiation Sources [1]. Requirements for the implementation of Ref. [1] are provided in International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources [2] (the BSS). Both Refs [1] and [2] are based on the recommendations of the International Commission on Radiological Protection (ICRP) as given in its Publication 60 [3].

The BSS establish basic requirements for protecting human beings against the risks associated with both external and internal exposure to ionizing radiation and for ensuring the safety of all types of radiation source. They are limited to specifying basic requirements of radiation protection and safety, with some guidance on how to apply them. The BSS complement standards already developed for large and complex radiation sources, such as nuclear reactors and radioactive waste management facilities. For complex sources, more specific standards, such as those issued by the IAEA, are typically needed to achieve acceptable levels of safety. As these more specific standards are generally consistent with the BSS, in complying with them, such more complex installations will also generally comply with the BSS.

Within the Safety Series publications, the BSS are supported by a number of Safety Guides, which provide guidance on fulfilling the requirements of the BSS. Each Safety Guide addresses a separate topic area, with necessary overlap on important issues. The primary audience of the Safety Guides are regulatory authorities, though the Guides may be of use to any organization or institution utilizing ionizing radiation. The Safety Guides are supported by Safety Reports, which focus on technical information typically common to a number of practices but which may be specific to a given practice. The primary audience of the Safety Reports is licensees or registrants for the use of radiation sources, but the Safety Reports may also be of interest to regulatory authorities.

The BSS, Safety Guides and Safety Reports emphasize key operational programme elements such as basic obligations, administrative requirements, management requirements, radiation protection requirements and verification of safety through inspection and monitoring processes. These documents do not address performance indicators designed to test the effectiveness of the regulatory programmes, but rather focus on identifying and explaining key elements of radiation safety programmes and on providing methodologies for compliance with these elements. In terms of performance, the apparent underlying thinking is that if all elements of the programme are satisfactorily addressed by licensees, registrants or regulatory authorities, then the resulting programme will achieve satisfactory and acceptable performance. Most countries have adopted the BSS or have developed an essentially equivalent set of criteria as their standards for radiation protection. However, the degree to which they have successfully implemented these standards is not readily apparent. It may be valid to assume that the low frequency of occurrence of serious radiological accidents, especially of fatalities, is proof of adequate implementation. However, such logic is not conducive to incremental improvements in regulatory programmes. Such improvements may prevent an incident which would have occurred had the improvements not been made.

Three publications, more specifically addressing the efficiency of regulatory programmes, are in preparation by the IAEA and are described in Sections 2.1–2.3 below.

2.1. Organization and Implementation of a National Regulatory Infrastructure Governing Protection Against Ionizing Radiation and the Safety of Radiation Sources

The publication under this title [4] is primarily intended to assist Member States needing to establish or improve their national radiation protection infrastructure in order to implement the basic requirements of the BSS. Member States receiving assistance in applications of nuclear energy or radiation technology from the Food and Agriculture Organization of the United Nations (FAO), the IAEA, the International Labour Organisation (ILO), the Pan American Health Organization (PAHO) or the World Health Organization (WHO) are expected, as a condition of the applicable agreements, to implement the BSS or equivalent radiation protection and safety standards as may be appropriate for their respective situations. This requirement can only be ensured by developing and implementing an adequate radiation protection infrastructure [4].

Reference [4] addresses the elements of a radiation protection and safety infrastructure at the national level needed to apply the BSS to radiation sources such as those used in industry, medicine and research. The term 'infrastructure' refers to the underlying systems and organizations in place to achieve the regulatory agency's mission. As radiation technologies have emerged or advanced, and as radiation protection has correspondingly become more complex, an adequate radiation protection and safety infrastructure has become ever more necessary. It is this system, rather than individual specialists, which provides the depth of protection necessary to protect the public constituency of the regulatory authorities. The BSS can only be implemented through an effective radiation protection infrastructure that includes adequate laws and regulations, an efficient regulatory system, supporting experts and services and a 'safety culture' shared by all those with responsibilities for protection. The infrastructure requires clear lines of authority and responsibility and adequate resources to operate the system at all levels.

Obviously, this process will vary greatly amongst countries, and Ref. [4] provides assistance for all nations, regardless of the current stage of development of the radiation protection programme. In addition to providing advice on the essential elements of a radiation protection and safety infrastructure at the governmental level, a further objective of Ref. [4] is to provide advice on the optimization of resource utilization within the infrastructure. As a result, advice is provided on approaches to the organization and operation of a national radiation protection programme in view of factors that have a bearing on optimization. This emphasis on optimization of programme elements and this focus on resources provide the key elements for a regulatory authority to consider when establishing performance indicators. In other words, key programme elements such as licensing, event response and inspection are ideal candidates for evaluation utilizing performance indicators.

Section 3.29 of Ref. [4] addresses performance indicators as they relate to licensee or registrant performance. The section points out that in addition to conducting inspections to determine compliance with all applicable regulatory requirements, an inspection should provide a general sense of the 'safety' of operations within the licensee's or registrant's programme. Performance indicators denote specific sets of circumstances that aid in identifying the potential for degraded safety performance. Performance indicators can be utilized as a basis for informing source users of the need to improve and also as a basis for establishing the frequency of inspection of any particular source user.

Section 6.0 of Ref. [4] contains a useful but limited discussion of the assessment of the effectiveness of national regulatory programmes. The discussion focuses upon the establishment of procedures relative to quality assurance and the analysis of programme data necessary to ensure an effective regulatory programme for radiation protection and the safety of sources. The document does not provide any further information on this topic, although the need for such information has been recognized by the IAEA. As a result, another publication (described in Section 2.3) is in preparation. It will set forth an approach for peer review of the regulatory infrastructure utilizing performance indicators.

2.2. Safety Assessment Plans for Authorization and Inspection of Radiation Sources

The publication under this title [5] is intended to assist regulatory authorities and those involved with the assessments and inspections covering radiation protection and safety of radiation sources. The document's primary objective is to enhance the overall efficacy, quality and efficiency of the regulatory process. The document provides advice on good practice in administrative procedures for the regulatory process relative to the preparation of applications, the granting of authorizations, the conduct of inspections and enforcement. It also provides guidance on the development and use of standard safety assessment plans for authorization (licensing) and inspections. These plans are to be used with more comprehensive guidance relative to specific technical options. As a result, this publication provides advice on a systematic approach to evaluations of protection and safety, with other IAEA Guides assisting in distinguishing the acceptable from the unacceptable.

Section 3.5 of Ref. [5] addresses performance indicators as they relate to licensee or registrant performance. As in Ref. [4], the document focuses on a specific set of circumstances that aid in the identification of radiation source users with the potential for degraded safety performance. In this sense, they are negative performance indicators which are an early subjective warning of degraded performance and are mainly management related. A list of performance indicators for radiation source users is given in Annex X of Ref. [5].

The document does not address performance indicators relative to the processes to be used by the regulatory authorities in issuing authorizations, conducting inspections or addressing enforcement issues. However, all of these processes could be subject to review through performance indicators. For example, managers of regulatory programmes could review their programmes to determine the extent to which all of the criteria and standard checklists given in the annexes of the document are followed by their regulatory staff. An alternative would be that, in those instances where inspectors identify significant problems within the licensee's programme, a retrospective comparative analysis could be conducted to determine how much of the problem might have been discoverable during the licensing process, or, if the issue was identified by a reviewer, whether it was brought to successful closure prior to issuance of the authorization to possess and utilize radioactive materials.

2.3. Assessment by Peer Review of the Effectiveness of a Regulatory Programme for Protection Against Ionizing Radiation and for the Safety of Radiation Sources

The publication under this title [6], still in the preliminary draft stage, will provide guidance on the conduct of an independent peer review of the effectiveness of a regulatory programme, which will serve as the basis for recommendations designed to strengthen the programme. The document will address not only those aspects of a radiation programme infrastructure but also those ancillary activities, such as the provision of dosimetry services, that directly affect the ability of a regulatory authority to discharge its responsibilities.

Reference [6] points out that the BSS are based on the presumption that a national infrastructure is in place which enables the Government to discharge its responsibilities for radiation protection and safety. Essential components of the national radiation protection infrastructure are legislation and regulations, a regulatory authority empowered to authorize and inspect regulated activities and to enforce the legislation and regulations, sufficient resources and adequate numbers of trained personnel. A national radiation protection infrastructure includes all persons, organizations, qualified experts, systems, documents, facilities and equipment that are in whole or in part dedicated to protection and safety. The requirements of the BSS apply only to those who possess and use radiation sources, but the managerial issues addressed by the BSS, particularly 'safety culture' and quality assurance, are also relevant to the overall effectiveness of the regulatory programme infrastructure designed to oversee the users of radiation sources and materials.

Reference [6] will point out that the purpose of an independent peer review is to examine the various components and activities of a regulatory programme, as they are established, organized and implemented by the regulatory authority, in order to assess whether they are performing their intended functions, to identify areas where adjustments might be made to optimize performance and to make recommendations for optimizing performance. The publication will point out that peer review is necessarily qualitative and that it is therefore important that such reviews be conducted by persons who, collectively, have a good understanding of and experience with the main components of a regulatory programme and the functions of a regulatory authority.

Reference [6] will stress the importance of standardization of the review process through the use of questionnaires addressing the key areas of a regulatory programme that assess its effectiveness. The review should address those areas of a country's radiation protection infrastructure that bear directly on its effectiveness, even though some of those areas may not be a part of an actual programme. Reference [6] will distinguish between the two components. The following areas are identified as subject to peer review:

(1) legislation/regulations,
(2) notification
(3) authorization (licensing/regulation),
(4) inspection,
(5) enforcement,
(6) emergency response,
(7) incident/accident investigation and follow-up,
(8) availability of technical services,
(9) interagency co-ordination and co-operation,
(10) staffing and training of regulatory staff,
(11) facilities and equipment (including operating budget of the regulatory authority),
(12) information dissemination.

In addition to identifying these major areas for review, Ref. [6] will provide checklists for use in peer reviews. The checklists will serve as an aid in collecting data and in better assuring the completeness of the review and standardization of report development. Reference [6] will address the use of performance indicators through the use of standardized questions designed to measure the effectiveness of the regulatory programmes examined. The answers to these questions are envisioned as relevant performance indicators. It is recognized that some parts of the regulatory programme will be deemed to be wholly effective and therefore satisfactory, while others will benefit from improvements of either a major or minor nature. The objective of the peer review is to identify those areas of the regulatory programme warranting efforts towards improvement. To facilitate this process, peer review recommendations would be prioritized, with greater importance given to those aspects of the programme which may cause significant problems with the regulatory programme and thus require the application of often limited resources. The proposed scheme for such prioritization is as follows:

(1) ESSENTIAL, meaning that a delay in implementation represents a substantial and immediate hazard to health and/or that it concerns a serious deficiency in the regulatory programme.
(2) IMPORTANT, meaning that a delay represents a significant hazard and/or that the recommendation concerns a significant deficiency in the regulatory programme.
(3) ADVISED, meaning that the recommendation identifies a relatively minor deficiency in the regulatory programme.

Reference [6], when completed, promises to be one of most definitive efforts to date, by the IAEA, to identify criteria and methods for the review of regulatory programmes using performance indicators. The peer review approach detailed in Ref. [6] has a number of similarities to the Integrated Materials Performance Evaluation Program (IMPEP) [7] currently utilized by the NRC and Agreement States[1] [8] in the USA. The IMPEP methodology has been tested and shown to work, and it has been generally well received by the affected regulatory authorities as a means of constructive peer review focusing upon critical programme elements. While this process has been generally applied to large scale regulatory programmes, its principles could also be applied to smaller programmes such as those in emerging nations. The IMPEP is discussed in Section 4 of this paper.

It should be noted that Ref. [6] is still under development and therefore has not yet undergone review and approval by the IAEA prior to being published. As a result, the contents are subject to change, but the draft version is nonetheless thought

[1] NRC Agreement State: An Agreement State is a State that has signed an agreement with the NRC pursuant to Section 274 of the Atomic Energy Act [8] allowing the State to regulate the use of radioactive material, other than use in reactor facilities, within the State.

provoking and useful relative to the application of performance indicators for evaluating the effectiveness of regulatory programmes designed to protect public health and safety relative to the use of radiation sources.

3. IMPROVING CONTROL OF GENERALLY LICENSED DEVICES IN THE USA

In the United States of America, much concern has been expressed by the metal recycling industries about the appearance of unwanted radioactive materials, principally radioactive sources and devices containing radioactive materials, in metal scrap. In the USA there are in use about two million radioactive sources and devices which contain radioactive materials regulated under the Atomic Energy Act, as amended [8]. Each year, about 200 of these are reported lost, stolen or abandoned. As a result, radioactive sources enter the public domain in an uncontrolled manner and become potential sources of radiation and contamination. The US steel industry, for example, has been put at risk as a result of radioactive sources becoming mixed with ferrous scrap metal intended for recycling. On 18 occasions, radioactive sources have been accidentally melted by US steel mills, resulting in radiation exposures of mill workers and contamination of the mill and its products and by-products [9].

The NRC and its staff have been concerned for more than two decades about general licensees maintaining control and accountability of devices. Throughout this period, there was substantial communication between the staff and the NRC as to the nature and scope of the problem. Several regulatory initiatives proposed by the staff in the early 1990s did not materialize, primarily because of resource constraints given the large staff effort necessary to account for and establish control of the large number of devices distributed under the general licence approach. In 1994, the NRC requested that the staff continue to explore the problem of accidental melting of licensed devices and that it develop recommendations for future staff actions in this area [10]. The staff proposed the formation of a joint NRC–Agreement State Working Group (WG) to evaluate the problem and propose solutions and indicated that the formation of the WG was necessary to address the concerns from a national perspective, to allow for broad Agreement State input and to reflect their experience, given that several Agreement States had already implemented programmes to improve the control and accountability of such devices. In June 1995, the NRC approved the staff's recommendation and provided guidance on how to proceed.

In October 1996, the NRC staff sent the NRC the final report submitted by the WG and requested permission to develop an action plan to address the numerous recommendations made in the report. The report contained a number of key recommendations, dealing with inadequate regulatory oversight, inadequate control over and accountability for devices by users and improper disposal of devices and orphaned devices. The NRC staff and the WG identified a number of issues to be addressed by the WG, including NRC and Agreement State compatibility, cost and fee considerations and radiation exposure savings; device design; changes affecting all devices or only newly acquired devices, device disposal, device identification and devices requiring increased oversight; generally licensed versus specifically licensed devices, identification of current users and devices, and possible restrictions on portable devices and on the storage of devices.

In November 1997 the staff sent the NRC a recommendation to develop and implement a registration programme for certain 10 CFR 31.5 general licensees[2] [11]. The recommended programme included rule-making to establish a regulatory basis for a registration programme, an automated registration system and related policy and guidance documents, implementation of the registration programme and follow-up activities. In April 1998, the NRC directed the staff to implement a registration and follow-up programme for the generally licensed sources and devices identified by the WG, to apply a schedule of fees to be charged these general licensees and to incorporate requirements for permanent labelling of sources and devices [12].

Implementation of the registration programme will necessarily involve the development of a fully automated registration system, which will be a large scale and significant information technology (IT) project. Within the USA, the Clinger–Cohen Act of 1996 [13] required Federal agencies to develop a capital planning and investment control (CPIC) process for IT investments and to apply performance and results based management to such projects. The CPIC process places great emphasis on the development and explicit clarification of the business needs for the IT system under development and requires that the project move forward only once the business need is clearly established and justified. Once this 'business' case for a system has been developed and the project is approved, development of the IT system must be carried out in accordance with the system development life-cycle (SCDLC) methodology developed by the NRC Office of the Chief Information Officer [14].

Almost all regulatory authority managers throughout the world are required to conduct adequate programmes designed to protect public health and safety, typically with inadequate or marginal resources. In this era of 'business process re-engineering', organizational cost cutting and trimming the size of governmental functions (particularly regulatory functions, in the USA), these managers face new challenges. Increasingly, they are being required to manage their regulatory programmes as if they were executives responsible for a business. Regulated entities are

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[2] 10 CFR 31.5 general licensee: Any person who acquires, receives, possesses, uses or transfers by-product material in a measuring, gauging, or controlling device pursuant to the general licence issued in accordance with Ref. [11].

concerned about the fees assessed them by regulatory bodies, and they tend to voice their concerns and to seek relief from the legislative bodies responsible for the oversight of regulatory programmes, including those dealing with radiation sources. None of this is inappropriate, and in fact it is a part of the democratic representative process, but it does require regulatory managers to reassess how they do business. For example, the type of justification required for IT systems under the CPIC process could be viewed as requiring managers to consider performance indicators before beginning such projects. In developing the 'business case' for these systems, managers must fully evaluate and understand their needs, assess alternatives and make their case through a requirements analysis. Once the project is approved, they must proceed with development of the project in a certain manner which carries built-in accountability for successful completion of the project on schedule and within budget. Excessive cost overruns and delays will no longer be tolerated; in fact, cost variances greater than 5% require certain actions and cost variances greater than 10% require reporting to the US Congress [14].

The extent to which regulatory authority managers in other countries will be subjected to similar requirements remains to be seen. Certainly, they can expect to find the management of their programmes under increasing scrutiny, as governments seek ways to husband scarce resources and increasingly expect their regulatory managers not only to address technical issues designed to protect the public from radiation sources but also to manage their programmes in a cost effective fashion. As a result, regulatory managers will need to rethink the concept of 'performance indicators' in the sense that they apply not only to the outcome of their regulatory efforts but also to how they manage their programmes in achieving those outcomes. The general licence registration programme under development by the NRC will ultimately prove extremely useful in improving the accountability of generally licensed devices. Similarly, the automated registration system will be an effective means for processing the registration of generally licensed devices and for facilitating the necessary follow-up regulatory actions such as inspections. The challenging issue for the regulatory managers involved with the project will be the application of performance indicators as they justify and manage the development of the IT system to support the regulatory process directed by the NRC. Increasingly, regulatory authority managers will need to include this function as they carry out their responsibilities and interface with their agency directors, governmental leaders and legislative bodies.

4. THE INTEGRATED MATERIALS PERFORMANCE EVALUATION PROGRAM

The Integrated Materials Performance Evaluation Program [7] was developed, in part, in response to an April 1993 report prepared by the US General Accounting

Office (GAO) entitled Better Criteria and Data Would Help Ensure Safety of Nuclear Material [15]. Under the approaches in use at that time, GAO found that it would be difficult to ensure that a uniform level of protection of public health and safety was being provided throughout the USA. The GAO recommended that, with respect to the NRC Regional[3] [16] and Agreement State materials programmes, "...the Chairman, NRC, establish (1) common performance indicators in order to obtain comparable information to evaluate the effectiveness of both [the Agreement States and NRC regional materials] programmes in meeting NRC's goal..." Later that year, the NRC staff presented to the Commission its plan and schedule to develop a programme employing such indicators [17].

In 1994, following substantial interaction with the Agreement States, the NRC staff documented the IMPEP programme in the form of a proposed management directive using common performance indicators in the review of NRC Regional and Agreement State materials programmes. The five proposed common performance indicators were [17]:

(1) status of the materials inspection programme,
(2) technical staffing and training,
(3) technical quality of licensing actions,
(4) technical quality of inspections,
(5) response to incidents and allegations.

The staff also informed the NRC of its plan to implement the directive on a pilot basis in the NRC Regions and in the Agreement States. In March 1994, the NRC approved the staff's plan, noting that the information gathered by the staff "...should be used in reformulating the draft common performance indicators in response to the GAO recommendations" [15]. The NRC also directed that under the pilot programme, the review of Agreement States should be done under the existing 1992 Policy Statement [18] and procedures for determining adequacy and compatibility and that the collection of information on common performance indicators should be done in addition to the normal review process for Agreement State programmes [17].

During 1995, the NRC staff evaluated the pilot programme and concluded that the IMPEP approach was viable. The common performance indicators were considered effective in evaluating a materials licensing and inspection programme and were sufficiently broad to be applicable for both NRC Regional and Agreement State

[3] NRC Regions: NRC's Regional Offices conduct inspection, enforcement, investigation, licensing and emergency response programmes for nuclear reactors, fuel facilities and material licensees within regional boundaries drawn by the headquarters offices [16].

reviews. The use of an interdisciplinary team from the Office of Nuclear Material Safety and Safeguards (NMSS), Office of State Programs (OSP) and the Regions under the IMPEP process was considered to be particularly effective. Other aspects of the pilot programme, including the issuance of a draft report for comment, the use of a five member Management Review Board (MRB) and Regional and Agreement State management participation in MRB meetings, provided greater openness, participation and management involvement in the review process [17]. In addition to these key points, the NRC staff also recommended implementation of IMPEP on an interim basis in the Regions and Agreement States using the five common performance indicators listed above, that Agreement State representatives be a part of the review teams and that non-voting Agreement State liaison to the MRB be appointed. Finally, the staff recommended that, as appropriate, certain programme areas that are not part of the NRC Regional and Agreement State programme (such as licensing of low level radioactive waste disposal or approvals of sealed sources and devices) be evaluated using non-common indicators. In June 1995 the Commission approved the staff's recommendations [17].

The NRC staff issued Management Directive 5.6, Integrated Materials Performance Evaluation Program (IMPEP) [7], in September 1995, outlining the responsibilities, authorities, review process and review criteria of the programme. All aspects of the staff's proposal for involving Agreement States in the review process and in participation on the MRB were satisfactorily brought to closure, and an initial cadre of 36 IMPEP team members was established. During fiscal year 1996, the cadre conducted nine reviews under IMPEP. These reviews included two NRC Regions and seven Agreement States. The performance of both NRC Regions was found to be 'satisfactory' with respect to all common and non-common performance indicators and therefore adequate to protect public health and safety. In five of the seven Agreement State reviews, the programmes were found adequate and compatible. The other two reviews resulted in findings ranging from 'Satisfactory' to 'Satisfactory, with Recommendations for Improvement' to 'Unsatisfactory'. These findings resulted in the development of appropriate corrective action plans by the affected State regulatory entities and/or in continuing scrutiny and review by the NRC. The IMPEP process continues, with the majority of findings being 'Satisfactory'. In those cases of less than 'Satisfactory' findings, corrective actions or other appropriate responses have been implemented.

Management Directive 5.6 was revised in November 1997 to include the NRC's final Policy Statement on Adequacy and Compatibility of Agreement States Programs and was approved by the NRC in June 1997. The Directive sets forth a description of the programme, including authority and responsibilities for the various aspects of the programme.

Part II of Handbook 5.6, which accompanies the Directive [7], describes the performance indicators (both common and non-common). Part III addresses the evaluation criteria including detailed descriptions of what constitutes ratings of 'Satisfactory', 'Satisfactory With Recommendations for Improvement', 'Unsatisfactory' and 'Category N', which addresses special conditions warranting a withholding of a rating. Part IV addresses programmatic assessment. It points out that the MRB will make the overall assessment of each NRC Region's or Agreement State's programme on the basis of the proposed final report and recommendations prepared by the team that conducted the review of that Region or State, including any unique circumstances. For NRC Regions, the MRB will only assess the adequacy of the programme to protect public health and safety, but findings for Agreements States will also address compatibility with NRC regulations [7].

The NRC Regions and Agreement States are currently being evaluated with respect to their ability to conduct effective materials safety programmes, using both the common and non-common indicators. The evaluation process utilizes an experienced cadre of investigators and employs the evaluation criteria set forth in Handbook 5.6. The evaluation criteria do not represent an exhaustive list of the factors that may be relevant in determining performance, because there may be additional considerations about a particular aspect of the regulatory programme which warrants atypical consideration. The evaluation criteria are designed to be objective and measurable. For example, under the category of Status of Materials Inspection Program, which is designed to ensure that periodic inspections of licensed operations are conducted, an NRC Region must satisfactorily address the following in order to achieve a rating of 'Satisfactory' [7]:

(1) Core licensees (those with inspection frequencies of three years or less) are inspected at regular intervals in accordance with frequencies prescribed in the NRC manual chapter.
(2) Deviations from these schedules are normally co-ordinated between working staff and management. Deviations consider the risk of licensee operation, past licensee performance and the need to temporarily defer the inspection to address more urgent or critical priorities.
(3) There is a plan to reschedule any missed or deferred inspections or a basis established for not rescheduling.
(4) Inspections of new licensees are generally conducted within six months of licence approval or in accordance with the NRC inspection manual chapter for those new licensees not possessing licensed material.
(5) A large majority of the inspection findings are communicated to licensees in a timely manner (30 calendar days as specified in the NRC inspection manual chapter).

By contrast, the following deviations will result in a finding of 'Satisfactory With Recommendations for Improvement':

(1) More than 10 per cent of the core licensees are inspected at intervals that exceed the NRC inspection manual chapter.
(2) Inspections of new licensees are frequently not conducted within 6 months of licence approval.
(3) Many of the inspection findings are delayed or are not communicated to licensees within 30 days.

The following deviations will result in a finding of 'Unsatisfactory':

(1) More than 25 per cent of the core licensees are inspected at intervals that exceed the NRC inspection manual chapter.
(2) Inspections of new licensees are frequently delayed, as are the inspection findings.

Implementation of the IMPEP has been generally well received by the NRC and by Agreement States' staff and management. The programme has proven itself useful for assessing the key components of regulatory programmes using common indicators in general and non-common indicators for unique programme elements. A number of IMPEP attributes contribute to its effectiveness in ensuring an accurate assessment of NRC Regional and Agreement State materials programme adequacy to assure public health and safety. First, the five common indicators are directly related to programme adequacy, and in-depth, root-cause analysis of concerns associated with an indicator can quickly lead to programme improvements when necessary. Second, the team approach provides sufficient resources to review each of the indicators in detail. Moreover, the differing backgrounds, work experience and technical expertise of team members provide a range of review insights that aids in the identification of issues and their assessment. Third, personnel from NMSS, OSP, Regions and Agreement States who have worked together on programme reviews have gained valuable insight into each other's programmes. As a result, a giant step has been taken in ensuring, nationwide, a consistent level of protection of the public health and safety in the use of radioactive materials and in assuring that Agreement State programmes are compatible with the NRC's programme.

The IMPEP is perhaps the most comprehensive and successful application to date of performance indicators to evaluate the critical components of a national programme to ensure the safe use of radiation sources. It will be interesting to monitor its success in the future and to compare its use and results with those of States opting to develop the process to be proposed by the IAEA in Ref. [6], discussed in Section 2.3. A comparative analysis, once an adequate amount of operational experience with both approaches has been gained (in perhaps 3–5 years), would appear to be of value.

5. USE OF PERFORMANCE INDICATORS WITHIN MANAGEMENT OPERATING PLANS

In recent years, an understanding has emerged that the US Federal Government needs to be run in a more businesslike manner than in the past. As companies are accountable to shareholders, so the Federal Government is accountable to taxpayers, and taxpayers are demanding as never before that the funds they invest in their government be managed and spent responsibly. As a result of this sentiment, the US Congress has passed several major pieces of legislation which have markedly affected the way in which the Federal Government, including the NRC, conducts business. The Chief Financial Officers (CFO) Act of 1990 [19] provided for chief financial officer positions in 24 major agencies and required annual reports on the financial condition of government entities and the status of management controls. The Information Technology Management Reform Act of 1996 [20] requires, among other things, that agencies set goals, measure performance and report on progress in improving the efficiency and effectiveness of operations through the use of information technology. The Government Performance and Results Act of 1993 (GPRA) [21] required Federal agencies to provide for the establishment of strategic planning and performance measurement in their operations. The GPRA required agencies to develop strategic plans covering a period of at least five years and to submit them to Congress and the Office of Management and Budget [22].

Implementation of the GPRA required agencies to develop a strategic plan which includes a comprehensive mission statement based on the agency's statutory requirements, a set of outcome related strategic goals and a description of how the agency intends to achieve these goals. The mission statement and strategic plan are to be closely interwoven with a performance plan and performance reports, and the budget is to be performance oriented and directly linked to the strategic plan. Implementation of the GPRA caused Federal executives to ask themselves a number of key questions [22]: What is our mission? What are our goals and how will we achieve them? How can we measure our performance? How will we use that information to make improvements? The GPRA forces a shift in the focus of Federal agencies, away from such traditional concerns as staffing activity levels and towards a single overriding issue: results.

During 1995, the NRC, under the direction of S.A. Jackson, initiated a Strategic Assessment and Rebaselining effort [23]. This was done, in part, to satisfy the requirements of the GPRA. The initiative was designed to provide a sound foundation for the NRC's direction and decision making for the rest of this decade and into the next. The initiative had four phases: Phase I, Strategic Assessment; Phase II, Rebaselining and Development of a Decision Paper; Phase III, Production of a Strategic Plan; and Phase IV, Implementation.

All major offices and their operating units within the NRC are required to have an Operating Plan (OP) approved by the Executive Director of Operations. As part of Phase IV, Implementation, those OPs were modified in 1996–1998 to clearly link operational line items such as the conduct of inspections or licensing actions to key components of the NRC Strategic Plan. As a result, managers are better able to understand whether their programmes are achieving the agency's objectives and how they link to the overall strategic plan. Because a key component of the strategic plan required by the GPRA is a focus on outcome, OP and budget reviews now focus not only on the number of inspections conducted or licences issued within budgetary constraints, but also on the outcome of those efforts as demonstrated through the use of 'metrics' (measurable quantities). For example, under the category of licensing actions and sealed source/device reviews, the metrics include the following [24]:

(1) *Quantity:* Budgeted number of completions. The number completed depends on the number received. Actual completions are tracked quarterly, with variances being identified and addressed.
(2) *Quality:* Technically accurate, complete, inspectible. Measured every two years via IMPEP.
(3) *Timeliness:* 90 day goal for new applications and amendments, 180 day goal for renewals and sealed source/device reviews.
(4) *Efficiency:* Budgeted labour rates are 0.009 FTE for most new applications, 0.003 FTE for amendments, 0.021 FTE for renewals.
(5) *Effectiveness:* No failures against materials programme output measures are attributable to licensing action deficiencies.

Implementation of the GPRA and the NRC Strategic Assessment and Rebaselining initiative resulted in substantial changes in the way in which agency executives manage their programmes. One of the key components in this change has been the use of performance indicators in the form of metrics designed to evaluate the outcome of actions. In time, as required by these two major directives, managers will report on those outcomes and will make modifications to improve their programmes and increase accountability. More and more, they will be asked whether their programmes are meeting the intended objectives. The focus of their efforts will be outcomes, customer satisfaction, quality and measures used to manage progress. The use of performance indicators in the form of metrics will play a major role in assisting the NRC and other Federal executives in accomplishing their mission. The degree to which this type of overall governmental process or strategic planning approach evolves in other States may become clear during the next several years. It does seem safe to assume that all regulatory authority managers will increasingly be asked to account for their programmes, with an emphasis on outcomes. Performance indicators, such as the metrics now included within NRC OPs, may be utilized to assist with this obligation.

6. CONCLUSIONS

A number of publications have been created by the IAEA, the NRC and other governmental regulatory agencies to help regulatory authorities conduct viable national programmes designed to protect public health and safety relative to the use of radiation sources. Ample guidance exists to assist their licensees in establishing and maintaining programmes resulting in the safe use of radiation sources by workers. The radiation industry's record generally supports this conclusion, certainly in terms of the low number of fatalities or typical exposures to workers or to members of the public arising from licensed activities. Despite this success, regulatory authorities continue to seek ways to improve their regulatory programmes, and this effort is made more difficult in today's budget conscious marketplace. Increasingly, regulatory managers are expected to find ways to maintain or improve their programmes with decreasing resources and with greater scrutiny from those charged with overseeing their programmes. Unfortunately, there is not yet much information to assist them in developing processes to assess the effectiveness of their national programmes.

Improvement of the effectiveness of national regulatory programmes will require that responsible managers seek innovative processes and that they increasingly subject their programmes to peer review. The review process should utilize informed teams employing standardized review criteria which have been developed through co-operative interaction with other regulators. In the final analysis, all regulatory authorities stand to gain from this process and should welcome the opportunity to participate in it. The IAEA, through the development of Ref. [6] (Section 2.3), will help Member States or other States improve their national regulatory programmes. The NRC and its Agreement States have co-operatively developed and implemented a very successful programme (IMPEP) employing performance indicators in a subjective manner. Other States may want to consider utilizing this or a similar programme to assist them in their efforts to improve their national regulatory programmes. The NRC has included performance indicators in its operating plans for programmatic offices responsible for the safe use of radiation sources. The performance indicators focus upon metrics designed to determine the outcome of regulatory programmes and to improve the agency's capacity to explain or justify its programme to those within the legislative process responsible to the public for the oversight of the agency.

Regulatory authorities and professional organizations involved with the protection of public health and safety relative to the use of radiation sources increasingly appear to be aware of the need to factor these concerns into the assessment of the effectiveness of their programmes. However, much work remains to be done in this area, and it is an area needing greater sharing of experiences and publication of literature that will serve to assist all developed and emerging States as they seek to assess and improve their regulatory programmes.

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SUMMARY OF DISCUSSION

Technical Session 6

Chairpersons: **E.C.S. Amaral** (Brazil)
Z. Pan (China)

Rapporteurs: **L. Camper** (United States of America)
L.A. Jova Sed (Cuba)

E.C.S. AMARAL (Brazil) *(Chairperson)*: In his presentation, L.A. Jova Sed spoke of basing inspection frequency on the risk associated with the practice in question. Should inspection frequency be based on that risk or on the doses received by individual workers?

R.E. CUNNINGHAM (United States of America): In the USA, the most important factor when deciding on inspection frequency is the risk of accidents; one considers the number of incidents discovered during previous inspections and the frequency of non-compliance within the practice in question in order to determine the accident risk. If a particular company has a bad record of compliance, it is inspected more frequently than a company with a good compliance record that is carrying out the same activities within the same practice. The normal exposures are a factor, but a less important one.

L. CAMPER (United States of America) *(Rapporteur)*: I would add that inspection frequencies can be reduced in cases of exemplary compliance.

P. ORTIZ LOPEZ (IAEA): Before you know the history of a particular establishment, you should base the inspection frequency on the potential exposure associated with the practice in question and on the extent to which safety may be affected by a degradation in maintenance, monitoring, etc. Subsequently, the inspection frequency can be adjusted in the light of experience with that establishment.

D.J. BENINSON (Argentina): I think that much depends on the type of practice. With some practices, the accidents which occur are purely random events, and inspection frequency is of little relevance. With other practices you may observe a degradation of safety, and the purpose of inspections is to determine how rapidly the degradation is proceeding; the more rapidly it is proceeding, the more frequently you need to inspect.

E.C.S. AMARAL (Brazil) *(Chairperson)*: I raised the question of inspection frequency because in Brazil we have encountered cases of operator overexposure more often in X ray diagnosis and other medical areas where radiation sources are used than in nuclear power plant operations and various industrial applications of radiation sources, although the risk associated with medical applications of radiation sources is considered to be relatively low. The reason is that those who operate devices with radiation sources for medical purposes tend to have a less acute awareness of the risk and hence of the need for effective radiation protection.

J.A. LOZADA (Venezuela): Pursuant to the presentation made by L. Camper, I would mention that performance indicators are being developed, in an exercise co-ordinated by Mexico, as part of an IAEA regional technical co-operation project for Latin America entitled Guidelines on Control of Radiation Sources (ARCAL XX; RLA/9/028). The performance indicators are to be used in all the countries participating in the project.

D.G. HERNANDEZ (Argentina): The Nuclear Regulatory Authority in Argentina is testing the use of performance indicators. If the trial results are satisfactory, it will start using performance indicators in connection with all regulatory activities.

L. CAMPER (United States of America) *(Rapporteur)*: As regards the usefulness of performance indicators in assessments of the effectiveness of national programmes for ensuring the safety of radiation sources, I would mention that the US Nuclear Regulatory Commission (NRC) is having to become more 'performance oriented'. The reason is that the present Congress, dominated by the Republicans, is not greatly enamoured of regulations and is inclined to be sensitive to the interests of major industries — including the nuclear industry, on behalf of some parts of which there has been strong lobbying for a relaxation of regulations and for closer scrutiny of the NRC's programme. If any regulatory bodies in other countries are seeing their programmes subjected to very close scrutiny, they may find the performance indicators described in my presentation useful.

P.N. MALHOTRA (India): Is the IAEA doing anything to disseminate the results of assessments of national programmes for the safety of radiation sources?

P. ORTIZ LOPEZ (IAEA): The IAEA Secretariat is preparing a publication entitled Assessment by Peer Review of the Effectiveness of a Regulatory Programme for Protection against Ionizing Radiation and for the Safety of Radiation Sources. Reference was made to this publication in Section 2.3 of L. Camper's presentation.

A.J. GONZALEZ (IAEA): In L. Camper's presentation there are references to 'Agreement States'. What does the term mean?

L. CAMPER (United States of America) *(Rapporteur)*: An Agreement State is a State whose Governor has entered into an agreement with the NRC to assume responsibility for materials which would otherwise be directly subject to NRC regulations. There are about a dozen States that are not Agreement States.

Z. PAN (China) *(Chairperson)*: In the USA, several Departments — the NRC, the Department of Energy, the Environmental Protection Agency, etc. — have responsibilities with regard to the safety of radiation sources. How are those responsibilities assigned to the different Departments?

L. CAMPER (United States of America) *(Rapporteur)*: By memoranda of understanding. Pursuant to one memorandum of understanding, if the ownership of a radiation source found in the public domain cannot be determined, EPA assumes responsibility for the source; if it can be determined, the NRC assumes responsibility.

A.J. GONZALEZ (IAEA): Commenting on the IAEA's draft TECDOC entitled Assessment by Peer Review of the Effectiveness of a Regulatory Programme for Protection against Ionizing Radiation and for the Safety of Radiation Sources, L. Camper states in his presentation that "peer review is necessarily qualitative and that it is therefore important that such reviews be conducted by persons who, collectively, have a good understanding of and experience with the main components of a regulatory programme and the functions of a regulatory authority." In that connection, I would point out that there is no tradition of verification of compliance with safety regulations relating to radiation sources similar to the traditions of verification of compliance with safety regulations relating to — for example — operational exposures and public exposures to radiation. Also, in the area of radiation source safety, there are as yet no quantified requirements — only unquantified requirements like 'defence in depth' and 'sound engineering'. In my view, ICRP 64[1] and ICRP 76[2] offer a basis for the formulation of quantified requirements, but until such requirements have been formulated we shall have to rely on performance indicators when verifying compliance with safety regulations relating to radiation sources.

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MEASURES TO PREVENT BREACHES IN THE SECURITY OF RADIOACTIVE MATERIALS (FROM PRODUCTION TO DISPOSAL), EXPERIENCE WITH CRIMINAL ACTS INVOLVING RADIOACTIVE MATERIALS

(Technical Session 7)

Chairperson

H.J. STRAUSS
United States of America

Summaries of Contributed Papers
IAEA-CN-70/7 and 15 were also presented

MEASURES TO PREVENT BREACHES IN THE SECURITY OF RADIOACTIVE MATERIALS (FROM PRODUCTION TO DISPOSAL), EXPERIENCE WITH CRIMINAL ACTS INVOLVING RADIOACTIVE MATERIALS

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Abstract

MEASURES TO PREVENT BREACHES IN THE SECURITY OF RADIOACTIVE MATERIALS (FROM PRODUCTION TO DISPOSAL), EXPERIENCE WITH CRIMINAL ACTS INVOLVING RADIOACTIVE MATERIALS.

The paper takes the position that prevention of breaches in the security of radioactive materials is the most important element in combating illicit trafficking in those materials. It outlines the main requirements for ensuring that the three most important elements in preventing uncontrolled movement of radioactive materials — accounting, control and physical security — are in good order. It emphasizes that these aspects all ultimately derive from appropriate national laws and regulations and from the presence of an effective national regulatory body. Uncontrolled movement, if it occurs, must of course be detected, e.g., at border crossings, and such incidents must be responded to appropriately; Germany's recent record in this regard is described.

1. SIGNIFICANCE OF PREVENTION

This technical session deals with measures to prevent breaches in the security of radioactive materials and experience with criminal acts involving such materials. We all agree that radioactive materials — and that includes special nuclear materials (plutonium and highly enriched uranium) — have to be kept under adequate regulatory control to avoid diversion, theft and any other illicit movement, no matter whether it is intentional or unintentional, inside States or across borders, with or without a criminal or political aspect. In my personal view, effective prevention is the most important element in combating illicit trafficking in radioactive substances.

It is, of course, necessary to detect 'forbidden' radionuclides (e.g., at border crossings) by proper monitoring and measuring technology; it is also necessary to be prepared for an adequate response by customs, border control or other law enforcement personnel once such materials have been detected.

However, in view of the potential risks to public health and safety and of the possible adverse effects on public opinion in many countries, our primary objective must be the prevention of any uncontrolled movements of radiation sources and other radioactive materials. In his oral presentation in Background Session 2, K.E. Duftschmid took the same position, when he called prevention "the first line of defence in illicit trafficking".

2. EXPERIENCE WITH ILLICIT TRAFFICKING

Let us have a look at some experiences with illegal activities involving radioactive materials. I take my own country, Germany, as an example, not only because we had a number of such cases — even some spectacular ones — in the past, but also because Germany is a typical 'transit country' between eastern and western Europe and because it is regarded by interested parties as a promising market. This paper is based on information provided by the Federal Office of Criminal Investigation at Wiesbaden and by the Customs Crime Office at Cologne. Table I shows the number of cases in which actual or suspected radioactive substances were illegally offered. There is a bad and a good message in this table: though the absolute figures are quite high, only a small fraction of these cases involved high risk materials such as special nuclear materials, and the figures have been decreasing since the peak we had in 1994. Practically all these cases may be divided into two categories: (1) fraudulent offers of radioactive substances and dealing (sometimes fraudulently) in non-radioactive substances, and (2) illegal trading in or handling of radioactive substances.

Concerning fraudulent offers, German investigators generally believe that the offenders do not really have access to the materials offered or that they falsely claim that the substances offered are radioactive. (The famous 'red mercury' is clearly in the fraudulent category.) In the minority of cases, there have been indications that the offenders actually had access to the materials in question. Such indications may be that the individuals are very knowledgeable in the matter or can provide convincing laboratory analysis documents or some other kind of proof. The following materials have actually been seized by the German authorities: natural uranium, uranium ore, uranium powder, typical uranium fuel pellets (enrichment 1.6–4.4% ^{235}U), ionization sources containing plutonium, ^{241}Am, ^{137}Cs, ^{85}Kr, ^{60}Co and ^{252}Cf.

In 1994 there were three cases where, as far as the isotope composition is concerned, basically weapons usable materials were confiscated: (1) in May 1994, a powder mixture with a plutonium content of 5.6 g (99.7% ^{239}Pu) was seized in the town of Tengen; (2) in June 1994, 0.8 g of highly enriched uranium (87.7% ^{235}U) was seized in Landshut in Bavaria; and (3) (the most famous case) in August 1994, 560 g

TABLE I. NUMBER OF CASES IN WHICH ACTUAL OR SUSPECTED RADIOACTIVE MATERIAL WAS ILLEGALLY OFFERED

Year	Number of cases
1991	41
1992	158
1993	241
1994	267
1995	163
1996	77
1997	102

of a plutonium–uranium mixture (containing more than 360 g of Pu) was seized at Munich airport on a scheduled commercial flight from Moscow.

In 1995 only radioactive gauges and small sources were detected. In 1996 only one (spectacular) case occurred, involving the seizure of 2.8 kg of low enriched uranium. In 1997 and in 1998, we have seen essentially nothing.

The significant drop in the number of cases since 1994 has in my opinion occurred for several basic reasons:

(1) Perpetrators have realized that there are essentially no buyers and that it is therefore unlikely that a profit can be achieved.
(2) From reports in the media, perpetrators have become more and more aware that high penalties are generally imposed for offences of this type.
(3) Intensive investigations in likely countries of origin and in typical transit countries have led to dentification of the materials before they could reach Germany.
(4) The German law enforcement authorities (police, criminal investigations, customs), on one side, and the Federal nuclear safety and radiation protection authorities, on the other side, have improved co-ordination and co-operation between the various agencies involved in dealing with cases of unlawful possession or use of radioactive substances, illicit trafficking and activities involving the possible release or dispersion of radioactive materials.

Thus the threat remains, but professionalism and preparedness in combating this threat and in deterring potential offenders are at a high level and are steadily improving.

3. PREVENTION MEASURES

3.1. Basic elements

Let me return to the main subject of this session, the prevention of breaches in the security of radioactive materials. Many points have already been raised in Briefing Session 2. Let me remind you of the talks of A.J. González on international standards [1], of A. Nilsson on the IAEA Materials Security Programme [2] and of K.E. Duftschmid on the forthcoming IAEA Safety Guide on Prevention, Detection and Response [3]. Moreover, G. Weimer presented a detailed overview on the regulatory control of radiation sources in Technical Session 1 [4]. Therefore, some overlap with the subject of this paper is unavoidable and necessary.

There is an international consensus that efficient prevention of breaches in the security of radioactive materials is based on three elements: (1) the accounting for radioactive materials, including radiation sources; (2) the control of such materials; and (3) the physical security of such materials.

3.2. Accounting and control

3.2.1. Regulatory provisions

For the three elements identified in 3.1, national laws and regulations should be in place, and governments should devolve their responsibilities on a regulatory body operating on the basis of objectives and tasks defined by the competent authorities and in accordance with internationally accepted principles, standards and practices, and (to repeat A.J. González's words from the Conference opening) having the necessary legal power, adequate resources (personnel, financial, technical) and the highest possible degree of statutory independence. To be more specific, an efficient system of accounting for and control of radioactive material should take into account the kind and activity of the isotopes used, the type of the radioactive material (e.g. sealed or unsealed sources, bulk material), the application of the material, the means of physical security applied (to minimize unauthorized removals) and the degree of interest in and capability for unauthorized intentional or unintentional removals.

The system should, specifically, consider (1) the conditions for storage, use and transfer, i.e. imports, exports and domestic transfers and disposal; (2) the starting point for accounting and control; (3) the termination point for accounting and control; (4) records and reports for sealed and unsealed sources; (5) requirements for measurement systems for the control of radioactive material; (6) reports on materials produced and consumed; (7) physical inventory taking, with special arrangements for accounting and control procedures for sealed radiation sources in industrial gauging, analytical instrumentation and irradiation devices and for radiation sources with low activity (e.g., reference sources); (8) inspections, including examinations of records and reports and measurements of radioactive materials; and (9) appropriate arrangements for the prompt notification of the appropriate authority in the event that evaluation of accounting and control information suggests loss, unauthorized use or removal of radioactive material.

3.2.2. Requirements at the facility level

For facilities using radiation sources or other radioactive materials, requirements should exist for (1) submission and review of relevant information at appropriate stages of facility design and construction to ensure that adequate accounting and control measures are defined, incorporated and approved before receipt of radioactive material at the site or before initiation of operation and the submission of required application; (2) the reporting and updating of design information for review in case of changes; (3) containment, surveillance and sealing procedures; (4) the granting of access for inspection by the authority; (5) the provision of in-plant equipment for measurements and of an accounting and control mechanism.

3.2.3. Requirements for transfer of radioactive materials

In addition, for any transfer of such materials, the following should be required: (1) the licensing of all national and international transfers; (2) contacts with other national authorities responsible for giving approvals for international transfers; (3) arrangements with these organizations to determine the point at which (in the case of exports and imports) the transfer of responsibility for the material will take place.

3.3. Inventory system

Establishing and keeping proper records is a further vital element of the prevention of unauthorized movements of radioactive materials. An information system, mainly based on reports by facility operators to the authority, should at least contain (1) a compilation of current facilities and of those radioactive materials outside facilities, e.g., radioactive materials in static eliminators or as sealed sources in industrial radiography equipment, with information on material accounting and control procedures and of relevant visual surveillance; (2) a record of data on radioactive inventories at each facility and outside facilities, showing types, activities and locations; (3) a record of inventory increases or decreases, including domestic and international receipts and shipments; (4) a record of inspection data and operational information; (5) a record on evaluation of facility reports on unusual incidents or circumstances that may lead to the belief that there are or may have been unauthorized activities; (6) an up-to-date record identifying all responsible individuals.

3.4. Auditing and inspection

To ensure compliance with the authority's requirements, an audit and inspection programme should be established. This programme should (1) ensure that the capability of, and performance by, each facility operator for the discharge of his or her responsibility for accounting and control of radioactive material satisfies the requirements; (2) assure, through independent verifications at facilities by the authority, that the accounting and control measures implemented by the facility operator are effective and that, in conjunction with other measures, it is justified to conclude that there has been no unauthorized removal or use of radioactive material.

To achieve and verify these objectives, the authority should carry out regular and case by case inspection activities, i.e., it should (1) examine the design information presented in the licence application; (2) examine the proposed information practices in order to determine the capability of the applicant to perform the required accounting and control functions; (3) conduct periodic inspections of operating facilities after the start of operation.

For these purposes, the following special activities may be appropriate: (1) examination of records, including laboratory and operating records of measurement quality, of calibration data and of radioactive material which has been measured (or estimated on the basis of measurements) and disposed of in such a way that it is not suitable for further use; (2) checking of containment and surveillance equipment; (3) physical inventory taking on a random basis, including independent measurements to assess the quality of the operator's measurements; (4) evaluation of data presented in accounting and operation reports for abnormal trends in book inventory.

3.5. Physical security of radioactive materials

The concept of physical security, as it is used throughout the nuclear community, requires (1) hardware (e.g., containment and surveillance devices); (2) procedures (e.g., the organization of staff members and the performance of their duties); and (3) facility design (including layout).

The system should be assisted by limiting access to radioactive materials to a minimum number of individuals and by designating protected areas. Information requirements and regular security surveys should also be an integral part of the security system.

Special regard should be given to materials in transit, an area in which detailed international guidance is available.

4. CONCLUSIONS

As K.E. Duftschmid mentioned in Briefing Session 2 [3], the regulatory infrastructure and physical measures needed for preventing illicit trafficking in radioactive materials are the subject of a draft IAEA Safety Guide. It is my conviction that any legal and regulatory system taking account of the guidance expected to be given in this document will be an efficient tool to prevent breaches in the security of radioactive materials and to successfully combat illicit trafficking.

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SUMMARY OF DISCUSSION

Technical Session 7

Chairperson: **H.J. Strauss** (United States of America)

Rapporteur: **L. Weil** (Germany)

H.J. STRAUSS (United States of America) *(Chairperson):* How are the relevant responsibilities divided in Germany, which has a federal structure, between the central — Federal — authorities on the one hand and the local — Land (province) — authorities on the other?

L. WEIL (Germany) *(Rapporteur):* Laws, ordinances and general administrative rules are promulgated at the Federal level. Also, the Federal Government is responsible for licensing shipments of nuclear materials and large radiation sources and for authorizing the import and export of radioactive materials and the final storage of radioactive wastes. The utilization of radiation sources and other radioactive materials falls within the jurisdiction of the Land authorities, which are responsible for deciding on such matters as safety inspections, exemption from licensing, and external and internal dosimetry. Thus, although the organization for which I work (the Bundesamt für Strahlenschutz) is a Federal body, my staff have had to obtain licences for the radiation sources used by them for calibration purposes from the local Land authorities.

J.U. AHMED (Bangladesh): Given the situation in Germany as just described by L. Weil, I should be interested in knowing whether Germany has a central registry of radiation sources — like, for example, Croatia's central registry.

K. COY (Germany): No, it does not. However, in Bavaria — as, I believe, in every other Land in Germany — an inventory is kept of all radiation sources with a strength above the exemption level. The Bavarian inventory is very comprehensive, even including the sources in smoke detectors and indicating the deficiencies of old devices that contain sources.

Jiaqi JIN (China): It is important to learn lessons from radiation accidents, but often the people directly involved are unwilling to provide information because they are afraid of being punished. What can be done about that?

A.J. GONZALEZ (IAEA): That is a difficult problem. Something should be done to encourage people who cause radiation accidents to report as fully and truthfully as possible on what happened. People who cause radiation accidents out of ignorance or foolishness — rather than with criminal intent — might well be susceptible to some sort of encouragement.

L. WEIL (Germany) *(Rapporteur):* I agree — the importance of learning lessons cannot be overemphasized. In Germany, when an accident occurs at a nuclear facility the competent authorities, including the Bundesamt für Strahlenschutz, disseminate all available information about it to all operators of such facilities inside and outside Germany, with a request that the operators report, within a certain time, on the conclusions which they have drawn from that information. As we now know, the Chernobyl accident was preceded by a number of precursor incidents. If there had been wide dissemination of information about those incidents as soon as they occurred, the Chernobyl accident might well not have happened.

S.I. KONDRATOV (Ukraine): I think that international organizations like the IAEA should put pressure on governments which have not done enough to prevent illicit trafficking in nuclear materials and other radioactive sources.

A.J. GONZALEZ (IAEA): International organizations like the IAEA cannot put pressure on governments in such matters — only other governments can do that. One way available to them would be the submission of an appropriately worded draft resolution for adoption by the IAEA's General Conference.

K.M. CHENG (Interpol, Hong Kong): As a rule, the exporters of devices containing radiation sources (for example, certain types of level gauge and density gauge) are under no obligation to check whether the customer in the receiving country has obtained from that country's regulatory authority a licence to take possession of such a device, and sometimes the exporters do not even make it clear that the device contains a radiation source. As a result, devices containing radiation sources are often returned to the exporter pending the issuing of a licence. This makes for inefficiency in international trade and is one of the problems which could perhaps be addressed through an internationally binding legal instrument of the kind which J.U. Ahmed seems to envisage.

A.J. GONZALEZ (IAEA): From this statement and other ones made here in the past couple of days, it is clear that people concerned with the safety of radiation sources and the security of radioactive materials at the scientific and technical level would like to see countries assuming international commitments in this regard. People concerned with them at the political level are probably less enthusiastic about such commitments, so it is for the scientific and technical people to push for what they consider to be necessary.

K. COY (Germany): My experience is that exporters of radiation sources normally take great care to ensure that the customer possesses the necessary licence. Where problems arise, it is usually in connection with the export of complete production lines or entire factories, especially second-hand ones; the presence of radiation sources as part of the 'package' is simply overlooked or forgotten.

J.U. AHMED (Bangladesh): Illicit trafficking in nuclear materials is a crime that has caused alarm in several — mainly developed — countries, which have alerted their customs authorities and border police and brought Interpol into the picture; so it is a crime against which substantial resources have been mobilized. The shipping of radiation sources across national borders without proper authorization should be regarded as an equally criminal act, since it is more widespread, affecting numerous developing countries as well as developed ones, and it should be the principal subject of the internationally binding legal instrument that I have in mind.

J.A. LOZADA (Venezuela): In connection with the preceding discussion and with what A.J. González said about borehole logging equipment in Technical Session 3, I would mention that in Venezuela we have not had problems in controlling the importation of such equipment — but considerable problems in controlling the importation of industrial radiography equipment with ^{60}Co and ^{192}Ir sources. The shipping containers often carry no markings to show that radiation sources are inside. It would help if the competent authorities in the countries of origin informed the competent authorities in the recipient countries that equipment containing radiation sources is under way. We have had positive experience with Argentina in this respect.

W. JOHNSON (United States of America): In his presentation, L. Weil did not mention successful technical countermeasures as a reason for the decline in the number of illicit trafficking cases in Germany. Were technical countermeasures unimportant?

L. WEIL (Germany) *(Rapporteur):* They were not as important as the reasons mentioned by me.

K.E. DUFTSCHMID (IAEA): In this connection I would mention that Poland's border crossing points are now almost all equipped with radiation monitoring systems and that, in the opinion of the Polish border police, the decline in the incidence of illicit trafficking detected at the borders is due to the deterrent impact of those systems.

DETECTION AND IDENTIFICATION TECHNIQUES FOR ILLICITLY TRAFFICKED RADIOACTIVE MATERIALS (I)

(Technical Session 8)

Chairperson

N. KRAVCHENKO
Russian Federation

Summaries of Contributed Papers
IAEA-CN-70/2 and 33 were also presented

DETECTION AND IDENTIFICATION TECHNIQUES FOR ILLICITLY TRAFFICKED RADIOACTIVE MATERIALS (I)

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Abstract

DETECTION AND IDENTIFICATION TECHNIQUES FOR ILLICITLY TRAFFICKED RADIOACTIVE MATERIALS (I).

The paper describes the parameters to be taken into account in choosing a policy to combat the illicit trafficking of radioactive materials and to organize the detection and identification of radioactive materials which are no longer under control. Several kinds of detection and various potential strategies must be considered. The paper shows that it is up to each State to decide what to do according to its own needs, and it emphasizes the necessary co-operation between the services in charge of the problem inside the State as well as that with foreign countries.

1. INTRODUCTION

One of the problems the authorities of a State have to face in the domain of radioactive materials is illicit trafficking. This traffic concerns both legal users of these materials and illegal possessors: legal users have to respect appropriate regulations and the States have to check that they do it properly; illegal possessors do not respect the regulations or try to bypass them, and the States have to act to ensure that the health of the public is not affected.

It is generally accepted that the security of radioactive materials has to be based on three components: (1) prevention of the loss of control of these materials, (2) detection of their loss of control; (3) response after the detection of any loss of control.

Prevention, discussed during Technical Session 7, comprises all the measures taken to avoid the loss of control of radioactive materials from their initial elaboration until their final disposal after use. Detection comprises all the means to be set up to reveal any possible illicit trafficking of thcse materials during their life. Response describes all the actions to be taken and all the means to be used when illicit traffic of radioactive material is detected.

Before going more deeply into the topic of detection, it is useful to note that the three components described above are interdependent. That means in particular that any modification in one of the components will necessarily have repercussions on one or both other components, and that full efficiency will be reached only if the means required for the operations of these three components are set up in a coherent way.

The means required to operate correctly a system for detecting the loss of control of radioactive materials is proposed below. Some of these means will depend directly on the measures taken to prevent loss of control.

2. DEFINITIONS

2.1. Detection

In order to define precisely the topic to be discussed, and because the same words can have various definitions according to the contexts in which they arise, it seems desirable to define 'detection' in the context of illicit trafficking of radioactive materials. In Ref. [1], detection is defined as a "[c]onclusion based on measurements and the interpretation of the results that there is a real case of illicit trafficking". This definition includes procedures and means to ascertain the presence or absence or even the illegal possession of radioactive materials by the detection of radiation. These procedures are complemented by investigations which can establish the occurrence of traffic in radioactive materials if that is the case.

The detection of radiation is possible only with fixed or portable detection equipment, adapted to the nature and the quantity of the radioactive materials to be detected. The detection of radiation does not mean a determination of illicit trafficking, however. Only a full investigation of each detection situation will permit a determination of whether there is illicit traffic or not. During this investigation, an intercomparison will be performed between all the measures and the various documents available. One will use an 'investigation level' above which there is presumably illicit trafficking. This notion of investigation level is detailed in paper IAEA-CN-70/R9 [2]. The kind of detection which uses detection equipment has been named 'technical detection'.

In Technical Session 7 it was mentioned that, throughout their lifetimes, radioactive materials must be surveyed and counted, both by the possessor and by the regulatory authority. It is possible to reveal a possible illicit traffic through document controls. The kind of detection which does not need any detection equipment has been named 'administrative detection'.

Radioactive materials may escape control and expose persons nearby. Action which would lead to the finding of radioactive materials which have resulted in health consequences for the population has been named 'medical detection'.

These three kinds of detection are discussed in Sections 3–5.

2.2. Identification

To properly detect any radioactive material, detection equipment is necessary. But common equipment usually shows only the presence of radiation and not its nature. The positive detection of radiation has to be completed with the identification of the material, if possible on-site. If no identification is performed, a doubt could remain even if the count rate is the one expected.

In the rest of this paper, each time the word 'detection' is used, it is to be understood as 'detection and identification'.

3. ADMINISTRATIVE DETECTION

As was shown during Technical Session 7, prevention is based on regulations and procedures set up to ensure the control of radioactive materials throughout their life. This regulation concerns the legal users of materials, and the detection of any possible loss of control, intentional or unintentional, is based on two tools, inventories and inspections.

3.1. Inventories

The inventory is the most elementary means to reveal a possible loss of control of radioactive material. It has to be performed at two levels, first by the user and then by the regulatory authority.

3.1.1. Inventory by the user

The user has to periodically confirm the physical presence of the radioactive material in the place where it is expected to be and of the conformity of its containment to its nature and its use. This operation is fundamental for the user who operates many sources, because it allows the user to check whether the management system which has been set up is working correctly, and to make any necessary corrections. This kind of inventory is less justified for a user of only a few radioactive sources, especially in fixed facilities. The inventories must be performed periodically according to the operations carried out by the users. They must be as frequent as the operations lead to changes of locations.

3.1.2. Inventory by the regulatory authority

It is desirable that, at least once a year, the users send an inventory to the regulatory authority. This allows the authority to establish (in a bookkeeping sense), a possible loss of control of radioactive material and also the 'legal' disappearance of short half-life radioactive material.

3.2. Inspections

Inspections fall within the competence of the regulatory authority. They must have three objectives: (1) to ensure conformity of the field in which the authorization to use the radioactive material was issued, (2) to ensure the effective presence of the radioactive material, (3) to ensure the respect of procedures and security measures. Inspections can be announced or unannounced, and should be based on inventories brought up to date from the information given by the users.

3.3. Detection during inventories and inspections

Some illicit trafficking of radioactive material can be detected during inventories or inspections. This detection must lead to an immediate information of the competent authority of the State in order to undertake the actions needed to re-establish control of the lost material and to inform the public of any potential dangers. This 'administrative detection' is the first form of detection to be performed. It does not need major investments. It is the demonstration of the intention of the regulatory authority to check the enforcement of procedures and regulations.

4. TECHNICAL DETECTION

In Section 3 it was shown that administrative detection can reveal the possible loss of control of radioactive material by legal users. This kind of detection might be sufficient if no one had made any mistakes or if there were no illegal users. Legal users may make some mistakes in the handling of the radioactive materials or may neglect their management duties as defined by the national regulation system and in so doing lose control of the radioactive materials they possess. Illegal users, of course, do not reveal the materials they possess. They can be classified in one of two categories. The first comprises traffickers who try to sell radioactive materials in the country where they are or to buyers in another country. The second comprises unscrupulous holders who try to sell or to get rid of, at the lowest cost, preferably in another country, radioactive products of various sorts (wastes from decommissioning of nuclear facilities, industrial wastes, etc.).

The only way to detect this traffic or to discover these materials which are no longer under control is to conceive and install a system adapted to the dimensions of the problem. Such a system will be mainly based on the use of radiation detection equipment, chosen according to the situation of the State and the objectives to be achieved.

Before describing the various factors to be taken into account in building up such a system, it is worth noting that the cost of installing it, unlike those of administrative detection, can be high because of the needed investments: purchases of equipment, maintenance, training of operators, etc. A real political will is needed before undertaking the necessary actions, and, before tailoring the system, it is necessary to consider some important parameters, prescribed in Section 4.1.

4.1. Analysis of the situation of the country

Several countries operate organizations and systems to detect radioactive materials which are no longer under control. If these systems are very different, it is because the situations in which those countries find themselves vis-à-vis this traffic are themselves various.

To conceive a detection system organization, the following factors are to be considered, at the minimum:

(1) Assessment of the traffic coming from foreign countries:
 - (a) volume of the imports,
 - (b) origins and destinations,
 - (c) ports of entry,
 - (d) means of transport used,
 - (e) possible nature of radioactive materials,
 - (f) number of bonded warehouses or centres of transit.

(2) Assessment of the domestic traffic:
 - (a) number and locations of facilities where radioactive materials are handled,
 - (b) volume of radioactive materials transported between those facilities,
 - (c) number and locations of final disposal areas for common wastes and for scrap,
 - (d) number and locations of melting facilities, etc.

The analysis of all these parameters allows the authorities of the country to get a general idea of the situation of the existing radioactive materials and of their movements, and allows them to assess the volume of the potential traffic with which they must likely cope.

4.2. Strategy

The detection strategy must be developed by the State according to the synthesis of the information resulting from analysis of the situation of the country, but also according to the objectives the State would wish to aim at, balanced against the means it can deploy. These objectives can be defined by the volume of traffic to be intercepted, and the nature of the radioactive materials and their quantities. This subject is taken up in Technical Session 9.

The detection strategy has also to consider the budget which will be available. Ideal situations, in which the needed budget is available, are very rare. So compromises will be necessary, and they must take into account the cost of equipment, its sensitivity, its maintenance, the number of operators to be trained, etc.

It is from consideration of all these factors that strategies of detection can be developed and assessed. It seems useful, in conceiving of different kinds of strategies, to distinguish the detection of traffic from foreign countries and the detection of domestic traffic.

4.2.1. Detection of traffic from foreign countries

Situation 1

Hypothesis:
— important potential traffic,
— limited number of ports of entry,
— sufficient budget.

Choice:
— installation of fixed detection equipment at every port of entry and systematic control of all the goods entering the country.

Situation 2

Hypothesis:
— important potential traffic but through the border with only one country,
— identification of potential traffic,
— limited number of ports of entry,
— limited budget.

Choice:
— installation of fixed detection equipment at every port of entry concerned, with systematic control of the goods coming through these ports of entry,
— random checking of the goods coming entering through other ports of entry with mobile detection equipment.

Situation 3

Hypothesis:

— important potential traffic,
— great number of ports of entry,
— limited budget.

Choice:
— random use of portable detection equipment.

These few examples show that strategies can vary according to situations. They can be very efficient if they lead to the use of fully adapted detection equipment. The weakness of some strategies (when the budget is low) can be mitigated by doing as little random checking as possible. For that purpose, intelligence is one of the most efficient ways to target the goods or people to be checked; international co-operation, bilateral or multilateral, can be of great help in this regard. These means will have to be employed systematically to reach full efficiency, whatever the strategy.

4.2.2 Detection of domestic traffic

A detection system for domestic traffic must lead to the detection of failures of the country's prevention system and must complement the work of the inspections and inventories organization.

Of course it is inconceivable to install detection equipment all over the country, but it is possible to conceive a strategy which is not expensive but which is nevertheless efficient. It consists in holding operators who deliver goods that are not naturally radioactive legally responsible for the goods leaving their facilities.

This strategy can permit the recovery of radioactive materials which are no longer under control before they re-enter commercial channels. It leads some operators to install a detection system at the entrance of their facilities to prevent further problems. This strategy mainly concerns industrial activities such as scrap dealing, casting or waste processing. It must be clear that the authorities of the country have to organize the means to collect any materials so detected. The strategy can also lead operators having radioactive materials inside their facilities to consider the installation of a detection system at exit doors to complement the internal procedures. In addition, random checking can be carried out with mobile detection equipment.

Finally, an important element for any strategy to be successful is the necessary co-operation which must exist between all the services which, in a State, are in charge of this mission (custom, police, border guards, etc.).

4.3. Philosophy of detection

Another important factor to be considered when studying the strategy of detection is the way the detection will actually be carried out.

For the detection of domestic traffic, detection equipment can be installed or operated in an overt way, with operators wearing a uniform or not. For the detection of traffic coming from foreign countries, especially by illegal possessors of radioactive materials, two possibilities exist, with their advantages and disadvantages. The first consists in installing and operating detection systems and operating them in an overt way, with operators in uniform. This way is dissuasive, facing the potential traffickers, but it can also lead them to bypass the locations so equipped and thus allow them to escape the controls. The second possibility consists in hiding the detection equipment, moving it very often, and using unmarked vehicles with operators in plain clothes. This can make it possible to detect traffic and identify the traffickers without their realizing it, to identify illegal channels and to arrest the traffickers at a place chosen by the law enforcement agents.

4.4. Radiation protection of operators

In accordance with the Basic Safety Standards of the IAEA [3] and national radiation protection regulations, personnel expecting to encounter radioactive materials in their work should have access to adequate protective equipment and should be familiar with the appropriate radiation protection procedures. These will typically include the use of personal alarm dosimeters for alerting them to radiation hazards in the field and the use of dosimeters that are suitable for demonstrating compliance with regulations that specify limits for radiation doses.

It is important in this connection to recognize that a dosimeter is a form of personal protection and that is not a detector. Even if dosimeters cost very little, and even if many dosimeters can be purchased, they do not constitute a detection system.

5. MEDICAL DETECTION

Unfortunately there exist some situations in which radioactive materials are no longer under control and cannot be detected by any of the systems installed to avoid loss of control. They can end up in locations where they do not lead to any consequences for the public; they can also end up close to or in contact with people who, day after day, are exposed to doses which lead to specific pathologies.

It is fundamental that doctors are trained so that they are able to diagnose these kinds of pathologies, in order promptly to trigger an investigation of the patient's residence and workplace and to inform the authorities.

One can see that, through medical diagnosis, it is possible to detect radioactive materials which are no longer under control.

6. INTERNATIONAL CO-OPERATION

For an organization that is operated or contemplated by a country to achieve full efficiency, this country will have to look for international co-operation and/or at least bilateral co-operation with those countries with which it has common borders. Exchanges of information allow improvement of the detection systems of both countries. Contacts with the IAEA may be the first step towards such exchanges.

7. CONCLUSIONS

This paper has tried to put in evidence the parameters to be considered in order to install a detection system organization. Generally speaking, such an organization has to be based on administrative measures and technical means. Among these technical means, detection equipment forms an important part; it can be fixed or mobile and can be used overtly or covertly.

The efficiency of the system is also based on the skill of the personnel, who must be carefully trained.

A universal solution does not exist to the problem of detecting radioactive materials that are no longer under control. Each country has to study its own case and define its own organization, adapted to its problems, recognizing the budget it has and the objectives to be achieved. Of course it may be possible to find one or more countries having similar problems. In that case, exchanges will be mutually fruitful.

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A BRIEF 'COMMERCIAL MESSAGE'

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The information provided by certain participants about the problem of preventing illicit trafficking in radioactive materials has raised the question of practical approaches to the organization of the control of nuclear and other radioactive materials.

There is another question which I should like to raise. We have information according to which specialists and specialized organizations, acting as users of radioactive materials, engage in smuggling in the course of legal import or export operations by replacing the material in question by some other material.

Until recently, no customs service, apart from Russia's, provided details such as radionuclide name, activity and isotopic composition on the customs declaration.

Consequently, a Russian firm, Green Star Ltd, has designed and built a gamma spectrometer which enables customs officers to check on radioactive materials in special containers without opening the containers. The measurement time is 30 min.

The equipment indicates the type of radionuclide, its activity, the degree of enrichment in the case of uranium and the isotopic composition in the case of plutonium. Its precision is sufficient for customs checks.

In February 1997, this equipment took part in an international trial comparison of methods for determining the degree of enrichment of uranium samples placed in containers. Fifteen laboratories and companies participated, from Argentina, Belgium, France, Germany, Hungary, the Russian Federation and the United Kingdom. The measurement precision of the spectrometer is on a par with that of the best European equipment.

Forty-eight per cent of the measurement results obtained with the other equipment had a deviation relative to the true value which is greater than that of the Russian results.

No equipment is comparable with the Russian equipment as regards measurement capacity and speed (the equipment has also been tested at Los Alamos National Laboratory, USA, in determining the isotopic composition of military plutonium). For the principal isotopes of plutonium, the measurement deviation relative to the reference value does not exceed 3.5%.

Russia's customs service has acquired some experience of methods of detecting nuclear materials which are being smuggled in the course of legal import and export operations.

We are ready to co-operate with the customs services of other countries which export nuclear and other radioactive materials and which are represented at this conference, and we are ready to arrange demonstrations of the equipment in Russia for representatives of customs and other services.

As a practical step, we invite interested customs services to conclude with us bilateral protocols on co-operation in controlling the transboundary flow of nuclear and other radioactive materials.

The discussions which I have had with colleagues from the customs services of other countries suggest that the control of radioactive materials at border crossing points is regarded as a secondary task. Consequently, the financial resources made available for it are inadequate and the frontier posts are badly equipped, or not equipped at all, for the identification of nuclear and other radioactive materials.

Most customs services do not have specialists trained to perform the necessary measurements. Serious thought should therefore be given to the proposals made in Vienna by the representatives of various countries (Austria, Greece and Turkey) and of the IAEA regarding the conclusion of a convention which would require States parties to install radiation measurement equipment on their borders. The convention could be a separate one on the prevention of illicit trafficking or (more realistically) an addendum to the Convention on the Physical Protection of Nuclear Materials.

Russia's practical experience of the customs control of nuclear and other radioactive materials accords well with the interest shown by the representatives of certain countries (Estonia, Germany, Poland, Slovakia, Sweden and the United Kingdom) in harmonizing, among the countries participating in the programme for combating illicit trafficking in radioactive materials, the criteria and conditions for the triggering of alarms at frontier posts.

Recently, various manufacturers of detection portals have specified different sensitivities for the detection of nuclear and other radioactive materials. Normally, only gamma detection is performed with portals, although, in order to detect nuclear materials effectively, one needs simultaneous gamma detection and neutron detection.

The cost of the system depends on the sensitivity level. That is why the formulation of unique sensitivity specifications should permit optimum utilization of the financial resources provided for the installation of equipment in the countries participating in the programme for combating illicit trafficking in radioactive materials.

SUMMARY OF DISCUSSION

Technical Session 8

Chairperson: N. **Kravchenko** (Russian Federation)

Rapporteur: **J.P. Gayral** (France)

W. JOHNSON (United States of America): With regard to J.P. Gayral's presentation, I should like to emphasize how important it is, when working out strategies for the use of detection systems at border crossings, to take into account the frequency and nature of the legitimate movements of radioactive materials.

C. MILU (Romania): I agree with J.P. Gayral's remark to the effect that investigations should begin already at the detection stage. Recently, two trains from Romania were turned back at the Italian border after a simple gamma ray determination of the absorbed dose in air, and the investigations were not carried out until a month later — in Romania. A lot of money and time was thereby wasted. I should like to see a general agreement whereby investigations are carried out on the spot at the detection stage with standardized procedures, use being made of multipurpose facilities which are capable of measuring dose rates and which also have spectrometers. This would help to reduce the number of false alarms and of unwarranted rejection of shipments.

H.W. ROSENSTOCK (Germany): With regard to paper IAEA-CN-70/2[1], can radiation damage to the neutron sensitive glass fibres result in reduced light transmission?

R.S. SEYMOUR (United States of America): The glass fibres are very resistant to radiation damage; they are designed for reactor dosimetry applications and can withstand very high fluences. A more serious problem is moisture, which causes a loss of optical transmission; the glass fibres have to be kept well enclosed.

Z. PAN (China): How sensitive are the neutron sensors from the point of view of detecting plutonium in soil?

R.S. SEYMOUR (United States of America): They should 'see' neutrons emitted at a depth of 10 cm or more, so that a 5000 cm^2 sensor should 'view' a soil volume of 50 000 cm^3, which corresponds to 100 000–150 000 g of soil. With this large

[1] SEYMOUR, R.S., et al., "Scintillating-glass-fiber neutron sensors, their application and performance for plutonium detection and monitoring", Safety of Radiation Sources and Security of Radioactive Materials, Contributed Papers (Proc. Conf. Dijon, 1998), IAEA, Vienna (1998) 237–241.

measurement volume, the calculated sensitivity is 4 pCi/g (0.1 Bq/g) for a counting time of about 30 min. I would mention, however, that our calculations have not yet been verified by empirical measurements.

DETECTION AND IDENTIFICATION TECHNIQUES FOR ILLICITLY TRAFFICKED RADIOACTIVE MATERIALS (II)

(Technical Session 9)

Chairperson

D.E. SMITH
United States of America

Summaries of Contributed Papers
IAEA-CN-70/32, 42 and 108 were also presented

DETECTION AND IDENTIFICATION TECHNIQUES FOR ILLICITLY TRAFFICKED RADIOACTIVE MATERIALS (II)

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Abstract

DETECTION AND IDENTIFICATION TECHNIQUES FOR ILLICITLY TRAFFICKED RADIOACTIVE MATERIALS (II).

Detection and identification of radioactive substances is an important part of the overall strategy against illicit trafficking. After a brief introduction to the topic, the paper discusses the framework which defines the characteristics and sets the goals of the detection effort, paying attention to national policy decisions regarding specific detection limits and response strategies. Response in general and different alarm conditions are discussed. A detailed overview of technical principles and recent developments of instruments is presented. Various types of instruments foreseen for applications in combating illicit trafficking are reviewed. The actual deployment of instruments is discussed, both in view of the type of material to be located and the type of checkpoint or means of transport where detection will take place. Attention is paid to considerations of general concern for the detection process, comprising the measurement effort, a possible alarm indication and the conclusions drawn upon assessing the situation. A short section on recommendations summarizes findings of a general nature and insights in instrument selection, choice of investigation level and training. The paper concludes with a brief overview of instrument comparison and testing activities.

1. INTRODUCTION

A number of incidents have been reported in which the loss of control of radioactive material has had serious consequences. These incidents have involved medical or industrial sources unintentionally included in scrap metal, radioactive material found by unsuspecting individuals or material deliberately diverted from the chain of custody and the regulatory measures usually applied to radioactive substances.

Other sessions in this Conference deal with various ways to avoid or at least minimize loss of control of radioactive substances, including 'defence in depth' strategies. However, once preventive measures have been circumvented, or when loss of control over radioactive substances must be suspected, the focus changes to the detection techniques required to regain control and reapply regulatory authority over those substances. Unauthorized possession, application, trading in or transportation of radioactive substances constitutes illicit trafficking, which is of concern not only to the regulatory authorities but to the many institutions involved in regaining control and, ultimately, to the general public.

The coherence between the regimes of prevention, detection and response is discussed elsewhere in these Proceedings [1]. Detection itself is a multifaceted process that entails much more than just the application of radiation measuring instrumentation. A number of sources lost from proper custody were detected by their pathological consequences on the individuals who inadvertently handled them. However, this session focusses on technical issues related to detection and identification instrumentation used to search for, detect and possibly identify radioactive substances under various scenarios of illicit trafficking.

In line with standard IAEA practice, in the following text the term 'radioactive material or substance' will be used to refer to both radioactive sources, natural or anthropogenic radioactive substances, and fissile materials, specifically special nuclear material (SNM).

2. FRAMEWORK

Detection from a technical point of view must be addressed in the context of the activities associated with exercising control over radioactive materials [2]. Individual cases will call for solutions in which both the technical capabilities and the application of the instruments employed in identifying a possible case of illicit trafficking are tailored to the circumstances. The choice made will be governed by an assessment of the threat potential (quantitatively, and regarding the design assumptions for the probable target incidents), by the expertise and training level of the institutions involved (the human 'detectors') and by the specific scenarios to be considered (e.g. scrap metal monitoring versus airport passenger scanning). The following sections outline a few of these considerations, then focus on various technical issues regarding instruments and finally attempt to derive general recommendations for technical specifications and application procedures.

2.1. National policy

National policy defines the overall plan for response to the loss of control over radioactive substances or to suspected illicit trafficking. The primary concerns are the technical detection methodology, the ensuing actions once an alarm has been generated and the associated requirements imposed on instrumentation. National policy will also define what actually constitutes a threat and what must be detected at a given checkpoint. The general concern is to avoid any hazard to health or the environment that may be presented by the substances illicitly trafficked and to detect 'small' quantities of SNM, i.e., amounts well below 1 kg. Radioactive substances associated with metal scrap (concealed sources) are usually not easy to detect and — though posing the largest commercial risk — are generally excluded from considerations in the border control environment, unless the source activity is so high as to constitute a health hazard. Nevertheless, issues relating to metal scrap are addressed in Section 4.1.1.

2.2. Detection limit — investigation level

'Detection' is defined in a draft IAEA publication [3] as a "conclusion based on measurement and the interpretation of the results that there is a real case of illicit trafficking". Detection therefore consists of two important processes, the measurement of elevated radiation levels and the interpretation of these readings to constitute a case of illicit trafficking, screening out other possible trigger events.

One of the most important properties of any measuring instrument is its detection limit. This is a value derived from laboratory tests of instrument performance, from controlled field tests or — less reliably — from statistical calculations, and defining the smallest signal at which reliable detection can be made. The 'signal' depends on the nature of the instrument and may constitute a specific activity, a dose rate or a relative reading. This issue is further complicated by the naturally occurring radionuclides in our environment and by the statistics inherent in the process of detecting radiation. Any criterion (or selected detection threshold) for deciding if a particular shipment contains any illicitly trafficked radioactive material has to take into account the spatially and temporally varying background and the statistics of detection.

Under most scenarios, a detection beyond a previously established warning threshold will result in some kind of alarm indication and will lead to further action in order to interpret the event. Though individual response plans may prescribe specific courses of action, the general tendency will be to investigate the validity of the alarm and to gather more information on this newly established 'case'. Therefore, it has been agreed to call the previously established warning threshold — which causes an alarm — the 'investigation level'. Elevated readings below the investigation level do not necessarily rule out the presence of radioactive material in a given situation; under pre-established guidelines, however, such readings simply do not give rise to further investigation. Readings exceeding the investigation level do not necessarily indicate a case of illicit trafficking, but they need to be further investigated.

The agreement on a specific investigation level is therefore a decision based on national policy. This level should be high enough to allow detection not to be adversely affected by variations in natural background radiation or by low levels of radiation originating from exempt practices or cleared radioactive materials in low quantities. Whatever the choice, it must be ascertained that the detection limit of the instruments used is below the selected investigation level. However, many natural or anthropogenic radionuclides will appear legally in quantities causing an alarm by exceeding the chosen investigation level. These may result from processes involving radioactive substances exempted from regulatory control or from substances excluded up to a certain activity concentration or total content. The various causes of alarms are analysed in the next section.

2.3. Alarms

Once an alarm has gone off, some form of investigation is called for. However, before elaborating on the general concepts of interpretation and identification, the different causes of alarms will be analysed.

2.3.1. True alarms

Considered from the point of view of the first responder who must to react to the indication of an alarm status, a 'true alarm' is one caused by some amount of radioactive material passing the detector. The signal delivered by the instrument indicates radioactivity beyond the pre-established investigation level. This may be caused by legal or illicit trafficking and needs further investigation. True alarms are quantified by the detection probability.

2.3.2. False alarms

Contrary to a true alarm, a false alarm is one that occurs without radioactive material associated with goods or people passing the detector. It may be caused by variations in natural background, by poor statistics, by instrument malfunction or by unknown reasons. Nevertheless, a detailed investigation must verify the alarm to be 'false', e.g., by repassing of the gate or manual scanning. Since all such measures are time consuming and will tend to obstruct normal operation, false alarms must be minimized by all means, since the credibility of the system will be compromised in view of the operating personnel. The quantitative measure is the false alarm rate, usually specified as a fraction of time or a fraction of passes through the gate. Generally speaking, the false alarm rate may be allowed to be higher with hand held equipment than with fixed installed systems.

2.3.3. Nuisance alarms

Nuisance alarms are true alarms caused by radioactive substances which do not constitute a case of illicit trafficking. Legal transports of radioactive materials may also trigger an alarm, but identification should be straightforward pursuant to transport regulations. Nuisance alarms are typically caused by naturally occurring radioactive substances such as ^{40}K or small amounts of uranium or thorium. Medical radionuclides administered to patients often trigger alarms, necessitating cumbersome interviews to determine the cause of the elevated radiation level. Evaluations of border scenarios have shown that most alarms (up to 80% in some situations) are caused by natural radionuclides, thus creating a major nuisance for the operating personnel and justifying the name selected for this type of alarm.

2.3.4. Missed alarms

The last category is not an alarm situation, although it should be one. As discussed in Section 3.1.4, even correct equipment specifications allow for a certain probability that an alarm will not sound when it should have sounded. Missed alarms and false alarms are closely correlated; pushing both in the favourable direction without reducing the probability of true alarms usually leads to significant cost increases. A number of studies indicate that a high percentage of cases of illicit trafficking may go undetected.

2.4. Alarm response

This session of the Conference does not focus on response measures. However, the instruments discussed and their characteristics must enable the detection process to achieve its goal, namely to ascertain whether an attempt of illicit trafficking has occurred. As outlined above, a logical first action will be to establish what kind of an alarm situation has evolved — true, false or nuisance (the missed alarm will of course go undetected).

In the case of nuisance alarms, actual radioisotopes or at least classes of radioisotopes must be identified (e.g., 'medical', 'natural'). Though some insights may be gained from shipping papers or interviews, the frequent occurrence of such alarms eventually leads to extended requirements for the instruments to enable such differentiation on the spot without involving cumbersome analysis or a laboratory.

Once a true alarm has been verified and the conclusion based on measurement and interpretation has been drawn that a case of illicit trafficking exists, a general response strategy will be to assess the hazard of the situation and possibly to isolate the shipment or person and conduct further measurements to pinpoint the exact location or source of the problem. Somewhere during this process, the front-line officer having detected the case will hand over responsibility to a specifially trained or more experienced 'responder' or to even more specialized institutions, depending on the complexity of the case and other factors. This strategy is defined specifically in the respective response plans. Regarding instrumentation, two requirements may be extracted from general response procedures: (1) the nature of the alarm must be clearly identifiable, and the interpretation must yield an unambiguous conclusion so that a reliable detection can be made; (2) localization and (possibly) identification of the source of the alarm must be possible. Based on general radiation protection considerations, a third requirement may be formulated: (3) the instruments must allow the operating personnel to take appropriate protection measures.

2.5. Goals derived

With respect to detailed instrument specifications, general considerations regarding instruments to aid in detecting cases of illicit trafficking are the following:

(a) The system must allow measurements from a distance during a short time interval.
(b) The indication of the result must be simple and unambiguous.
(c) Operation of the instruments must be as simple as possible so as to aid and not burden the executive forces.
(d) The system must perform self-checking automatically and must not require frequent adjustment or recalibration.
(e) The variation of the natural background must be accounted for.
(f) The instruments must be rugged and must withstand harsh environmental conditions.
(g) Detection probability (for the application selected) must be high, and the false alarm rate must be low.

3. INSTRUMENTATION

Instruments and systems to measure radioactive parameters are available for many different applications. We restrict ourselves to typical applications associated with the problems of illicit trafficking, disregarding — unfortunately — a host of other potentially interesting techniques and systems. Monitoring is primarily considered at control points, e.g., at boundaries of nuclear facilities or at customs checkpoints.

3.1. Technical principles

A radiation detector converts information from gamma and/or neutron radiation into electrical pulses, thus allowing computation of various properties associated with the radiation received. Usually solid state detectors are involved (scintillation type detectors), since they yield more information per unit detector volume than, e.g., gas filled devices (Geiger–Müller tubes, ionization chambers). Almost all models are microprocessor controlled, allowing the presentation of the desired result in the most appropriate form. Examples are (1) a simple warning device, yielding as a result basically a yes/no information, and (2) spectroscopic equipment, yielding a complex spectrum for radioisotope identification.

3.1.1. Indication of intensity

Though international agreement has been established on the unit of measurement regarding radiation, relative information may be more useful for a front-line officer not necessarily well experienced in radiation physics. A number of instruments therefore have a relative scale (e.g., 0 to 9) with simple instructions associated with each indication (e.g., "if reading is 9, retreat until reading falls below 9"). Hence the display resembles a relative indication of intensity, mostly based on gamma intensity.

3.1.2. Dose rate

The dose rate, measured in sieverts per hour (rem per hour or roentgen per hour in the USA), is the chosen unit of radiation intensity. A specific value was also selected as the defining criterion for the setting of the investigation level. At first glance, this may seem less than optimal, since the quantity to be controlled is the amount of radioactive substance, i.e., the activity (usually measured in becquerels or curies). However, a source of specific activity may either be found or missed with the same detection equipment, depending on factors such as shielding and geometry. Though it is still desirable to find all sources exceeding a specific activity, for the purposes of testing and comparing equipment, and especially for setting reproducible levels for an investigation, the radiation intensity (i.e. the dose rate) at a specific location (i.e., 10 cm from the surface of a consignment) is a much more reliable approach and has therefore been chosen as criterion for the investigation level in the draft IAEA Safety Guide [3].

3.1.3. Activity

Although the specific amount of radioactivity (i.e, activity) is the quantity to be controlled under regulatory practices, detection based on source quantity is feasible only in certain situations where geometry, shielding and type of radiosiotope are exactly known (or may be controlled). Such is the case, e.g., for pedestrian monitors at access control points in nuclear facilities. These monitors are characterized by the amount of SNM (plutonium or highly enriched uranium, HEU) they may identify. Under less defined circumstances, the detection system would have to either identify the information required (e.g., the radioisotope concerned) or work on assumptions that may yield misleading results.

3.1.4. Statistics

Detection can only be accomplished with a certain probability at a specific confidence level. For instance, a specific source may be detected in four out of five passes (80%) at a confidence level of (typically) 95%, meaning that the system may yield even less than 80% detection probability in rare cases. Manufacturers, testing laboratories and field tests may specify the results at different confidence levels or for different detection probabilities, which makes them hard to compare with one another and not only for the layman in statistics. Consequently, even after wise choices have been taken regarding the alarm threshold and in selecting the proper equipment, further investigation is required once an alarm sounds.

3.2. Recent developments

3.2.1. Sensitivity

It is beyond the scope of this paper to attempt a review of recent developments in radiation detection. However, for the purposes of aiding detection in illicit trafficking, specific developments have been made recently, namely

(a) Small and ruggedized versions of scintillation detectors, applicable for pocket size instrumentation.
(b) Inclusion of neutron detection methodology with standard gamma radiation detectors to aid in detection of shielded sources of nuclear material.
(c) Advanced statistical evaluation procedures to increase detection probability or minimize detection time.

Over the past few years, a general increase in detection probability has taken place, specifically for identifying small amounts of radioactive materials in the scrap recycling process.

3.2.2. Background suppression

An important feature required of the instrumentation is automatic adjustment to variations in natural background level and the ability to carry out measurement even below background level in situations where shielding effects are caused by the object being measured. This background suppression by loaded trucks or railway wagons may amount to up to 50% of detector count rate, depending on detector placement and geometry. Because of background suppression, a vehicle carrying a potentially significant amount of radioactive material may not produce a signal that exceeds the

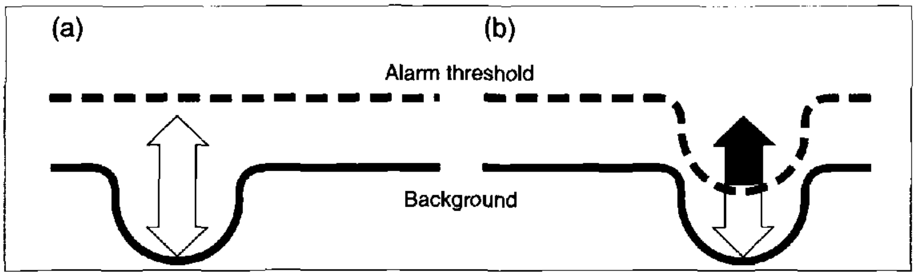

FIG. 1. Principle of background suppression. (a) Fixed threshold, signal ignored; (b) adaptive threshold, signal recognized.

usual alarm threshold, or even the usual background signal. See Fig. 1 for clarification. Hence, specific evaluation procedures based on correlation of more than one detector signal are required. Various manufacturers are offering equipment allowing such evaluations.

3.2.3. Identification

As noted earlier, most alarms are nuisance alarms. However, these have to be identified securely as nuisance alarms before the case may be closed. This entails cumbersome procedures and/or interviews. Therefore, it is highly desirable to have equipment that makes identification simple. A number of manufacturers have developed hand held instruments based on spectroscopic evaluation of the emission of sodium iodide scintillation crystals, allowing the identification of previously programmed radioisotopes by their characteristic emissions and thus aiding the drawing of conclusions through interpretation of the measurement result.

3.3. Type of instrumentation

Measuring instruments have been classified into different categories, with associated specific performance characteristics and areas of application.

3.3.1. Pocket sized instruments

This type of instrument should be easy to use, even by non-specialized staff. Their purpose is to allow a quick and qualitative assessment of suspect materials. They must be battery powered and shock and water resistant, and should have low requirements for maintenance and calibration. Typically, those instruments are autoranging and serve as alarm indicators by audio, visual or vibrational alert. The high sensitivity required to detect small quantities of radioactive materials usually requires solid state detectors and rules out classic Geiger–Müller tubes.

3.3.2. Hand held instruments

Hand held instruments are used for localization and identification. They are generally more bulky than pocket sized instruments and have more features. With the requirement for increased sensitivity, more complex evaluation procedures are required, leading to the inclusion of spectroscopic evaluation techniques yielding information on the type of radioisotope. However, the use of such instruments is more demanding and requires a higher degree of training. Usually such instruments are less rugged than their pocket sized counterparts and are more costly. Under the guidelines of response strategy, such instruments are typically employed when a detection has already been made and more detailed characterization of the material detected is desired, specifically when detailed localization or identification is required.

3.3.3. Mobile systems

The distinction between hand held and mobile systems is somewhat vague. Mobile systems are regarded as being even more complex and bulky, allowing measurements at even higher sensitivity from mobile platforms, e.g. specially adapted cars, helicopters or loading cranes. Their area of application comprises, e.g., searches from unmarked vehicles within the interior of a country, large area scanning or application at loading docks.

3.3.4. Fixed installed instruments

Such instruments are designed to be located at checkpoints at borders or at the boundaries of nuclear facilities or other facilities requiring monitoring (e.g., at the scrap metal entry to steel works). Monitors are often designed like gates, causing the traffic to flow through them. They should allow monitoring of the flow of goods or people at the shortest distance possible. The control and display units are located in a separate place and usually have some form of tamper protection. Operation requires only a low level of training, concentrating on first line response and functional checking. Ideally, the flow of goods, baggage, persons or vehicles may be monitored at considerable speed without obstruction and with low false alarm rates.

3.3.5. Special instruments

According to the complexity of a specific case, more elaborate equipment may be employed and more specialized personnel involved in characterizing, isolating and regaining control of an illicitly trafficked radioactive substance. Though capabilities equivalent to those of field laboratories have been introduced, with recent instruments allowing complex in situ identification techniques (e.g., high resolution gamma spectroscopy by means of high purity germanium detectors), certain problems will still have to be referred to laboratories and their highly specialized staff and equipment. These special instruments — though called upon at some times — will not be discussed further in this paper.

4. DEPLOYMENT

The application of certain instruments is closely coupled to the detection goal to be achieved and the investigation limit chosen. The discussion below elaborates on questions of usage based on the type of material and on the means of transport involved. The papers submitted in this session and in Technical Session 8 focus on various aspects of detection or experience associated with such tasks.

4.1. Type of material

4.1.1. Scrap metal

As pointed out above, scrap metal imposes most stringent requirements on detection sensitivity. Publications by the Institute of Scrap Recycling Industries [4] recommend a minimum detectable activity of ^{137}Cs, shielded to allow a surface dose rate on the container of 10 μSv/h and buried at least 1 m in loose iron scrap. The effective increase in dose rate at the outside of the vehicle based on these assumptions is a mere 6 nSv/h, under background conditions of typically 100–300 nSv/h. This constitutes an increase over background radiation level of only 2–6%, depending on ambient background. By comparison, monitoring gates for SNM are set to approximately 4% above background. Investigation levels recommended in the draft Safety Guide [3] will be finalized — after initial studies have been completed — at between 100 and 500 nSv/h, thus being of the order of standard background levels.

4.1.2. Fissile materials

Similarly, monitoring for fissile materials, namely plutonium and HEU (SNM), requires extremely high detection sensitivities. Since the gamma signatures of certain plutonium isotopes are very weak, SNM monitoring is often complemented by neutron detection techniques. Los Alamos National Laboratory has published a compilation of standards from the American Society for Testing and Materials, applicable for certain monitoring applications [5]. There are also a number of excellent evaluations and reviews available from Los Alamos National Laboratory on this subject [6, 7].

Since the radioisotopes being searched for and the associated geometries are usually well defined, the detection limit is usually specified as activity or mass of SNM. Searching for fissile materials usually requires more stringent and elaborate monitoring procedures than detecting illicit trafficking.

4.1.3. Radioactive sources

Illicit movement of radioactive sources should be securely detected when the source activity is high enough to constitute a health hazard. Depending on shielding arrangements and concealment techniques, such detection may not be warranted under all circumstances. Basic design requirements for illicit trafficking detection equipment have been considered in view of such cases. However, even strong sources in shielding containers may emit only weak signatures, especially if buried in steel scrap.

4.1.4. Natural radioactivity

Many alarms are caused by naturally occurring radioactive substances, e.g., ^{40}K in artificial fertilizer. These fall into the class of nuisance alarms and should be screened out as far as possible by the equipment itself.

4.1.5. Medical isotopes

Automated identification of medical isotopes would be highly desirable to reduce the number of nuisance alarms for this type of radioisotope.

4.2. Means of transport

4.2.1. Automobiles

Passenger automobiles cross borders in large numbers. Within the European Union, and under the Schengen Agreement, the crossing of borders may be accomplished even without slowing down considerably. Monitoring by means of fixed installed portals or gates must allow quick monitoring of large traffic loads even at considerable speed (up to 30 km/h). Another approach is a second line of defence comprising highly sensitive mobile monitoring systems mounted in cars or helicopters, scanning busy roads or suspect streets. Once a detection has been made, open or concealed further investigations may ensue by standard monitoring techniques.

4.2.2. *Trucks*

Because of elaborate customs procedures, trucks are easy to monitor at slow speed by means of stationary systems at border checkpoints or even by highly sensitive hand held instruments moving along columns of waiting trucks. The problem might not be finding a radioactive substance but dealing with too frequent alarms — true, false and nuisance. Even contaminated air filters of truck engines have been known to trigger alarms with sensitive equipment. Depending on the detailed situation at the checkpoint, various monitoring systems may be employed. Problems with sensitivity may be caused by shielding effects from the truck or the cargo itself, as discussed in Section 4.1.1.

4.2.3. *Railroad wagons*

Railroad wagons typically move faster than trucks, and the detection equipment has to be specifically adapted for such purposes. A number of manufacturers produce dedicated equipment, and various tests have been undertaken demonstrating performance comparisons of such equipment. Problems have arisen with railroad wagons constructed with slightly contaminated steel.

4.2.4. *Airplanes*

Airport checkpoints allow for separate monitoring of luggage and people in transit. In both cases a significant throughput must be established, which creates stringent requirements on the false alarm and nuisance alarm rates. Instead of monitoring by portals or gates, security personnel may be equipped with highly sensitive concealed instruments. Selection of suspect individuals to be monitored at closer distance may be based on the security personnel's operational experience.

5. RECOMMENDATIONS

Deriving general recommendations for the great variety of situations and possible encounters with illicit trafficking is no simple task. It has already been pointed out that the national policy in counteracting illicit trafficking has to exhibit coherence in the areas of prevention, detection and response. Based on the overall strategy, the availability of experienced personnel and the resources committed, a tailored solution must be established for any given situation.

5.1. Equipment selection

A critical question demanding considerable financial resources lies with the procurement of appropriate detection equipment. Natural checkpoints (e.g., border crossings), where the flow of traffic is constrained to a few lanes only, serve as ideal monitoring points. The choice between fully automated fixed installed equipment or the flexible deployment of highly sensitive hand held units by experienced staff cannot be based solely on considerations of the desirable investigation level, but must also rely heavily on the overall concept of detection and response. Similarly, the proper equipment (pocket sized or hand held) to be used by customs inspectors or other executive officers on everyday duty is closely linked to the training programmes and the scope of authority of the specific institution in cases of illicit trafficking. Clearing an alarm situation by identifying it as a nuisance alarm obviously requires more expertise (and authority) than just registering an alarm condition.

As a rule of thumb, it may be said that the more throughput is anticipated, the higher the degree of automation should be and the less the requirements for specialized expert knowledge should be. The more complex equipment gets for front-line officers, the greater the training demands and the fewer officers will be available.

5.2. Investigation limit and response

The desirable investigation limit governs the selection of instruments, and their associated detection limits and the deployment strategy. A discussion of instruments to achieve a certain investigation limit may thus be conducted only in conjunction with discussing the response method. If a limit is to be applied to certain activity levels, further considerations have to be made regarding possible shielding, type of radioisotope and detection geometry. The generalization of these assumptions may lead to reduced detection probabilities under adverse conditions; nevertheless, valid design criteria may be established for instrument specifications to maintain the chosen limits on the amount of radioactive substances.

An important planning step is to consider the actions to be taken following an alarm condition. The associated instruments must enable the officers to verify the validity of an alarm and to acquire enough information for the follow-up response to continue seamlessly. It is not unlikely that for particular cases independent limits will be established, as a guideline for the experts called in on second or higher levels of response. For example, once the radionuclide has been identified and found to be the ubiquitous ^{137}Cs, foodstuffs may be treated differently than other materials. Different recommendations may hold for various naturally occurring radioisotopes.

5.3. Training and training exercises

Training is an extremely important factor influencing the detection process. A successful detection can only be made if the measurement or alarm situation is interpreted properly by adequately trained personnel. It is very likely that front-line officers will be burdened with many duties. Identifying possible cases of illicit trafficking is another complex job that may even give rise to personal safety concerns, which may only be offset by proper training and exercising. There are frequent reports of excellent instruments having been shut down or having been ignored when an alarm occurs because of lack of training or because follow-up procedures are so cumbersome that response (i.e., interpretation) is too costly (regarding time, convenience and personnel). Training incorporates the 'human factor' into the overall detection strategy and the philosophy of instrument selection. Once training has been completed, exercises should be conducted that are a close simulation of a real world scenario. They are best conducted not in the classroom but right at the checkpoint, where the chosen implementation of defence against illicit trafficking may be put to test.

6. CURRENT INSTRUMENT TESTING ACTIVITIES

The following is a brief and non-exhaustive overview of current testing of instruments for detecting illicit trafficking.

6.1. The Illicit Trafficking Radiation Assessment Programme

The Austrian Government is supporting the efforts of the IAEA in counteracting illicit trafficking in radioactive and nuclear materials as a donor in kind. The Austrian Research Center Seibersdorf, Department of Radiation Protection, was asked to conduct a pilot study in this area in close collaboration with the newly installed IAEA Illicit Trafficking Radiation Assessment Programme (ITRAP), headed by K.E. Duftschmid.

The pilot study started late in 1997 and is to run for approximately two years. The scope had been defined in previous experts meetings.

The problem to be addressed is multifaceted and relates to the following:

(a) radioactive materials in scrap causing substantial problems in the steel manufacturing process,
(b) smuggled radioactive sources posing a potential health risk to the population, especially if disposed of illegally,
(c) radioactive or nuclear materials used for terrorist activities,

(d) illicit movement of fissile materials with the inherent threat of creation of weapons of mass destruction.

Whatever countermeasures are taken must be discussed in close co-operation with the relevant international organizations,which include the IAEA, the World Customs Organization (WCO), Interpol and the European Union. The latter has embarked on a dedicated programme to secure its outer border within the scope of the Schengen Agreement.

The goal of the ITRAP study is to perform intercomparison testing on stationary and hand held equipment of various manufacturers in a controlled laboratory environment and to conduct field tests on selected units. The main emphases will be on the technical aspects of monitoring equipment (e.g., detection threshold and detection probability), the operational aspects (e.g., ease of use, training requirements, rate of false alarms and support) and the commercial viability of the proposed equipment to regular border type situations. As of September 1988, 14 stationary systems were being tested. Final results are not yet available (for details, see Ref. [8]).

6.2. RADTAP

Various scenarios were extensively simulated and tested by the US Customs Service with a great variety of instruments in the so-called RADTAP testing effort at Harvey Point, North Carolina, USA, in May 1997. The results of the study have so far not been released for publication. Interested parties are referred to the chairperson of this session.

6.3. National investigations

A great number of tests have been conducted by national institutions, testing laboratories and manufacturers themselves. This session includes reports on a few such investigations. They will be summarized in more detail at the end of the session.

7. CONCLUSIONS

The variety of instruments and detection techniques available to aid in efforts to combat illicit trafficking is considerable. General recommendations as to instrument selection are rather limited, because instruments must be considered in conjunction with the overall response plan defined under national policy, the choice of detection methods not associated with instrumentation (e.g., administrative) and the choice of investigation level based on the threat potential perceived. Various options have been reviewed and both scenarios and associated detection strategies discussed. The wide discussion at this Conference of experiences with various instruments, various detection scenarios and various detection goals and strategies should be of considerable benefit.

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SUMMARY OF DISCUSSION

Technical Session 9

Chairperson: **D.E. Smith** (United States of America)

Rapporteur: **C. Schmitzer** (Austria)

D.E. SMITH (United States of America) *(Chairperson)*: In his presentation, C. Schmitzer, referring to the IAEA's draft Safety Guide on Prevention, Detection of and Response to Illicit Trafficking in Radioactive Materials, said that 'detection' is defined there as "[a] conclusion based on measurement and the interpretation of the results that there is a real case of illicit trafficking". In the US Customs Service, if a radiation detector is actuated by a radioactive substance, the customs official considers that 'detection' has occurred, regardless of whether subsequent investigations show that there is a real case of illicit trafficking. In my opinion, the definition of 'detection' in the draft Safety Guide could, if retained, confuse customs officials.

K.E. DUFTSCHMID (IAEA): The question of the definition of 'detection' is not closed; more work still has to be done on the draft Safety Guide.

P. DRYAK (Czech Republic): In his poster paper, M. Fabretto[1] refers to a railway wagon that was radioactively contaminated despite being accompanied by a 'not radioactive' certificate. Where was the wagon from, and by whom had the certificate been issued?

M. FABRETTO (Italy): The wagon was from Slovakia. It was not clear who had issued the certificate, but certainly it was not a governmental agency. This was a particularly impressive case (over 200 μGy/h), but one frequently finds high dose rates on wagons travelling with 'not radioactive' certificates, especially wagons from Slovakia.

K. DOLLANI (Albania): I would mention in this connection that two years ago the Italian customs stopped a number of Albanian trucks after measuring dose rates of more than 100 mrem/h. It transpired that the truck engines, made by Skoda, were contaminated.

D.E. SMITH (United States of America) *(Chairperson)*: Was it surface contamination?

K. DOLLANI (Albania): No, some of the engine parts were clearly already contaminated when the engines were assembled.

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[1] FABRETTO, M., "Some interesting findings from the radioactivity control of trucks and wagons", Safety of Radiation Sources and Security of Radioactive Materials, Contributed Papers, IAEA-TECDOC-1045, IAEA, Vienna (1998) 313–316.

P. CHARBONNEAU (France): I believe it has been established that the cylinder heads of the truck engines in question became contaminated during manufacture.

D. DRÁBOVÁ (Czech Republic): About 100 LIAZ trucks have radioactively contaminated engine parts; approximately 60 of them have been located, and the search for the others is continuing. In 1990, a used ^{60}Co radiation therapy source was lost from a temporary repository, probably stolen for its valuable lead shielding. It was later melted down at a steel works and incorporated into steel from which the aforementioned engine parts were manufactured.

C. SCHMITZER (Austria) *(Rapporteur)*: I should like to hear from those who work at border crossings whether they feel the need for very sensitive detection equipment, given the fact that such equipment is likely to result in a high rate of nuisance alarms.

A.G. ROTHER (Germany): I think there comes a point where, if the rate of nuisance alarms is high because the natural radiation background is high, the customs officials will simply switch the detectors off.

P. CHARBONNEAU (France): What one needs is detectors which allow for the natural background and with which the alarm is triggered when the signal to background ratio exceeds a certain value.

H.S. JEZIERSKI (Poland): Although the rate of nuisance alarms on Poland's border with the former Soviet Union is high (about one case every two days per border crossing), the Polish customs officials, who are required to report all cases to their superiors, do not switch off their radiation detectors. Among the reasons for the high rate of nuisance alarms are the vicinity of the Chernobyl region, through which many trucks pass on their way to Poland's border, and the fact that the alarm threshold for portal monitors is only 1.5–2 times the natural background.

W.P. VOORBRAAK (Netherlands): In paper IAEA-CN-70/73[2], H. Bitt talks of a neutron detector "capable of generating an alarm in 1 s as soon as the neutron flux is equivalent to 300 g plutonium source". I think that, in making such a statement, one should give details such as the form of the plutonium (whether it is in oxide form), the amount of shielding and the shape of the source.

P. CHARBONNEAU (France): The comparison of different plutonium measurement systems must be based on clear criteria such as the geometry, the distance and, above all, the thickness of the shielding used. Otherwise, the results obtained are not comparable. Similarly, the criteria for comparing detectors should be clearly defined in a protocol that specifies either a fixed distance and minimum

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[2] BITT, H., "Prevention of uncontrolled dissemination of radioactive materials", Safety of Radiation Sources and Security of Radioactive Materials, Contributed Papers, IAEA-TECDOC-1045, IAEA, Vienna (1998) 317–320.

detectable activity or a fixed activity per radionuclide and the distance at which the activity is detected.

K.E. DUFTSCHMID (IAEA): In the drafting of the aforementioned Safety Guide, we are considering, as minimum requirements for plutonium detection, 300 g of weapons grade plutonium (with 6% ^{240}Pu) detected by means of the neutrons (that is to say, complete shielding of the gamma radiation) at a distance of 3 m.

RESPONSE TO DETECTED CASES AND SEIZED RADIOACTIVE MATERIALS, STRENGTHENING OF THE AWARENESS, TRAINING, AND EXCHANGE OF INFORMATION

(Technical Session 10)

Chairperson

H. TAKIZAWA
Interpol

Summaries of Contributed Papers
IAEA-CN-70/11 and 97 were also presented

SECURITY OF RADIOACTIVE MATERIALS
Response to detected cases and seized radioactive materials, strengthening of awareness, training, and exchange of information

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Abstract

SECURITY OF RADIOACTIVE MATERIALS: RESPONSE TO DETECTED CASES AND SEIZED RADIOACTIVE MATERIALS, STRENGTHENING OF AWARENESS, TRAINING AND EXCHANGE OF INFORMATION.

Customs officers, border police and some national police are the chief enforcers of their country's laws or regulations concerning the importation, exportation or trans-shipment of goods. Today, these agencies must be trained to detect and interdict illicit traffic in materials, components and commodities associated with the development and deployment of weapons of mass destruction (nuclear, chemical, biological and missile) and the illicit movement of radioactive materials. The paper discusses response to detected cases of seized radioactive materials, strengthening of awareness, and training and exchange of information, with major emphasis nn training and exchange of information for border enforcement officers. Much needed attention is now being paid to the growing importance of the illicit movement of radioactive materials and the threat that is posed to the general public and to those officers who may come in contact with these substances in their work. Border enforcement officers must understand the hazards and should know how to protect themselves and the public from those hazards. Fortunately, radioactive materials may be easier to detect and identify than other contraband because of their radiological signature and the properties of any shielding materials used to reduce or eliminate that signature. The paper discusses some of the training being conducted to inform and protect border enforcement officers and the public from the hazards associated with illicit movement of radioactive materials or materials associated with weapons of mass destruction.

1. INTRODUCTION

Today's world is faced with many challenges, including that of preventing the proliferation of weapons of mass destruction (WMD), which includes nuclear, chemical and biological weapons and their missile delivery systems, their components and the technology necessary to manufacture them. Many of the supplier nations of these commodities, components and technologies have banded together to ensure that these items do not fall into the wrong hands.

However, no matter how many laws or international regulations are put into place or how many agreements are signed, there will always be those who attempt, illicitly, to acquire or sell such materials. In the end there is only one mechanism that is globally available to help stop the spread of WMD and of illicit radioactive non-fissile materials. That mechanism is the watchful eye of highly trained, motivated and properly paid border enforcement officers. It behoves all of us to take an active role in ensuring that these officers receive all the training and equipment they need to impede the illicit movement of radioactive and other WMD materials.

The break-up of the Soviet Union resulted in the creation of many new countries, with new borders to be controlled. In many cases, the new borders of the former Soviet Union (FSU) and some of the borders of Central Europe are guarded by enforcement officials with limited experience and training. While most established countries have many seasoned border enforcement personnel, there are thousands of border enforcement personnel who only began their careers within the last five to six years. In many of these countries the turnover rate of border enforcement personnel is high.

In this Conference there has been extensive discussion of radiation sources, their safety and their transportation, and on international co-operation, including reporting systems and databases. There have been discussions of the security of radioactive materials and of techniques for detection and identification of illicitly trafficked radioactive materials. If all of the laws, regulations and safety procedures are followed, radioactive materials would be properly licensed and properly utilized, and the world would be much safer.

A problem arises, however, when a radioactive material is knowingly or unknowingly transported in a covert manner. This material poses a public health risk and may be used for acts of terrorism or in a nuclear weapons programme.

Thus there is an urgent need to detect illicit traffic and to provide protection for those performing the detection, for bystanders and for the public. This leads to the basis for this paper, in which we emphasize training and the need for the rapid exchange of information on the illicit movement of radioactive materials and for the full co-operation of adjacent and transit countries.

In this latter context, it is important that radioactively contaminated materials detected at a border crossing not be sent back to the country of origin without alerting the appropriate officials on the other side. Otherwise the shipper may attempt to cross at another port unprotected by detection equipment. This manoeuvre, called port shopping, is a common smuggling approach. For instance, radioactively contaminated scrap metal was detected at one location and was sent back into the country from which it was exiting; from there it was shipped to an unprotected border crossing and entered the intended country. The scrap was reprocessed and the product went out to the public before the manufacturer discovered that the scrap was radioactive.

2. TRAINING

Many countries and agencies have joined together to exchange information and training. The IAEA and the World Customs Organization (WHO) have formalized their co-operation in a Memorandum of Understanding signed in May 1998. The IAEA and WCO co-operate in areas that include training, exchange of technical information and the organization of technical meetings such as this Conference. In June 1997, the IAEA and WCO co-sponsored a training course for customs personnel in Central and Eastern Europe [1, 2].

Most nations have customs and border police training academies where general training is conducted. Many of these academies, however, have limited ability to conduct hands-on radiological training because the handling of radioactive material may not be permitted at these sites or because the sources needed may not be available. However, classroom radiological training can be conducted at these sites.

Some countries utilize their nuclear research facilities (e.g., the Institute of Nuclear Energy in Swierk, Poland) for radiological training. While in general we do not like to single out a particular country, we were most impressed with the radiological training of Poland's border guards, who have heavy responsibilities for interdicting illicit radioactive materials (e.g., materials contaminated as a result of the Chernobyl accident).

In May 1996, when we were in Poland, we saw that at virtually every border crossing there were several sensors for alpha, beta and gamma radiation. However, even in Poland, the most radiologically protected country that we have encountered during our assessment tours, the green border is virtually impossible to secure fully. Other countries, recognizing the severity of the problem, are beginning to employ radiation detection at their borders, and their border enforcement personnel are increasingly being trained in the detection of radioactive materials.

The US Department of State funded the development of a US Customs Service training programme, called Project Amber, for which the US Department of Energy provided technical expertise. This programme provides seminars on the identification, interdiction, investigation and seizure of nuclear and nuclear related materials

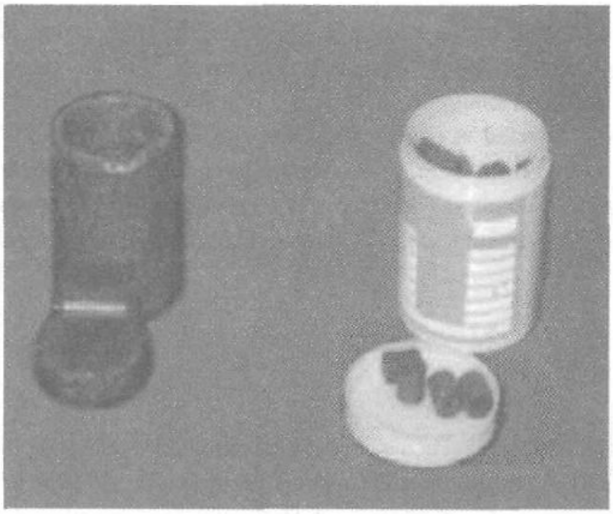

FIG. 1. Illicit uranium cylinder (with lead pig) (left) and reactor fuel pellets (right)

and on other WMD issues. The training is conducted within participating Central and Eastern European countries. To date, over 600 border enforcement officers in nine countries have received this training.

Each training session lasts five days. The training is directed at front line officers and supervisors. Before the course is given, assessments are conducted at the country's borders to identify the needs of the country, the locations at threat and the country's enforcement and investigative capabilities.

This project continues under the name Amber II and is expanding to include other countries. An enhanced version of this programme is the US Customs Service–Department of Defence Counterproliferation Programme. This Department of Defence–funded programme provides similar training but also includes the loan of high technology and low technology equipment to the receiving country. Another facet of this programme is the possibility of stationing a US Customs Service specialist in the recipient country to assist with training or to help upper-level border enforcement managers establish new policies, procedures, regulations or laws. The third aspect of this programme is the training of mid-to-upper level managers and of national training academy officials in the USA.

At one border crossing there were 120 trucks backed up, resulting in an estimated three day wait to cross the border. We visited this location in the winter, and there were not enough felt winter boots for each officer for each shift. Some of the boots were left behind for the next shift, and when they wore out, inspections ceased. There was insufficient gasoline to chase smugglers if the incursion happened more than a few kilometres from the border crossing.

At another border crossing, stationary radiation monitors had been installed, and hand held radiation detection systems were deployed. At this site there had recently been a seizure of radioactive materials as a result of the radiation sensors deployed and the well trained border enforcement personnel. At this site, everything was very well handled and the personnel were well trained with regard to radioactive materials attempting to cross the border.

At another border crossing, radiation detection equipment was available but the batteries in the equipment were dead. Clearly, even with the right equipment and technical training, border enforcement personnel must be motivated. The motivation is supplied by intensive training on the dangers of the materials that they may encounter and how important it is for their own people that the officers stop the traffic in this type of contraband.

At another location we were told about the seizure of uranium metal concealed in a lead container and about some smuggled reactor fuel pellets (Fig. 1). The lead pig in which the smuggled uranium metal was contained had a dented lid, permitting radiation to stream out. Without the dent, the uranium might have been sufficiently shielded to allow it to pass through the radiation detectors at the border.

The reactor fuel was of considerable interest, because its size and colour showed that it had not gone through the final sintering process required for use in a reactor. The size and shape of the fuel indicates that the fuel pellets are for a particular, identifiable reactor type. The pre-sintering and other conditions of the fuel indicate that it came from the reject line of the fuel fabrication plant. Fuel for a specific reactor type is often produced at a small number of sites and in some instances at only a single site. With this type of information it would be possible for border enforcement investigators to identify the handful of people who could have access, motive and opportunity to perpetrate such a theft. This type of information is extremely valuable for a comprehensive, transnational investigation that might result in completely shutting down a dangerous ring of WMD thieves and smugglers.

Even if a country has sufficient detectors to cover every border crossing, and portable radiation detectors to assist with green border incursions, it is still a difficult challenge for enforcement personnel to discover and seize illicit radioactive materials. It is difficult to determine whether the radioactive materials in question are in fact illicit. The material can be going under a legitimate export license, but may be something other than that stated on the manifest. In this case, the radiation detection systems would alert, but the shipment would appear legitimate. Without additional information or additional means to identify the isotope, directly or indirectly, the officer cannot ascertain if the shipment is what it is purported to be. Thus some training is required in order to make such a determination even for a manifested radioactive shipment.

One will also encounter legitimate radiation sources going to a legitimate destination. In fact, the great majority of radioactive 'hits' that occur at borders will be legitimate. These may be industrial sources for X raying welds, for example, or shipments going to a medical treatment or research facility. People under medical treatment with radioisotopes may themselves be radioactive for some period of time. This time will depend upon the biological half-life (this includes both the radioactive decay of the isotope and the rate at which the isotope is removed by normal bodily excretions) of the isotope used in the treatment. The border enforcement officer must be able to distinguish between a person receiving radiological medical treatment and a person transporting illicit radioactive material.

At the well protected borders of even small counties, one may encounter thousands of hits each year from the legal shipment of radioactive materias. Many common materials, such as lantern mantles, fertilizer or bananas, contain thorium, potassium or other elements, which have enough radioactive isotope to set off very sensitive detectors or to give a reading well above background. Radiation sources are used in the metal fabrication industry, in medical research and in moisture sensing equipment and are incorporated into products such as runway lights, smoke detectors and instrument dials. Radiation sources are also used in the nuclear industry as calibration standards and in radioisotopic thermal generators for electrical generation in remote locations.

Radioactively contaminated metals are continually found in global commerce. One area of particular concern is radioactive sources left behind when an industry, factory or medical facility is abandoned. When the site is cleaned up, the new owner may be unaware of the presence of the abandoned source, and it is likely to be thrown in with other scrap metal and shipped to a scrap metal reprocessing site. After recycling, the material may enter commerce as a seemingly innocent, but dangerously radioactive, product.

It is also important that in the training it is stressed that illicit radioactive materials may not always come directly from the supplier. Frequently, radioactive sources have been discarded, or have been in a location other than where they were manufactured. That is, radioactive sources are not even necessarily coming directly from their country of origin. In fact, as is the case with many illicit commodities, the goods may have been parked in another country or location for some period of time. Then, when it is believed that a high price can be got, they enter the global trade in contraband, the world of the smuggler or terrorist.

Many isotopes are used in cancer therapy and in the treatment of arthritis. The training the border enforcement officer receives must help in identifying the radiation source and in making an educated judgement as to whether or not a shipment is legitimate. The officer must know when to hold a shipment and call for an expert opinion before releasing it.

A border enforcement officer must also be aware of the effects of radiation on humans and of the basic factors associated with radiological protection, such as minimizing the exposure time, maximizing the distance from the source and providing shielding.

The training must also focus upon the many frauds that are perpetrated today concerning radioactive materials. The officer must understand that the shipper may not know the true nature of the materials found in the shipment. Project Amber training concentrated on the various methods the US Customs Service uses to locate and identify illegal shipments. Also taught is targeting, profiling and search techniques for cargo containers, trucks, automobiles and people. The training also teaches behavioural analysis techniques and how to read body language to help separate truthful from untruthful people. Also it is vitally important for the officer to understand international shipping documents, manifests, bills of lading and airline tickets. All these items are usually printed in a foreign language, making it doubly difficult for the customs or border police officer to comprehend the information they hold.

While much of this training (including role playing) can be conducted in the classroom, hands-on practical exercise training is better. Experience with Project Amber indicated the need for more practical training in a border enforcement environment. In light of this, the US Congress provided funding for the US Department of Defense to support the US Customs Service. The purpose of this funding is the threefold approach cited earlier. This joint initiative will establish training of border enforcement personnel from all of the FSU and central European countries and from other 'at risk' or transit countries.

A portion of this funding provided for the establishment of a special training centre, called INTERDICT/RADACAD, at the US Department of Energy's HAMMER training facility at the Hanford Nuclear Site in Richland, Washington. HAMMER is a 50 ha (120 acre), US $30 million facility for training in enforcement, worker health and safety and emergency response. This facility brings mid-to-upper level border enforcement personnel to the USA for concentrated training away from their normal duty station. The purpose is to help them become familiar with the problems and dangers their line officers may encounter trying to identify or intercept a shipment of WMD materials. This training will help them establish or implement new WMD polices, procedures or regulations. The so-called INTERDICT portion of the programme concerns the interdiction of materials, components and commodities associated with the development or deployment of WMD. The 'Radiation Academy'(RADACAD) portion concerns training for all radioactive materials. The special nuclear materials ^{235}U, ^{233}U and ^{239}Pu, which fall into the WMD category, are also dealt with in the RADACAD portion of the training, and samples are available for training purposes.

In this programme, the border enforcement participants are primarily customs officers, border guards and national police. INTERDICT/RADACAD includes training on all WMD types, their components and the materials, commodities and components used in their development, deployment and manufacture. The training also covers the international lists associated with nuclear and nuclear dual use items

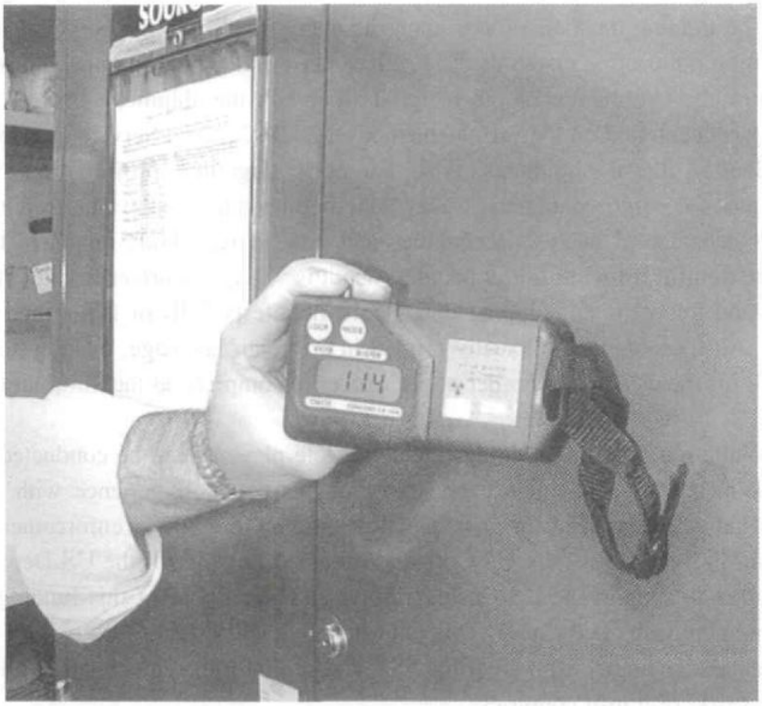

FIG. 2. Gamma densitometer.

found in the Nuclear Suppliers Group Lists [3], the biological and chemical items of the Australia Group[1] and missile components and materials of the Missile Technology Control Regime[2].

The training deals with the targeting of particular shipments and the people involved who may cross at any border location. It covers vehicle searches and the body language of persons crossing the border. The course also includes training on a mobile X ray unit which the US State Department has provided to several Central European countries. This system includes a transmission and backscatter X ray system combined with a very sensitive gamma detector. If a gamma emitting material is not well shielded, the gamma detector will pick it up. If it is a highly shielded source, the X ray detector will pick up the shielding materials. During the training each person is issued a so-called radiation pager. The radiation pager, developed for the US Customs Service, is a very sensitive gamma sensor using a caesium iodide scintillator and is worn on the belt or carried in a breast pocket. The system can be set

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[1] Australia Group: see <http://www.acda.gov/chemical.htm>.

[2] Missile Technology Control Regime: see <http://www.acda.gov/treaties.htm>.

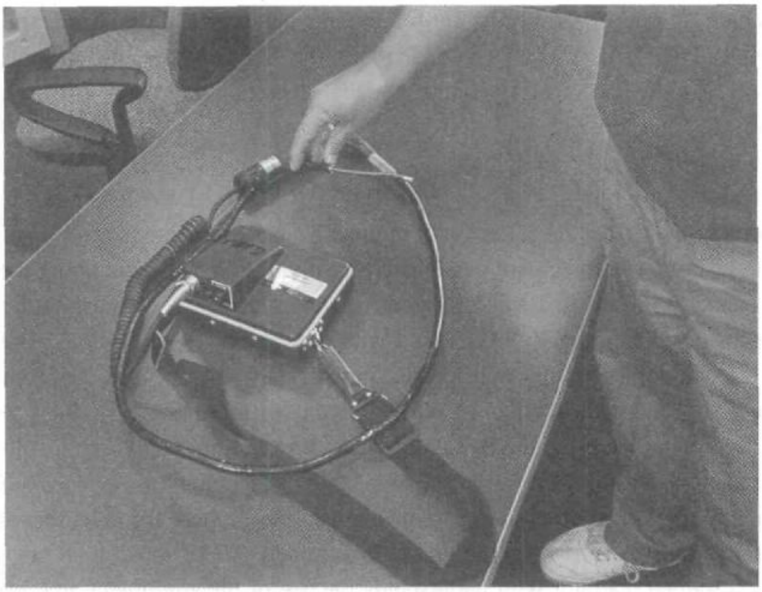

FIG. 3. Fiber optic scope.

to various threshold levels. Training in the use of the radiation pager, including how to interpret readings and change settings and how to determine if it is working properly, are part of the course. The radiation sensor associated with the mobile X ray van is also brought into the training. A gamma spectrometer is also used in the training. The gamma spectrometer is a hand held unit that takes about a minute to identify many of the radioactive isotopes likely to be encountered. This permits the officer to determine whether a source is legitimate and, if so, to permit the shipment (or medically treated person) to proceed without delay. Suspicious shipments are moved aside for a full accounting and a safe and informed search of the vehicle, conveyance, shipment or person in question.

Another detection system that personnel are trained upon is a material identification system which uses eddy current technology to detect and identify strategic materials. Other advanced detection devices that personnel are trained on are (1) a gamma densitometer (Fig. 2) called the Buster, used to detect density anomalies or hidden compartments; (2) electronic measuring tapes to look for false bulkheads; (3) fibre optic scopes (Fig. 3) to look within confined spaces for hidden objects and (4) an ultrasonic pulse echo interrogation System to search for and identify liquids and other items hidden in sealed containers. The material identification system and the pulse echo interrogator may also have a significant role in preventing ordinary customs fraud, thereby enhancing revenue production.

Once a country's border enforcement personnel have been trained at INTERDICT/RADACAD, it is intended that the US Government, at some future date, will loan the participating country much of the equipment they used in training. The US Customs Service will deliver the training in country, directly to the line officers that will use the equipment.

Training programmes such as INTERDICT/RADACAD demonstrate the need to incorporate training for the detection of radioactive materials into the full training programme of border enforcement personnel. Sensitivity to WMD smuggling must be a global standard for all border enforcement personnel. However, it must not become a burden for personnel already overloaded with duties and responsibilities. The use of multiple technologies, routine and advanced, may relieve the line officer of some of the burdens associated with an effective WMD interdiction programme. We have seen how the X ray system backs up the radiation sensor, how the fibre optic scope, ultrasound and the gamma densitometer can locate hidden items that might not be accessible, how the material identification system can distinguish one element from another and how the gamma spectrometer identifies specific isotopes. All of these tools are useless without a trained operator who understands the use of the equipment and will use it enthusiastically. The training and the tools go hand in hand. No matter how good the equipment is, there is no replacement for the watchful eye and sixth sense of a well trained border enforcement officer. We can only hope that, with better training and equipment, we can increase the effectiveness of these officers, permitting the unfettered flow of legitimate cargo through our ports of entry and yet significantly improving the chances of detecting illicit movement of radioactive and other strategic goods.

3. INFORMATION SHARING

At this point it is easy to see that information sharing has become extraordinarily important, not only information about the types of materials illicitly transferred around the world, but also information about the means by which they are transferred and the methods of concealment.

Although national intelligence agencies are naturally reluctant to provide any information that could compromise their sources or methods, every effort must be made to share the most sensitive WMD intelligence with all concerned border enforcement agencies. Databases such as the International Atomic Energy List database and other national databases are very important in the sharing of information. At INTERDICT/RADACAD, information that is brought by the participating countries is freely shared with the other participating nations. The US Department of State is providing assistance to INTERDICT/RADACAD by developing a database that will be made available to participants (with a password) on the Internet. As verified

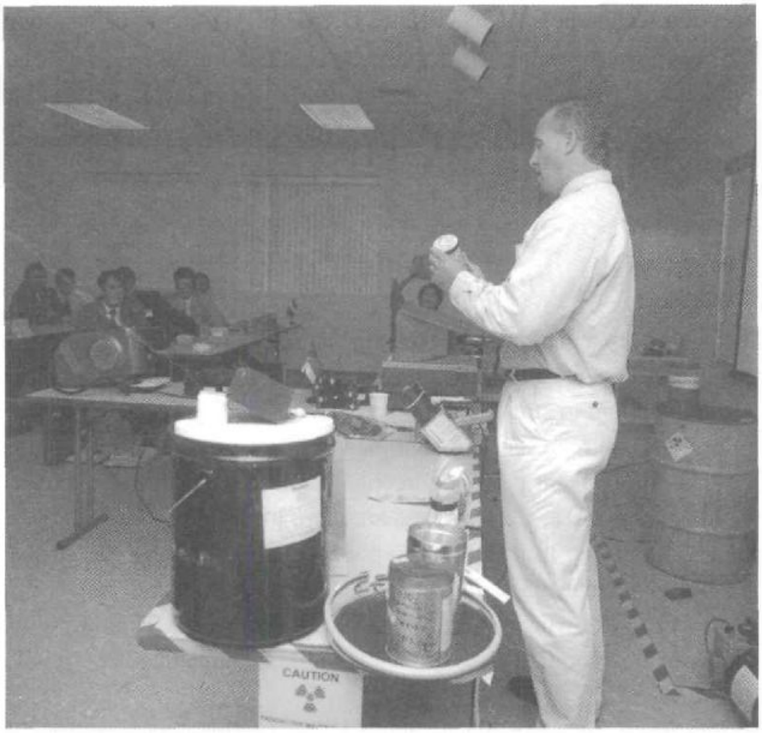

FIG. 4. Training on signatures of weapons grade and non–weapons grade plutonium and uranium.

information is received, it will be included in the database and will quickly become available for use by participating countries.

The US Department of State will fund additional infrastructure development at RADACAD. Soon, the facility will provide a complete border enforcement environment, from large commercial passenger aircraft to the trucks, trailers, containers and even a fishing vessel that officers may encounter at their posts. We plan to offer new training in green border and riverine incursions and patrol operations to cover every aspect of the clandestine movement of WMD materials. Some newer agencies need knowledge and practice in task force operations, both national and transnational. Soon, we will offer training to upper-level managers on how they might set up command, control and communications centres and intelligence sharing among their national agencies and their colleagues on the other side of the border.

With regard to training in the detection and interdiction of radioactive materials, it is important that students be able to handle and study actual radiation sources. It is important that sources are distinguishable from other sources by shielding and by other detection techniques. At INTERDICT/RADACAD, many of the sources that one might encounter at the border are provided, including weapons grade and reactor grade plutonium; weapons grade, natural, low enriched and depleted uranium (Fig. 4), and other common radioactive sources such as americium, strontium, caesium and cobalt.

4. CONCLUSION

There has been a marked increase in the amount and depth of training provided by various nations to control the illicit movement of radioactive materials. During this training it is important to stress that the great majority of radioactive hits at a border crossing are likely to represent the legitimate transfer of radioactive materials. It is important that enforcement personnel recognize these legitimate shipments and not unduly hold up commerce. Certain areas are more likely to encounter large numbers of legitimate shipments. In a Bellona Report [4] it is stated that "as of the first of January 1993 more than 9352 radioactive sources were in civil hands distributed among 39 companies or institutions on the Kola Peninsula". Highly industrialized areas, mining and exploration areas are likely to have a large number of civil uses for radioactive sources.

The traffic in illegal WMD materials is most vulnerable at national borders, where shipments must cross from one country to another. This is where any type of contraband is most likely to be recognized, intercepted and seized. Training and technical assistance to those most likely to encounter this type of material must continue to be emphasized.

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[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Range of Topics on IAEA Meeting Agenda, IAEA News Briefs **13** 3 (80) (July/August 1998) 9–10.

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Communication Received from Certain Member States Regarding Guidelines for the Export of Nuclear Material, Equipment and Technology, Rep. INFCIRC/254, Rev. 3, Parts 1 and 2, IAEA, Vienna (1997 (Part 1) and 1998 (Part 2)).

[4] NILSEN, T., BØHMER, N., Sources to [sic] radioactive contamination in Murmansk and Arkhangel'sk counties, Bellona Report No. 1, Bellona Foundation, Oslo (1994); <http://www.bellona.no/e/russia/murmark/murmark8.htm>.

SUMMARY OF DISCUSSION

Technical Session 10

Chairperson: **H. Takizawa** (Interpol)

Rapporteur: **W.C. Cliff** (United States of America)

F.G. GILFEDDER (United Kingdom): The seizure of nuclear material may be followed by a criminal prosecution (as indicated by A. Strezov[1]), for which forensic analysis of the material is necessary in order to link the material (or its packaging, or the means by which it was transported) to a particular individual. The technical experts carrying out forensic analyses should know their own countries' legal requirements in that connection and should be aware of the needs arising from those requirements — for example, the need to maintain an audit trail from the time of seizure to the time of final disposal and the need to avoid cross-contamination. In addition, they should know how to present evidence (witnesses' statements, photographs, etc.) in court.

J.M. KARHNAK (United States of America): Listening to the numerous accounts of incidents involving damaged radiation sources, I am concerned that some countries might start refusing admission to all radiation sources, even those urgently needed in medicine and industry.

S.I. KONDRATOV (Ukraine): What are the criteria for the selection of participants in the World Customs Organization/IAEA training courses described by E. Saka[2]?

E. SAKA (World Customs Organization): Participants are selected by the States putting them forward for the courses. The WCO and the IAEA inform the States which categories of people (for example, customs trainers) are likely to benefit most from the courses, indicating also the language requirements to be met and the kinds of experience the participants should ideally have.

P.N. MALHOTRA (India): I gained the impression from Technical Sessions 4 through 7 that illicit trafficking in nuclear and other radioactive materials is not such

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[1] STREZOV, A., "Problems and management of radioactive sources and measures against illicit trafficking of nuclear materials in Bulgaria", Safety of Radiation Sources and Security of Radioactive Materials, Contributed Papers, IAEA-TECDOC-1045, IAEA, Vienna (1998) 337–339.

[2] SAKA, E., DUFTSCHMID, K., "The WCO/IAEA Joint Training Programmes for Customs Services on Radioactive Material Smuggling", Safety of Radiation Sources and Security of Radioactive Materials, Contributed Papers, IAEA-TECDOC-1045, IAEA, Vienna (1998) 329–333.

a big problem. From Technical Sessions 8 through 10, on the other hand, it would seem that it is indeed a big problem and that the same sort of co-ordinated effort should go into combating it as into the fight against drug trafficking. What is being done to mobilize such a co-ordinated effort?

E. SAKA (World Customs Organization): The May 1997 Memorandum of Understanding between the WCO and the IAEA, referred to in paper IAEA-CN-70/97, is one step in mobilizing a co-ordinated effort. In addition, the WCO is establishing closer ties with Interpol, the European Commission and a number of governmental and non-governmental organizations, the aim being greater co-operation and information exchange.

S.K. SHKSHOUKI (Libyan Arab Jamahiriya): Most developing countries are ill prepared to combat illicit trafficking in nuclear and other radioactive materials, and smugglers are likely to take advantage of that situation. I should like to see the IAEA and other international organizations helping developing countries through the provision of legal advice, information, training and equipment.

K.E. DUFTSCHMID (IAEA): In the past few years, the IAEA has organized several technical committee meetings, with participants from developing countries, and several expert missions to developing countries. There are plans for holding a symposium on various technical issues in the year 2000, and the IAEA is publishing a considerable amount of relevant literature.

W.C. CLIFF (United States of America): It would be a good idea to make more financial resources available to pay for the participation of people from developing countries in meetings of the kind being organized by the IAEA. Also, the Internet could be used as an economical way of keeping developing countries informed, perhaps through the use of secure sites accessible only to law enforcement authorities and the like.

H. TAKIZAWA (Interpol) *(Chairperson)*: I would add that the entire raison d'être of Interpol is information exchange, in which developing countries can participate and from which they can benefit.

I.A. SLAVNOV (Interpol, Russian Federation): The United Nations International Drug Control Programme's database relating to money laundering contains information on relevant national legislation. Is there a database on national legislation concerned with illicit trafficking in nuclear and other radioactive materials?

H. TAKIZAWA (Interpol) *(Chairperson)*: Not as far as I am aware.

SUMMARIES BY CHAIRPERSONS OF THE TECHNICAL SESSIONS

(Concluding Session)

Chairperson

D.J. BENINSON
(Chairperson of the Scientific Conference Programme Committee)

CHAIRPERSON'S SUMMARY OF TECHNICAL SESSION 1:

THE REGULATORY CONTROL OF RADIATION SOURCES, INCLUDING SYSTEMS FOR NOTIFICATION, AUTHORIZATION (REGISTRATION AND LICENSING) AND INSPECTION

Chairperson
G.J. DICUS
US Nuclear Regulatory Commission,
Washington, DC, United States of America

The intent of Technical Session 1 was to provide information about what constitutes an effective regulatory programme and to provide insights into existing regulatory programmes. The session had 17 contributed papers, including two oral presentations. I again want to thank our rapporteur, G. Weimer, for the great work he did to provide an overview of the session and his synopsis of the papers.

The programmes and activities defined in the submitted papers, including the oral papers, included a wide range, from those long in existence to those very new — a year old or less; the papers included programmes that are very mature and strong and programmes that are in their infancy; and finally, the session included programmes that are very effective and those that appear to be much less effective.

Recognizing that we have such a range of programmes is critical to our definition of the issues and our resolutions.

For example, and I recognize that this is a very sensitive issue, it has been suggested that radioactive sources and materials and radiation producing machines should not be transferred to areas that have regulator programmes that are known to be (or believed to be) ineffective. I take no position today on this issue, but I recognize it as a serious question, and perhaps it should be discussed at least at some point in the future.

The following is a list of those programme elements that most regulatory authorities had in common and that were identified as essentials of an effective radiation control programme.

(1) Legislative authorization.
(2) Regulations.
(3) Authorization to possess and use radioactive sources and materials or radiation producing machines through a licensing or registration programme which includes notification.

(4) Inspection.
(5) Response to inspection findings, including positive feedback for performance improvement and quality assurance or (as necessary) fines and, in extreme cases, cancellation of the licence or registration.
(6) Training and retraining.

Additionally, some programmes included the following:

(1) Waste storage requirements.
(2) Documentation of transfers.
(3) Programme updates and modifications.

Also, in most cases there were multiple agencies involved in the control of radioactive materials and radiation producing machines.

Some countries noted the following as particular problems:

(1) Record keeping and communication.
(2) Ineffective inspections and feedback.
(3) At least one country noted an uncompleted legal framework and insufficient training.

This calls into question the issue of priority. Sometimes, out of necessity, a country cannot give high priority to radiation protection when it is difficult for the country to provide the basic necessities of life for its people.

Less frequently mentioned elements in the papers were:

(1) Security of radioactive sources and materials.
(2) Performance indicators.
(3) Inventories and registries.
(4) Co-ordination with customs officials.
(5) Funding of programmes.

It is worthwhile to spend a little time discussing funding. A country may have all of the basic elements and support systems for an effective programme, but if it is not sufficiently funded, all or most of the worthwhile infrastructure is for nought. So what constitutes sufficient funding, and how it should be supplied, become important points. Should funding be supplied entirely by the government, or by the licensees and registrants through fees, or by a combination of these? Obviously, this is a decision to be made by individual States, but it should not be overlooked as an essential element.

Returning briefly to one of the basic elements, licensing, registration and notification, let me put a slightly different twist on the issue. When nuclear materials or radiation producing machines are transferred between countries, should the regulatory authority in the country of origin notify the regulatory authority in the receiving country? I believe this is another issue appropriate for discussion.

Finally, two additional important items were identified in the session:

(1) Consideration of asking the IAEA to establish a registry of lost, stolen and abandoned radioactive sources.
(2) Consideration of a convention on radiation safety.

CHAIRPERSON'S SUMMARY OF TECHNICAL SESSION 2:

SAFETY ASSESSMENT TECHNIQUES APPLIED TO RADIATION SOURCES

Design and Technological Measures, Including Defense in Depth and Good Engineering Practice

Chairperson
D.J. BENINSON
Nuclear Regulatory Authority,
Buenos Aires, Argentina

The first part of Technical Session 2 consisted of two rapporteur's overviews.

N. Sugiura covered assessment technology for radiation sources. He reviewed the state of the art of probabilistic methods and their potential use for radiation sources. Probabilistic methods are necessary to identify possible weaknesses in safety systems which might be overlooked by deterministic methods. The presentation reviewed the sequence of steps for their application:

(a) Identification of possible accidental and disruptive scenarios using techniques such as Hazard and Operability (HAZOP) and Failure Mode and Effects Analysis (FMEA), complemented by the use of checklists and 'what if' analysis.
(b) Once scenarios have been identified, probabilistic techniques based on fault trees and event trees can be used to estimate the probability of all detrimental consequences.

The presentation addressed specifically the uncertainty associated with human behaviour and with dose estimation.

The methodology was illustrated by an application of these techniques to an example of the potential for chemical explosion that may occur during a procedure for cleaning an ion source to remove the adherent caesium from the sandpaper, to wash it and to rinse with ethyl alcohol.

The presentation summarized ICRP Publication 76 and the criteria presented therein for protection against potential exposures.

The second overview, by R.G. McKinnon, dealt with design safety and technological protective measures. He described the components of 'defence in depth' for typical irradiators.

(a) Some of the systems described could be backfitted to equipment of older design, improving safety substantially, as shown by the ICRP Publication 76 example.

(b) Good engineering practice helps to reduce the probability of accidents.

The rapporteur gave a list of good practices by the suppliers, in particular the need of keeping a surveillance of sources and equipment over their life, and suggested that the supplier conduct safety audits at the time new sources are added to the supplied equipment.

It can be shown that the major component in almost all fatal accidents is human error arising from lack of understanding. It is therefore evident that proper training of users is essential. Also important is to have the operating and maintenance instructions avail able in the local language.

CHAIRPERSON'S SUMMARY OF TECHNICAL SESSION 2:

SAFETY ASSESSMENT TECHNIQUES APPLIED TO RADIATION SOURCES
Design and Technological Measures, Including Defence in Depth and Good Engineering Practice

Chairperson
D. QUÉNIART
Institute for Radiation Protection and Nuclear Safety (IPSN)
Fontenay-aux-Roses, France

I have little to add on the subject of Technical Session 2, the last two presentations of which described the safety and security strategy adopted in Israel.

The first of these highlighted the importance and, at the same time, the difficulty of establishing a system of regulatory control for the effective verification of the way in which users discharge their responsibilities.

The last presentation was a summary of the only contribution on standardization, which is clearly a way of sharing and formalizing good practices, not only in terms of the design, but also in terms of the use of radioactive sources.

CHAIRPERSON'S SUMMARY OF TECHNICAL SESSION 3:

MANAGERIAL MEASURES, INCLUDING SAFETY CULTURE, HUMAN FACTORS, QUALITY ASSURANCE, QUALIFIED EXPERTS, TRAINING AND EDUCATION

Chairperson
D. DRÁBOVÁ
National Radiation Protection Institute,
Prague, Czech Republic

The International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources establish basic requirements for protection against the risk associated with exposure to ionizing radiation and for the safety of radiation sources that may deliver such exposure.

1. REGULATORY AUTHORITY

An adequate regulatory safety infrastructure requires the existence of a regulatory authority, established by legislation, and a programme consisting of the following basic elements:

(a) Regulations that establish the requirements and standards of safety,
(b) A system for notification and authorization (registration and licensing),
(c) Compliance monitoring, including inspections,
(d) Actions to enforce compliance with regulatory requirements,
(e) Investigation of accidents and management of emergencies,
(f) Dissemination of information related to the safety of sources.

The efficiency of this system is strongly dependent on the availability of reliable information on the inventory, location and ownership of radiation sources and installations, the administrative status of the facilities, prompt processing of inspection reports and follow-up of regulatory actions.

Several comprehensive national information systems for regulatory authorities are already generally available or under development. The IAEA has developed the Regulatory Authority Information System (RAIS), which is being simultaneously introduced in 53 countries receiving assistance under the Model Project on Upgrading Radiation Protection Infrastructure.

2. FACTORS INFLUENCING THE SAFETY OF RADIATION SOURCES

Despite advances in equipment design and improved safety and security systems, sources get out of control owing to many factors. The primary causes of sources escaping control can be categorized as follows:

(a) Failure to follow operational procedures, including the requirements of a regulatory authority.
(b) Inadequate training, which includes ineffective initial and refresher training programmes.
(c) Inadequate regulatory control. This may be due to an ineffective regulatory authority, or it may be that no radiation protection infrastructure has been established. Effective regulatory control by a system of authorizations is essential to establish standards for the possession, use and disposal of radiation sources and radioactive materials.
(d) Inadequate maintenance. Failure to meet the manufacturer's recommended level of maintenance may result in breakdown of essential components. An inspection of equipment prior to its use is very important, because it will detect unsafe conditions.
(e) Human error. Even if equipment is operating properly and effective operating procedures are established, the safety of a source relies heavily on personal judgement and response. The probability of human error increases during work under adverse and stressful conditions.
(f) Wilful violation. Training, equipment design and the implementation of effective operating procedures cannot stop an individual from deliberately violating safety procedures. The probability of these deliberate acts increases during work under stressful conditions and is due especially to fatigue, economic factors, production pressures and the like. Wilful violations are more likely to occur in organizations where there is no strong safety culture.

3. SAFETY CULTURE

Two general components of safety culture have been defined by the International Nuclear Safety Advisory Group:

(a) A framework in the organization that is created by management.
(b) The attitude of staff at all levels in responding to and benefiting from that framework.

The development of these components is of great importance considering the widespread use of radiation sources in medicine, industry, agriculture, research and teaching. Safety culture and feedback from operational experience are of critical significance for preventing radiation sources from escaping control.

4. THE PROBLEM OF 'ORPHAN' RADIOACTIVE SOURCES

International experience has shown the existence of radioactive sources not attributed to an authorized user or installation and therefore out of the control of the user or the regulatory authority. These sources, often called 'orphan' sources, may have been displaced, discarded, lost or stolen, and in some cases the regulatory authority may have no notice about them until an abnormal situation occurs.

The regulatory authority should have mechanisms to enable timely detection and management of such sources.

There are good examples of orphan sources programmes from the USA and Argentina. The activities of the US Environmental Protection Agency's programme include:

(a) A survey to identify sealed source types and potential quantities.
(b) Investigation of source management problems and finding alternatives to present systems for the control and disposition of sources.
(c) Development of a nationwide sources database.
(d) Development of a programme for the efficient and cost effective disposition of orphaned sources.
(e) Expanding outreach to the widest possible audience to help with source identification and to publicize disposal options for sources and the availability of sources no longer needed by current users.

The problem of orphan radiation sources is of growing importance, especially in countries of the former Eastern bloc. There are quite frequent events involving contamination or ionizing radiation sources in loads of metal scrap or in metallurgical products. The problem of metal contamination is a long term one and requires that the level of radiation be constantly measured by scrap users and metallurgical works. It also requires that licensees be forced to handle sources according to procedures stipulated by law. Indirectly, this issue is linked with an unsatisfactory state of institutional radioactive waste disposal.

5. CONCLUSIONS

It is clear that some international measures should be taken to achieve better and more or less harmonized control of radioactive sources worldwide. It would be useful if the key elements of orphan radiation sources programmes could be included in an international recommendation on management of such sources. It also seems necessary to achieve a kind of international consensus on clearance levels for metals. There is already a consensus on exemption levels, but clearance levels differ strongly from country to country. It might be helpful, prior to continuing discussion on clearance levels, to reach a consensus on what is in fact meant by the terms exclusion, exemption, authorization and clearance.

There is quite a lot of work ahead of us in this field, but this is challenging work and every success, no matter how small, will be a step towards a better system for the safety of radiation sources and the security of radioactive materials.

CHAIRPERSON'S SUMMARY OF TECHNICAL SESSION 4:

LEARNING FROM OPERATIONAL EXPERIENCE

Chairperson
P.E. METCALF
Council for Nuclear Safety,
Hennopsmeer, South Africa

A considerable amount of operational experience has been amassed in the control of radiation sources, beginning shortly after the discovery of radioactive materials. Experience with the loss and recovery of radium sources, driven by economic considerations, was accrued in the early parts of the twentieth century. Since the large increase in the use of radiation sources in the past few decades, the incidence of control being lost over sources has been commensurately greater. Such loss of control occurs for a variety of reasons, including safety equipment and procedural shortcomings, and also because of security shortcomings leading to loss or theft of sources. The consequences vary in significance from minor to extremely costly and tragic. While unfortunate, the instances of control being lost have enabled valuable lessons to be learned and experience to be fed back, with a view to preventing recurrence of similar events. Technical Session 4 dealt with learning from operational experience and comprised a rapporteur's overview, two oral papers and a rapporteur's summary of 12 contributed papers.

Several common areas where shortcomings have been identified as contributing to the loss of control over radiation sources emerged from the presentations and in subsequent discussion.

Effective regulatory control over activities involving radiation sources was seen to be a major component in ensuring their safe use and disposal. Adequately resourced regulatory bodies working within a competent legislation framework were seen to be essential. The need for effective management systems for the regulatory process was evident, and a mechanism to ensure the effectiveness of regulatory systems was seen to be necessary. It was recognized that the IAEA's Model Project in radiation protection is working towards this end in Member States of the IAEA that do not have adequate regulatory control regimes. In addition, the RAIS system is seen to be a useful management tool for systematic control of the regulatory process. Peer review of regulatory processes was seen to be a potentially important activity.

Design weaknesses have been identified in equipment containing and utilizing radiation sources. In addition, shortcomings in monitoring devices and their application have also been identified. Mechanisms to identify such weaknesses and to disseminate such information to other users was seen to be an area where improvements could be made. Procedural failures and human factors were also identified as contributors in many instances. To the extent possible, it was considered that human aspects should be designed out, but it was recognized that in many instances, operational controls provided an important component to safety and aided in providing defence in depth. It was seen to be essential that designs and operational programmes be subject to thorough and systematic safety assessment to demonstrate their adequacy, and to focus on essential elements of operation such as inspection, testing and maintenance requirements. Operating personnel must be adequately trained, examined and retrained. With a view to dissemination of feedback from operational experience, it was generally agreed that greater use could be made of the IAEA's Incident Reporting System (IRS).

Application of good quality assurance programmes, particularly in the area of radiotherapy, was seen to be an important element in radiation safety and security programmes.

The safe storage and disposal of radiation sources following their useful life was identified to be a major area of concern. Numerous incidents have arisen where control over such radiation sources was lost because of inadequate storage or disposal arrangements. The optimal arrangement in this regard appears to be one where sources are returned to suppliers or to a designated State body at the end of their useful lifetime. Impediments to such arrangements should be removed where possible. Regulatory systems should also make provision for control over transfer of source ownership.

It was evident that in some countries where control over sources has been lost, for whatever reason, efforts to search for them and re-establish control should be mounted. A particular problem in this regard appeared to exist in some countries of the former Soviet Union, where control has been lost over sources previously employed for military purposes. It appeared that technical resources were available in some countries that could be employed in searching for such sources. It is possible that the IAEA could assist in providing a service to search for such sources where it is considered that they may present serious safety problems.

The matter of clearance, and the problems identified with this concept, were discussed. The need for international consensus on clearance was clear, particularly in terms of determining an agreed meaning of the concept and what role it should play in radiation safety.

As in several other technical sessions, the need for and desirability of an international convention on the safety and security of radiation sources was discussed. While the utility of such a convention seemed to be evident, there was not unanimity on whether there would be sufficient support for such a convention.

CHAIRPERSON'S SUMMARY OF TECHNICAL SESSION 5:

INTERNATIONAL CO-OPERATION, INCLUDING REPORTING SYSTEMS AND DATABASES

Chairperson
S. MAGNÚSSON
Icelandic Radiation Protection Institute,
Reykjavik, Iceland

International co-operation is a very important element in achieving satisfactory safety of radiation sources and security of radioactive materials worldwide. This was a recurring theme in the presentations of the representatives from the international organizations at the beginning of this Conference. The rapporteur of Technical Session 5, K.E. Schnuer, began his overview with a summary of national responsibilities with regard to safety of radiation sources and security of radioactive material. He emphasized the need for an adequate legislative and administrative infrastructure, including comprehensive and sound legislation, appropriate regulatory control, a system of prior notification and authorization and a system of training and information. He pointed out that national responsibilities in the prevention of illegal activities include an adequate safety assessment structure, an adequate investigation and law enforcement system, and adequate training and education.

The Rapporteur, having laid out the national responsibilities, then moved on to the extensive international co-operation that is needed. There are complex interactions between governments, intergovernmental institutions and international organizations. The Rapporteur stressed the need for harmonization of national legislation, regulations and administrative acts, the synchronization of legislative and regulatory actions and optimization in the use of available financial and administrative resources. Training and education need to be harmonized by measures such as establishing minimum requirements for professional education and arranging for exchanges of experts, scientists and students. There is a need for far reaching co-operation with law enforcement bodies and customs authorities, including a multidisciplinary exchange of information utilizing databases, information systems and the interconnection of involved services. Finally, the Rapporteur stressed the need for international co-operation in non-harmonized sectors and the importance of maintaining international dialogues through regular meetings with other professional associations and involved national and international authorities.

G.A.M. Webb presented a paper on the IAEA's subprogramme aimed at providing Member States with guidance and assistance in achieving regulatory control and the safe use of radiation sources. The guidance addresses the establishment of a regulatory programme, with focus on a system for notification and authorization and inspection of radiation sources. Technical guidance for the safety of radiation sources includes both prospective and retrospective safety assessments. Practice specific reports, to be published, will address the major radiation sources. A research programme will be dedicated to the application of probabilistic safety assessment (PSA) to major radiation sources. The IAEA programme includes comprehensive training manuals for use in training events for the development of personnel in the Member States.

Contributed papers to Technical Session 5 from Latvia, Morocco, the Republic of Moldovia, Tanzania and Tunisia focused on various aspects of infrastructure in their countries with regard to radiation safety and the prevention of nuclear accidents. International co-operation, and especially IAEA co-operation, seems to have played an important part in establishing the available infrastructure in these countries.

CHAIRPERSON'S SUMMARY OF TECHNICAL SESSION 6:

VERIFICATION OF COMPLIANCE, MONITORING OF COMPLIANCE
Assessment of the Effectiveness of National Programmes for the Safety of Sources, Including Development of Performance Indicators

Chairperson
Ziqiang PAN
Ministry of Nuclear Industry,
Beijing, China

1. INTRODUCTION

The verification of safety usually includes safety assessment, monitoring and verification of compliance and records. In order to judge the level of implementation, one must study and develop qualitative and quantitative indicators. Papers in Technical Session 6 summarized past experience and provided many valuable suggestions. From the lessons and experiences of accidents in China and elsewhere, it would appear that in addition to the verification of compliance in the operation of facilities with radiation sources, it might be necessary to pay more attention to the verification of compliance and records in the design and decommissioning of radiation sources.

2. VERIFICATION OF SAFETY IN DECOMMISSIONING

Table I shows the four accidents causing death or severe injury in China.

It can be seen from Table I that two of the accidents are related to decommissioning. In 1963 a ^{60}Co irradiator used for research was not decommissioned according to standard procedure. Instead, the sourse was simply buried without engineered barriers or physical protection. The source was taken away accidentally and caused two deaths and four severe injuries. The 1992 accident in Shanxi happened in the decommissioning process. For an unknown reason, one of the sources was taken home by a worker and caused three deaths. Both the accident in Goiânia[1] and the

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, The Radiological Accident in Goiânia, IAEA, Vienna (1988).

TABLE I. FOUR SEVERE RADIATION SOURCE RELATED ACCIDENTS IN CHINA

Date	Place	Situation	Consequences
1963	Anhui	A 0.43 TBq ^{60}Co irradiation source was taken home from a burial place	Individual dose, 80–2 Gy; two fatalities, four cases of acute sickness
1980–1989	Shanghai	Power lost, interlock out of order, irradiation room was entered; 2.22×10^{15} Bq ^{60}Co source	A worker received 5.22 Gy; acute radiological sickness
1990–1996	Shanghai	Control motor of protection door broken and removed, another protection door failed due to power lost, room was entered; 0.85 PBq ^{60}Co source	2–12 Gy received by seven workers; two fatalities
1992	Shanxi	A 4×10^{11} Bq ^{60}Co source was taken home	Three fatalities

melting of sources with metal scrap[2] are related to decommissioning. A comprehensive decommissioning plan, the related safety assessment and its verification are thus clearly very important.

3. VERIFICATION OF SAFETY IN DESIGN

The reason for the 1980 irradiator accident in Shanghai (Table I), which caused one severe injury, is that the loss of power caused the interlock and other safety measures to fail. This does not conform with the design standard.

4. VERIFICATION OF RECORDS

The cause of the Shanxi accident (Table I) is related to the reliability of records. According to the number of sources inventoried by the individual concerned, all of

[2] LUBENAU, J.O., YUSKO, J.G., Radioactive materials in recycled metals — An update, Health Phys. **74** 3 (1998) 293–299.

the sources had been treated. In fact, there was a source out of control. Before the accident, the authorities concerned had checked the situation. However, they did not pay attention to the difference in the number of sources in different documents.

As in most other countries, we have set up standards for safety assessment surveillance and verification of records of irradiators and the radiation facilities used in medicine and industry. However, there is still much more to be done to achieve high quality safety assessments and to tighten up the verification of safety in safety assessments, surveillance and record keeping during design, operation and decommissioning. I suggest that the IAEA and related international organizations consider preparing guidance on the verification of radiation source safety or adding more information on verification to the present draft Safety Series Guide entitled Safety of Radiation Sources.

CHAIRPERSON'S SUMMARY OF TECHNICAL SESSION 6:

VERIFICATION OF COMPLIANCE, MONITORING OF COMPLIANCE

Assessment of the Effectiveness of National Programmes for the Safety of Sources, Including Development of Performance Indicators

Chairperson
E.C.S. AMARAL
National Nuclear Energy Commission,
Rio de Janeiro, Brazil

This session dealt with two different but complementary subjects: (1) verification of compliance, monitoring of compliance, and (2) assessment of the effectiveness of national programmes for the safety of sources, including development of performance indicators. One overview paper was presented on each topic.

The importance of the verification of compliance in the regulatory control process was highlighted. It was mentioned that different programmes should be conducted, such as regulatory inspections, quality assurance of measurements and procedures, accreditation of measuring laboratories, training and personnel certification. Although all those programmes are generally being conducted, the effectiveness of each regarding the success of the regulatory control process has to be assessed, and indicators have to be established as well. This was very well emphasized, together with a description of available methodologies.

The main conclusions and recommendations on both subjects can be summarized as follows.

1. Developing countries have weak radiation verification of safety programmes, for the following reasons:
   (a) Regulatory activities discontinued by government changes.
   (b) Competition with other government priorities.

   Recommendation: an international undertaking and commitment on the control of radiation sources which can ensure continuity in regulatory control should be established.

2. Countries generally have good radiation protection programmes but do not appear to assess them through the use of logical and measurable parameters (performance indicators).

3. The IAEA is preparing a publication entitled Assessment by Peer Review of the Effectiveness of Regulatory Programmes for Protection against Ionizing Radiation Sources. The publication will prove very useful for countries to assess their national programmes.

4. In the USA, a similar approach, the Integrated Materials Performance Evaluation Programme (IMPEP), is being conducted with success.

   Recommendation: as soon as the IAEA publication is available, it should be applied by countries, and after four or five years the IAEA should evaluate and compare the results of both approaches.

CHAIRPERSON'S SUMMARY OF TECHNICAL SESSION 7:

MEASURES TO PREVENT BREACHES IN THE SECURITY OF RADIOACTIVE MATERIALS (FROM PRODUCTION TO DISPOSAL), EXPERIENCE WITH CRIMINAL ACTS INVOLVING RADIOACTIVE MATERIALS

Chairperson
H.J. STRAUSS
US Department of Defense,
Washington, DC, United States of America

L. Weil began the session with a Rapporteur's overview. He emphasized that, in light of potential safety and health risks to large populations, a primary objective of governments must be the prevention of uncontrolled movements of radiation sources and other radioactive materials.

Following a detailed presentation on the German experience with illicit trafficking, the Rapporteur discussed the importance for a State to have specific laws and regulations implemented to account for, control and secure radioactive materials, as well as for governing the movement and transfer of such materials. The Rapporteur emphasized the importance of maintaining comprehensive information on such materials, and of ensuring that a proper audit and inspection programme is in place.

The Rapporteur then summarized the seven contributed papers. The first discussed the strengthening of the security of radiation sources in Ghana. The second outlined requirements applied in Cuba to the transport of radioactive materials. The third discussed Ukrainian efforts in this area. The fourth detailed French efforts undertaken by their Ministry of Defence regarding the security of ionizing radiation sources. Estonian efforts in preventing the illicit trafficking of radioactive materials were discussed in paper five. A sixth paper overviewed the protection and control of nuclear materials in France. The final contributed paper described the regulatory system of Argentina for the use of radiation sources and radioactive materials.

Technical Session 7 also comprised two oral presentations of contributed papers, the first by G. Zika-Ahlberg et al., which described in detail the efforts of the Swedish Customs Service to prevent the illicit trafficking of radioactive materials into and out of Swedish territory. The second presentation, by H. Böck, described how radioactive materials are properly secured within a university research institute.

The ensuring discussion covered a number of areas and related topics:

(1) The suggestion that manufacturers be required to describe more fully the nature of radioactive materials for customs purposes.

(2) The suggestion that an international organization develop rules to protect 'whistle blowers', so that no one is punished for identifying a potential problem or for supplying accurate information to appropriate authorities.

(3) The suggestion that an international organization provide a full range of assistance — legal and regulatory, border control and law enforcement, etc. — to developing countries to ensure that illicit trafficking of radioactive material is controlled.

(4) The suggestion that international organizations strengthen and enhance overall efforts in the area of combating illicit trafficking of radioactive substances and other contraband substances.

CHAIRPERSON'S SUMMARY OF TECHNICAL SESSION 8:

DETECTION AND IDENTIFICATION TECHNIQUES FOR ILLICITLY TRAFFICKED RADIOACTIVE MATERIALS

Chairperson
N. KRAVCHENKO

State Customs Committee of the Russian Federation,
Moscow, Russian Federation

The issues discussed in Technical Session 8 are key aspects (but not the only ones) in the prevention of illicit cross-border movement of radioactive materials.

The characteristics of radioactive materials are such that these materials cannot be detected without adequate detection equipment.

During the session, speakers from various countries stressed that the development of a strategy for organizing border control of radioactive materials should be the responsibility of each State based on its national legislation and international agreements. The relevant national bodies should not expect international organizations to solve the problem of controlling the cross-border movement of radioactive materials for individual countries. International organizations such as the IAEA and the World Customs Organization only give recommendations and advice on this subject.

The most effective way of solving this problem is bilateral co-operation with neighbouring States. Agreement on general criteria for such control and on general principles can be reached much more quickly within the framework of such co-operation.

At the same time, consideration during the session of the places where illicit movement of radioactive materials has been detected led to the identification of a number of general principles which it would be useful for international organizations to develop.

Figure 1 indicates another aspect of this problem. Outside of what we may call the 'legal common life' of radioactive materials, there are two points of concern: nuclear weapons proliferation and illicit trafficking. The first of these points is addressed by international conventions; the second is not.

Conclusions

(1) There must be detection and identification of radioactive materials at borders;

(2) Detection system criteria should be harmonized. A group of experts from the IAEA and WCO, headed by K.E. Duftschmid, is working on this issue.

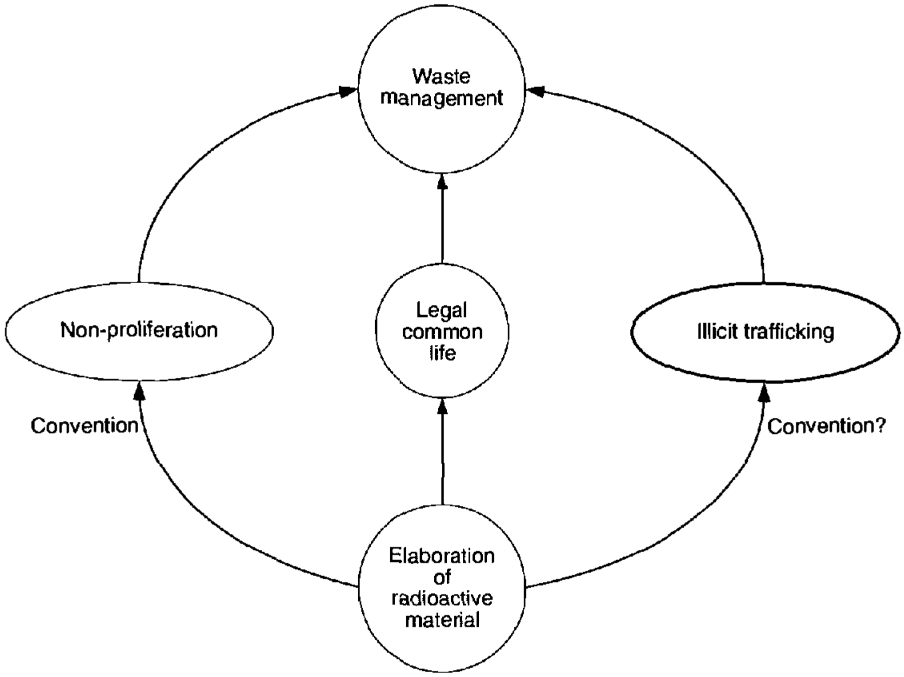

FIG. 1. Nuclear facilities in Sweden

(3) The obligation to carry out detection and identification of radioactive materials at borders must be reinforced by international documents, because States would then allocate sufficient financial resources to deal with this problem.

The efforts of the IAEA and WCO to tackle the problem of illicit movement of radioactive materials should be welcomed.

CHAIRPERSONS'S SUMMARY OF TECHNICAL SESSION 9: DETECTION AND IDENTIFICATION TECHNIQUES FOR ILLICITLY TRAFFICKED RADIOACTIVE MATERIALS

Chairperson
D.E. SMITH
United States Customs Service,
Washington, DC, United States of America

The Rapporteur for this session, C. Schmitzer, presented an excellent overview of this session's topic. He noted that detection and identification of radioactive substances are an important part of the overall strategy against illicit trafficking. In his presentation he discussed the framework which defines the characteristics and sets the goals of the detection effort, paying attention to national policy decisions regarding specific detection limits and response strategy. He gave a detailed discussion of technical principles and the various types of instrumentation foreseen for application in combating illicit trafficking.

I have grouped the ten papers presented orally or synopsized by C. Schmitzer into four categories, based on my perception of the primary objective addressed in the respective papers:

(1) Nuclear proliferation,
(2) Perimeter detection and nuclear proliferation,
(3) Nuclear facility security,
(4) Radiation sources in scrap metal.

For this summary, I would like to review briefly the papers presented in each of these categories.

Nuclear proliferation

The six papers in this group have nuclear proliferation and nuclear smuggling across international borders as their main concern.

Clearly, some countries have moved more rapidly to protect their borders from radiological risk than others. For example; the representative from Belarus [1] spoke of a program under way since 1994 to provide all border crossing points with highly sensitive gamma and neutron detection equipment aimed at detecting small quantities of special nuclear material (SNM) and other illicit radioactive materials being imported or exported. A family of detection devices were identified and are in place at many border crossing locations for use in alarm detection, localization, identification and radiation protection. Belarus has developed the legislative basis and the specialized equipment to provide effective protection for unauthorized trafficking in radioactive materials crossing the East–West border.

In the USA, efforts to counter nuclear smuggling at the border are just now beginning to reach fruition. The development of highly sensitive gamma ray detectors for use with luggage X-ray systems [2] allows customs inspectors to screen for radioactive contraband, including SNM, at the same time they are screening for other contraband (e.g., drugs, weapons and explosives). The detection capability developed had to meet the challenge of working in the presence of X ray scattering from luggage and cargo X ray systems with few or no false alarms. H.R. McHugh described the barriers that were overcome between the first and second generation detectors and the significant improvement in Pu detection that was achieved with a new design. In addition to US installations, mobile X ray vans with these gamma ray detectors have been purchased by the US State Department for delivery to the Baltic countries, Eastern European countries, and states of the Former Soviet Union.

R.L. York discussed the technical and operational parameters relating to the use of portal radiation detectors for personnel and vehicles [3]. (The technology of automatic pedestrian and vehicle monitors was developed at Los Alamos in the 1970s and early 1980s). York described the difference between radiation contamination monitors, SNM monitors for nuclear facilities and SNM monitors for use at international borders. Selecting the best radiation monitors to prevent the transportation of radioactive materials across international borders requires an acceptable nuisance alarm rate while achieving the necessary sensitivity to deter or detect the passage of special nuclear material. "Only with the careful selection of the operating characteristics of radiation portal monitors and the use of sophisticated portable isotope identification instruments is this goal achievable."

In the paper [4] by P. Funk, he noted that it would be natural to adopt the fixed detection portals used in the nuclear industry for use in preventing illicit trafficking. He discussed the parameters that influence the detection of nuclear materials, and using ^{239}Pu as an example, he showed how difficult it is to actually detect a radioactive substance. He noted how unlikely it is that portal detectors could be installed at *all* strategic points which exist in the prevention of nuclear trafficking. He also raised the issue of using small, inexpensive detectors, worn permanently by personnel to signal abnormal dose rates. While admittedly less sensitive than detection portals, they have a wider detection range than fixed detectors and the ability to get closer to the source. A combination of fixed portals and personnel-worn detectors is suggested by the author. It may be noted that at least two countries are committed to the use of the personnel-worn detectors: the USA and Norway. In the USA, each customs inspector wears a sensitive 'radiation pager' that signals in response to slightly above background gamma radiation.

As indicated in the Session title, there is the need to identify radiation sources which have been detected by other instrumentation. This requirement arises, in part, because of the many nuisance alarms that are sounded when using sensitive detectors. Probably foremost among these nuisances are the many travelers who have undergone treatment with radioactive isotopes. W. Murray described the Ranger gamma ray and neutron detection system and its integrated, knowledge based pattern recognition system, the RangerMaster [5] as being a possible solution to this problem. This hand-held instrument has a library of medical, industrial and nuclear material isotopes that permits *field identification* of the most frequently encountered isotopes in a matter of seconds. The instrument has two modes of operation: advanced and easy. The easy mode is a 'point and click' isotopic identification tool for a non-technical user, while the advanced mode is a full featured multichannel analyzer. This recently emerging technology will help field users to make timely decisions regarding the release of cargo, passengers and pedestrians crossing international borders.

In the oral presentation, H.W. Rosenstock described the intended equipping of a transportable container with sophisticated equipment for detection, identification and characterization of radioactive material inside objects with unknown content [6]. The container will be equipped with systems for passive and active nondestructive measurements and is transportable by lorry and by air (helicopter or airplane). The system described is an ultimate detection system with state of the art technology capable of being transported to the site of unknown objects containing radioactive materials. This system should be well suited to providing real time, accurate measurements by scientists wherever required.

Perimeter detection and nuclear proliferation

A single contributed paper falls into this category. The instrumentation discussed is aimed at both radiation detection at fences of commercial facilities using radioactive sources and at international boundaries.

Two detection systems are described in the paper by H. Bitt [7]. The Environment Radiation Monitoring System is characterized as the Austrian Early Warning System and has been in operation for many years. Its objective is the timely detection of radioactive aerosols in the atmosphere and of any increase of the gamma radiation level at the fence of facilities using or otherwise dealing with radioactive materials and at the borders of countries for early warning in case of accidents with transboundary effects, the latter clearly having nuclear proliferation implications. The second system, a radiation gate monitoring system, is being tested for timely detection of any kind of radioactive material. It has rapid response to gamma and neutron radiation and emits an alarm signal on the equivalent of 300 g of Pu. 'In' and 'Out' gates capture occupants until any alarm is resolved. This configuration is clearly more useful at the fences of facilities involved in nuclear material production than at high volume personnel or vehicle border crossings.

Nuclear facility security

The paper by L.E. Levelut describes procedures and equipment used at the French Atomic Energy Commission (CEA) to screen vehicles exiting nuclear sites for a radioactive source or contaminated materials [8]. The system uses plastic scintillators to surround the vehicle. Alarms from the system fall into two classes: (1) those due to natural radioactivity of manufactured equipment or raw materials and (2) alarms due to artificial activity (fire detectors, ionization chambers and abnormal existence of contaminated materials). The results of several years' routine monitoring at all CEA centres were discussed in terms of the cause of the alarm, the identified radionuclide, and the source strength.

Radiation sources in scrap metal

Two papers were submitted in this category.

Through January 1995, there were 38 reported instances worldwide in which radioactive sources were unintentionally smelted in the course of recycling metal scrap. In some of these instances, contaminated metal consumer products were distributed worldwide. The safety and cost implications of these events are immense. G. Dicus, in her keynote presentation in Briefing Session 1, indicated that cleanup costs for such events averaged US $8–10 million each, with a high of US $23 million. It is no wonder that thorough monitoring of incoming scrap for radioactive material continues to be a high priority for the industry.

Therefore, it is essential that detectors used in facilities using scrap metal achieve high sensitivity with low false alarm rates. In the paper of Dryak et al. [9], the performance of 10 different stationary devices was quantified for detecting radioactive sources at a rail test bed location. A train, comprising an engine, an empty wagon and a scrap filled wagon containing specifically placed radiation sources, passed by the detector instrumentation more than 1000 times. Systems were also tested in a climate chamber for stability of response to different temperatures. Eight of the 10 systems tested were approved. Despite a different test regime, some of the results were found to be similar to those obtained in a test of scrap monitoring systems conducted at Koppel Steel in Pennsylvania, USA, in October 1996.

M. Fabretto discussed the results of 20 months of monitoring scrap contained in 20 000 railroad wagons and several hundred trucks at an important steel plant in northeast Italy [10]. Monthly statistics compiled over the period showed the fraction of traffic for which a significant increment above background radiation was measured. An interesting finding of the study was that increased radiation levels were due to the railroad wagons themselves rather than the contents. Investigation of several radiation incidents led to the conclusion that wagon doors of a single type wagon manufactured in 1990 were contaminated with ^{60}Co. Other radiation incidents involving contaminated products were noted.

Based on the papers presented during Technical Session 9, the issues associated with radioactive materials are multifaceted, ranging from the sinister — the smuggling of bomb grade SNM across international borders, to the mundane — the detection of normally occurring radioactive materials such as ^{40}K in fertilizers or ^{131}I implanted in individuals for health purposes. Lying between these extremes are the very important matters of nuclear plant security, perimeter safety and radiation contaminated scrap metal. It falls to our respective countries' law enforcement agencies — customs, border police, environmental and energy organizations (and others) — to employ detection and identification technologies to sort out the innocent sources from those potentially injurious to individuals and even whole populations.

It is clear to me from the papers presented during this session and Technical Session 8 that detection and identification technology exists or is emerging to combat effectively the wide range of problems discussed. We are only impeded by the will or desire (and budgets) of our respective countries to implement these technologies at critical 'choke points'.

In closing, I wish to commend the Rapporteur, C. Schmitzer, and the authors of the papers of this session, for jobs well done. The subjects presented were timely and relevant to the intent of the conference.

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CHAIRPERSON'S SUMMARY OF TECHNICAL SESSION 10:

RESPONSE TO DETECTED CASES AND SEIZED RADIOACTIVE MATERIALS, STRENGTHENING OF THE AWARENESS, TRAINING, AND EXCHANGE OF INFORMATION

Chairperson
H. TAKIZAWA
Interpol,
Lyon, France

The session dealt with practical measures to be undertaken by the customs, law enforcement and regulatory authorities, with particular emphasis on training.

1. RAPPORTEUR'S OVERVIEW

The Rapporteur, W.C. Cliff, gave an overview on the subjects of the session. He focused on the training for border enforcement officers (customs and border police) who are exposed to the new challenge. The main purpose of the training is to provide protection to the officers engaged in detection, and to innocent bystanders and the general public. As a good example, W.C. Cliff introduced the joint training programmes conducted by the IAEA and WCO. The participants were informed of Project AMBER and AMBER II, in which the US Customs Service provides training courses for border enforcement officers of foreign countries (mainly the former Soviet Union and Central and Eastern Europe). Also mentioned was Project INTERDICT/RADACAD, where the US Department of Defense offer practical training courses, including field exercises. These training courses cover a wide range of subjects, from a scientific class for detection to practical investigative techniques such as interrogation of suspects.

2. ORAL PRESENTATIONS

The WCO/IAEA joint training programmes for customs services on radioactive material smuggling

E. Saka made an oral presentation on the joint training courses, which started last year. The courses were designed for customs officers at border checkpoints in the former Soviet Union and Central and Eastern European countries and were financially supported by several developed countries. The main purpose of these courses was awareness raising, prevention and detection. Another training course was planned for October 1998 as an extended joint course including law enforcement officers, also co-hosted by Interpol.

Financial consequences of the detection and seizure of smuggled products

J.-P. Montmayeul gave a valuable and informative presentation on the financial implications of smuggling of radioactive materials. Experience has shown that the costs of decontamination or disposal of the smuggled materials cannot be ignored. It is often the case that the government agencies concerned are not prepared to bear the costs and are thus unable to take necessary measures. In that regard, a 'polluters should pay' approach should be taken. It was also emphasized that customs experience and expertise should be fully exploited. Approaching the issue from the financial aspect is useful in identifying and breaking up trafficking networks.

3. RAPPORTEUR'S SUMMARY OF PAPERS SUBMITTED

W.C. Cliff summarized the five papers submitted of which oral presentations were not given. The authors were A. Strenov (Bulgaria), B. Causse (France), A. Slimani (Tunisia), J. Penneroux (France) and S.K. Shkshouki (Libyan Arab Jamahiriya). While those papers dealt with a wide variety of subjects — some from the viewpoint of the regulatory authorities, others focusing on enforcement — it was understood that they all emphasized the effectiveness of a multiagency approach and the top priority to be given to training. Some papers also described the difficulties encountered in developing countries, such as lack of expertise and financial/human resources.

4. DISCUSSION

Active discussion followed the presentation. Participants showed interest in items such as forensic evidence for court procedures, details of the training courses presented and the commonality to other types of smuggling (e.g., of drugs). Channels for information exchange were also a subject of discussion, a point on which the Chairperson reminded participants that Interpol channels may be optimized for criminal information. The participants reaffirmed the effectiveness and importance of a multiagency approach.

MAJOR FINDINGS OF THE CONFERENCE

G.A.M. WEBB
INTERNATIONAL ATOMIC ENERGY AGENCY,
Vienna

This International Conference brought together for the first time all aspects of the safety of radiation sources and the security of radioactive materials. It benefited considerably from the co-sponsorship and involvement of the European Commission (EC), the World Customs Organization (WCO), International Criminal Police Organization (Interpol) and the International Atomic Energy Agency (IAEA).

The attention of the radiation protection community has in the past been focused on the prevention of accidents involving sources, but the rise in incidents of illicit trafficking during the early 1990s has raised awareness of the problem of sources that are outside of control systems for various reasons. Bearing these two aspects in mind, the conference came to a number of conclusions:

(1) Sources must have sufficient protection to allow for safe normal operations.

(2) The possibility of accidental exposures must be anticipated and sufficient safety devices and procedures must be incorporated. In this respect, the following broad issues must be addressed:
   (a) Weaknesses in design and construction of sources must be corrected.
   (b) A good safety culture must be promoted so that human errors are minimized by good training.
   (c) The regulatory infrastructure for the control of sources must be (i) supported by the government and (ii) able to act independently, and the regulatory authority must maintain oversight of all sources in the country, including those imported.

(3) Sources should not be allowed to drop out of the regulatory system. This implies that the regulatory authority must keep updated records identifying the person responsible for each source, monitor transfers of sources and track the fate of each source at the end of its useful life.

(4) Efforts should be made to find sources that are not now in the regulatory authority's inventory, either because they were in the country before the inventory was established, because they were never specifically licensed or because they were lost, abandoned or stolen. In the Conference all of those were referred to as 'orphan' sources.

(6) Because there are many orphan sources in countries throughout the world, efforts to improve detection of radioactive materials at borders or inside countries by measurement and intelligence should be intensified. Optimum techniques for detection need to be established, and it would avoid confusion if

international agreement on investigation levels at border crossings could be achieved.

It is clear from these points that the key common element which would have the greatest part to play in the avoidance of 'orphan' sources, with their potential for misuse or accidents, and the development and maintenance of safe operating conditions, is an effective national regulatory authority operating within a suitable national infrastructure. Governments are urged to create such a regulatory authority if it does not exist. Whether it is newly created or already existing, governments must provide the regulatory authority with sufficient backing and human and financial resources to enable it to function effectively. Only in this way can the problem of source safety and security be tackled at its roots and eventually brought under control. It would be interesting to investigate further whether international undertakings concerned with the effective operation of such national systems and attracting broad adherence could be formulated.

SUMMARY OF ROUND TABLE

International Co-ordination of Security

Chairperson: **D.J. Beninson** (Argentina)
Members: **G.J. Dicus** (United States of America)
K.E. Duftschmid (IAEA)
N. Kravchenko (Russian Federation)
S.M. Magnússon (Iceland)
P. Ortiz Lopez (IAEA)
E. Saka (World Customs Organization)
K.E. Schnuer (European Commission)
D.E. Smith (United States of America)
H.J. Strauss (United States of America)
H. Takizawa (Interpol)

D.J. BENINSON (Argentina) (*Chairperson*): I suggest that we focus first on the question of training.

W.C. CLIFF (United States of America): I would mention that the largest training programme in the world at present is the US Department of Defense's INTERDICT/RADACAD training programme for law enforcement officers.

H.J. STRAUSS (United States of America): I would add that at the US Department of Defense we have for the past year and a half been developing — together with the US Customs Service, the Federal Bureau of Investigation, the Department of Energy, the Department of Commerce, the State Department and other agencies — an array of training courses, for officials from the former Soviet Union and from Eastern Europe, on how to prevent, detect and investigate incidents involving radioactive, chemical and biological substances; the activities in question have Congressional funding for a further five years.

Something I have noticed in this connection is that quite often our training efforts are duplicated by those of agencies based in other donor countries, especially Western European countries, and I think it would be helpful if an international organization such as the IAEA were to establish and maintain an inventory of the various training opportunities being offered and perhaps even to co-ordinate the training.

K.E. DUFTSCHMID (IAEA): There is certainly a need for such international co-ordination, and also for financial support for the future joint training activities of the World Customs Organization (WCO), Interpol and the IAEA.

K.E. SCHNUER (European Commission): In 1991, the European Union (EU) adopted a programme (the MATTHEUS Programme) for the training of customs officers, and that programme has in recent years been used as a vehicle for training in the prevention and detection of illegal transborder movements of radioactive materials.

In December 1996, the European Parliament and Council adopted an action programme for customs in the Community (Customs 2000). This €156 million programme is devoted, amongst other things, to developing co-operation with other countries, particularly the associated countries of Central and Eastern Europe, and with competent international organizations. Special attention is to be paid to the development of training for instructors and to the initial training given to customs officers, in order that common teaching modules relating to the full range of customs rules and procedures and common policies may be drawn up and provided. Specific actions must be introduced and carried through in support of Member States' efforts in the field of continuing training so as to provide staff of customs administrations with the level of training necessary to carry out their tasks. The foreseen budget for training is about €4 million.

K.E. DUFTSCHMID (IAEA): Is it envisaged that some of that US $750 million might be used for the training of customs officers from countries not belonging to the EU?

K.E. SCHNUER (European Commission): Yes, certainly for the training of customs officers from countries which are likely to be joining the EU. In fact, I recently had discussions with the relevant authorities of Cyprus and Malta about the training of their customs officers.

D.J. BENINSON (Argentina) (*Chairperson*): Clearly it would be useful if there were close co-ordination between the EU and the IAEA.

E. SAKA (World Customs Organization): We have started co-ordinating and co-operating with the IAEA and plan to co-ordinate and co-operate with the EU and Interpol and with interested governmental and non-governmental organizations. In that connection, I invite all those who have gained relevant experience through bilateral and multilateral assistance programmes to share that experience with us.

D.E. SMITH (United States of America): Although the perceived threat from illicit trafficking in radioactive materials is not as great in the USA as in Europe, at the US Customs Service we are issuing 'radiation pagers' to about 6000 inspectors and giving those inspectors each four hours of training in how to use them and what to do if a pager emits an alarm signal. The training is designed for non-technical people, but we think that it is sufficient for customs purposes.

M. KEREN (Israel): I think there is a need to ensure that training in measures to combat illicit trafficking in nuclear and other radioactive materials does not focus too much on radiation safety aspects.

K.E. DUFTSCHMID (IAEA): The training being offered jointly by the WCO and the IAEA places great emphasis on customs investigation techniques.

K.M. CHENG (Interpol, Hong Kong): Is any training being offered in measures to combat illicit trafficking in biological and chemical substances as well as in nuclear materials?

H.J. STRAUSS (United States of America): The Department of Defense's programmes of training in measures to combat illicit trafficking in nuclear materials now also cover biological and chemical substances.

C. SCHMITZER (Austria): Relatively little attention is being paid at this meeting to the law enforcement response to illicit trafficking in nuclear and other radioactive materials. Why is that?

H. TAKIZAWA (Interpol): We hoped that more law enforcement officers would attend this meeting, but some countries are unaware of the problems associated with this form of illicit trafficking; also, some countries are suffering from personnel shortages in the law enforcement area.

J.U. AHMED (Bangladesh): I believe that attention should have focused on the strengthening of national infrastructures for the safety of radiation sources and the security of radioactive materials. If all countries had adequate infrastructures, there would be less need to worry about things like the training of customs and law enforcement officers. Some of the US $8 billion earmarked for the Douane 2000 programme would be well spent on strengthening national infrastructures worldwide.

K.E. SCHNUER (European Commission): J.U. Ahmed has a point. Too little importance has been given to the safety of radiation sources and the security of radioactive materials, which used to be covered, in most Western countries, by regulations. Infringements of those regulations were regarded as administrative offences and were not prosecuted under criminal law. It was only after a number of incidents, through which those countries came to realize the potential dangers associated with illicit trafficking in nuclear and other radioactive materials, that a number of acts which had been regarded as administrative offences came to be regarded as crimes — at which point the police became involved when such acts were committed.

For customs officers to become involved, a mandate is necessary — a governmental mandate to join in the fight against illicit trafficking in nuclear and other radioactive materials. Customs officers cannot act without such a mandate. For example, until they received the necessary mandate they could do nothing about illicit transborder trafficking in women. Besides being given a mandate, customs officers need to be made aware of what radioactive substances can be used for — both legally and illegally.

D.J. BENINSON (Argentina) (*Chairperson*): It would be interesting to know how often radioactive substances have deliberately been used for illegal purposes — in other words, how serious the problem really is.

G.J. DICUS (United States of America): In carrying out inspections and in investigating incidents, the US Nuclear Regulatory Commission has discovered cases of deliberate misuse of radioactive materials. The cases were referred to the US Department of Justice for prosecution.

H.J. STRAUSS (United States of America): At the US Department of Defense, we have found that some countries with export control laws covering radioactive materials do not have the necessary implementation rules and regulations or enforcement mechanisms. These are, in my view, areas where a co-ordinated assistance effort would be useful.

S.K. SHKSHOUKI (Libyan Arab Jamahiriya): On the question of training, there should be an international programme to train people who will then hold training courses in their own regions using a local language. That is the only way of overcoming the language barrier.

W.C. CLIFF (United States of America): The US Department of Defense's training courses are held in the languages of the participants, with translated course materials.

P.E. METCALF (South Africa): The IAEA caters for regional training needs through three regional technical co-operation programmes — RCA (for Asia and the Pacific region), AFRA (for Africa) and ARCAL (for Latin America). These activities could perhaps be extended to include training for customs and border police officers.

P.N. MALHOTRA (India): It would be useful if the IAEA, the WCO and Interpol were to create a database on illicit trafficking methods and to make the information available — as 'warning signs' — to interested countries.

D.J. BENINSON (Argentina) (*Chairperson*): Changing the subject, should an attempt be made to arrive at an agreed radiation detection level for intervention by customs and border police officials?

J.A. AHMED (Bangladesh): I do not think such an agreed radiation detection level would be helpful. Smugglers could ensure that the level was not exceeded simply by using plenty of shielding.

K.E. SCHNUER (European Commission): It is unlikely that customs officers would fail to notice large radiation shielding structures in road vehicles.

With regard to the question of radiation detection, it may be worth recalling that radioactivity from Acerinox, in Spain, was first detected by France's system for giving early warning of nuclear accidents. Perhaps formal arrangements could be made for the use of such systems also in connection with efforts to locate 'orphaned' radioactive sources and the like.

R.S. SEYMOUR (United States of America): Considerable emphasis has been placed at this meeting on border crossings manned by customs officers and border police. However, smugglers and terrorists are likely to cross national borders at points other than manned border crossings. Radiation monitoring vehicles patrolling near national borders are one way of countering this strategy, but remote sensing by systems of the kind just mentioned by K. Schnuer might also be helpful.

W.C. CLIFF (United States of America): The 'green border' issue raised by R.S. Seymour is a very difficult one.

H. TAKIZAWA (Interpol): Manned border crossings were emphasized at this meeting because they constitute a subject of common interest to all four sponsoring organizations. For Interpol, detection at a manned border crossing is just the starting point of an investigation in which we are likely to use information from many different quarters.

W. JOHNSON (United States of America): There are two distinct problems which we should be considering: the smuggling, by knowledgeable professionals, of nuclear materials which are of low intrinsic radioactivity but which could be used in disastrous ways; and the movement, inadvertently or by uninformed petty criminals, of large radiation sources. Once we decide which problem is the more important, most of the detection instrument and law enforcement issues will become clear.

D.J. BENINSON (Argentina) (*Chairperson*): Many of the radioactive materials that one will wish to detect emit radiation of very low energy, which makes detection very difficult. The detection equipment will therefore have to be sensitive, but not so sensitive as to trigger numerous false alarms.

K. DUFTSCHMID (IAEA): In arriving at a compromise between high sensitivity and the avoidance of false alarms, one must also bear the economic aspects in mind.

D.J. BENINSON (Argentina) (*Chairperson*): At this meeting, reference has been made to the idea of an international convention on the safety of radiation sources. It would be interesting to see how much support there is for that idea.

S.K. SHKSHOUKI (Libyan Arab Jamahiriya): In my opinion, such a convention is very necessary.

J.J. FLETCHER (Ghana): In my opinion also.

Z. PAN (China): And in mine.

J.A. LOZADA (Venezuela): I believe there is a need for an international convention. For example, the countries of Western Europe are building a 'Maginot Line' against the incursion of radioactive materials from the former Soviet Union, but such materials may well enter from elsewhere in the present situation.

E. SAKA (World Customs Organization): In 1996, a joint technical committee of the WCO and the IAEA recommended that the two organizations look into the question of the need for an international convention on the prevention of illicit trafficking in nuclear and other radioactive materials.

D.J. BENINSON (Argentina) (*Chairperson*): In my view, one would have to ensure that an international convention did not conflict with the IAEA's Regulations for the Safe Transport of Radioactive Material[1] (the Transport Regulations). For

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[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Regulations for the Safe Transport of Radioactive Material, 1996 Edn, Safety Standards Series ST-1, IAEA, Vienna (1996).

example, hundreds of thousands of packages containing radioactive materials are transported about the world every year, covered by the Transport Regulations, which do not require that either countries of transit or countries of destination be notified.

S.M. MAGNÚSSON (Iceland): The negotiation of an international convention would be a major undertaking, and I have doubts whether the countries which most need to strengthen their radiation safety infrastructures would become parties. The best response to the call for an international convention might be to intensify and expand the IAEA activities directed towards strengthening radiation safety infrastructures.

H. TAKIZAWA (Interpol): In an international convention, whether it just covers the prevention of illicit trafficking or is wider in scope, there should be provisions relating to law enforcement, so that police and customs authorities can react appropriately in cases of non-compliance.

D.J. BENINSON (Argentina) (*Chairperson*): I expect that the idea of an international convention will be discussed further within the IAEA and elsewhere.

CHAIRPERSONS OF SESSIONS

Opening Session	J.-P. GAYRAL	France
Briefing Session 1	J.-P. GAYRAL	France
Briefing Session 2	J. SHAVER	World Customs Organization
Technical Session 1	G.J. DICUS	United States of America
Technical Session 2	D.J. BENINSON	Argentina
	D. QUÉNIART	France
Technical Session 3	D. DRÁBOVÁ	Czech Republic
Technical Session 4	P.E. METCALF	South Africa
Technical Session 5	S.M. MAGNÚSSON	Iceland
Technical Session 6	E.C.S. AMARAL	Brazil
	Ziqiang PAN	China
Technical Session 7	H.J. STRAUSS	United States of America
Technical Session 8	N. KRAVCHENKO	Russian Federation
Technical Session 9	D.E. SMITH	United States of America
Technical Session 10	H. TAKIZAWA	Interpol
Concluding Session	D.J. BENINSON	Chairperson of the Scientific Conference Programme Committee

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