

IAEA-TECDOC-1638

Setting Authorized Limits for Radioactive Discharges: Practical Issues to Consider

Report for Discussion



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**SETTING AUTHORIZED LIMITS
FOR RADIOACTIVE DISCHARGES:
PRACTICAL ISSUES TO CONSIDER**

REPORT FOR DISCUSSION

IAEA-TECDOC-1638

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SETTING AUTHORIZED LIMITS FOR RADIOACTIVE DISCHARGES: PRACTICAL ISSUES TO CONSIDER

Report for Discussion

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2010

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Assessment and Management of Environmental Releases Unit
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Vienna International Centre
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FOREWORD

Application of the principles of radioactive waste management requires the implementation of measures that afford protection of human health and of the environment, now and in the future.

The IAEA has issued safety standards and other publications that provide a framework for the control of releases of radionuclides to the environment. This framework is relevant for regulatory bodies that issue authorizations and for organizations that (i) use radionuclides for medical or research purposes, (ii) operate nuclear reactors or (iii) reprocess nuclear material.

An IAEA Safety Guide on Regulatory Control of Radioactive Discharges to the Environment was issued in 2000 that outlines the roles and responsibilities of regulatory bodies, licensees and registrants and provides guidance on the authorization procedure. However, there have been significant developments in radiological protection policy since the publication of this Safety Guide, most notably the issue of ICRP Publications No. 101 on Assessing Dose of the Representative Person for the Purpose of Radiation Protection of the Public and the Optimisation of Radiological Protection and No. 103 on The 2007 Recommendations of the ICRP.

The objective of this IAEA-TECDOC is to stimulate discussion on the practical implementation of the control of radioactive releases in order to inform the review and revision of IAEA guidance on this subject.

This IAEA-TECDOC is based on the practical experience of Member States and on information provided at Technical Committee Meetings held in 2003 and 2008 and gained by means of a questionnaire. It summarizes international experience on the optimization of discharges and the setting by the regulatory body of authorized limits on discharges for nuclear installations and non-nuclear facilities.

Its issue at this stage is intended for consultation as a preparatory step pending the current process of revision of the IAEA's International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (Safety Series No. 115), issued in 1996, and the subsequent revision of related Safety Guides.

The IAEA wishes to acknowledge the contributions of the experts M.E. Clark (USA), L. Moberg (Sweden), and J.R. Simmonds and C.A. Robinson (United Kingdom) in the preparation and review of this IAEA-TECDOC. C. Robinson, T. Cabianca and D. Telleria of the Division of Radiation, Waste and Transport Safety were the IAEA officers responsible for this publication.

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1. INTRODUCTION

1.1. Background

This report provides an overview of some of the key practical aspects of setting discharge limits and authorization conditions. It includes a description of the main processes involved in setting discharge authorizations and presents examples of current practice drawn from both nuclear and non-nuclear industries. The range of approaches adopted in Member States is considered and the advantages and shortcomings of different approaches are discussed where appropriate. Information on international experience has been gathered by means of a questionnaire and from focused comments and discussions at Technical Committee Meetings held in 2003 and 2008. A number of key issues and trends have been identified for further consideration.

In the year 2000, the International Atomic Energy Agency issued a Safety Guide on the Regulatory Control of Discharges [1], which outlines the underlying principles of discharge limitation, the roles and responsibilities of regulatory bodies, licensees and registrants and general guidance on the authorization procedure. The need for additional guidance on practical aspects of this procedure was identified during the course of a Technical Meeting in 2001. Subsequently, a group of consultants prepared draft guidance material for discussion at a second Technical Committee Meeting, which took place in July 2003.

In the course of the development of this report, it was recognized that the current Safety Guide would require revision in light of the upcoming revision of the ICRP Recommendations [2], which were subsequently published in 2007 [3]. The focus of the present report was therefore modified with the objective of providing an overview of national experience and key practical issues to inform the debate on the development of future Safety Standards and supporting guidance on the control of radioactive discharges. An additional Technical Committee Meeting was therefore held in 2008 to initiate and broaden this debate by finalizing this report, within the context of the revised recommendations of the ICRP [3] and progress in the IAEA Basic Safety Standards [4] revision process, started in 2006.

1.2. Scope of the report

The scope of this report is limited to planned exposure situations that arise from discharges to the environment of radioactive substances in the form of airborne (gases, aerosols) or liquid effluents from the normal operation of a source. The sources considered range from radionuclides used for medical and research purposes to nuclear reactors and reprocessing facilities. The term ‘discharge’ is used here to refer to the ongoing or anticipated discharges of radionuclides arising from the normal operation; releases associated with emergency or existing exposure situations are beyond the scope of this report. Discharges to atmosphere and discharges directly to surface water bodies are considered, but discharges of liquid radioactive substances by injection deep underground are not considered.

Issues related to setting discharge limits for new sources and existing sources are considered. This report deals with the process of authorization and, as such, the issues of exclusion, exemption and justification are beyond its scope. Furthermore, the process under discussion is based on the assumption that dose constraints are specified in advance by the regulatory body.

The report is based on current practice and the context of the requirements of the Safety Fundamentals [5] and the International Basic Safety Standards (BSS) [4]. However, an effort has been made to indicate other considerations that may arise from ongoing developments in radiological protection policies, arising from the revised recommendations of ICRP and the

on-going BSS revision process. Thus, while this report is primarily concerned with the protection of human health, as is the present Safety Guide on the Regulatory Control of Discharges [1], recent developments in environmental radiation protection are also considered.

The interpretation and use of the concept of ‘best available techniques’ (BAT), to the control of radioactive discharges is also discussed.

Discharges from uranium mining and milling facilities and from the disposal of solid radioactive waste are not considered; specific guidance on these matters is given elsewhere [6–8]. However, criteria expressed and discussions in this document are also potentially applicable to other industries that give rise to discharge of NORM¹, where these discharges are amenable to control. Different Member States have a range of industries that given rise to NORM discharges, examples include oil and gas extraction, phosphate industry, metal processing, fossil fuel plants. General consideration of the approaches and experience related to the regulatory control of NORM industries’ discharges is included in this report.

1.3. Principles

The general principles governing the regulatory control of discharges are outlined in detail in Safety Guide on the Regulatory Control of Discharges [1] and the International Basic Safety Standards [4] and reflect the principles of radiological protection, recommended by the International Commission on Radiological Protection in ICRP Publication 60 [2]. These are further incorporated in the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, [9] which places commitments on Contracting Parties to “provide for effective protection of individuals, society and the environment, by applying ... suitable protective methods...in the framework of its national legislation which has due regard to internationally endorsed criteria and standards”.

More specifically, Article 24 of this Convention includes the following commitment:

“Each Contracting Party shall take appropriate steps to ensure that discharges shall be limited:

- (i) to keep exposure to radiation as low as reasonably achievable, economic and social factors being taken into account; and
- (ii) so that no individual shall be exposed, in normal situations, to radiation doses which exceed national prescriptions for dose limitation which have due regard to internationally endorsed standards on radiation protection.”

The Convention also includes a number of General Safety Requirements (Article 11) that are relevant to this report:

- Ensure that the generation of radioactive waste is kept to the minimum practicable;
- Take account of interdependencies among the different steps in radioactive waste management;
- Aim to avoid imposing undue burdens on future generations.

¹ For brevity and clarity the acronym NORM is used to encompass all naturally occurring radioactive materials where human activities have increased the potential for exposure in comparison with the unaltered situation. Concentrations of radionuclides may or may not have been increased.

Additional provisions related to transboundary movement of radioactive materials are also included in this Convention. This issue is also addressed in the Safety Fundamentals [5], as part of Principle 7: which states that “people and the environment, present and future, must be protected against radiation risks”. It is recognized that “radiation risks may transcend national borders and may persist for long periods of time. The possible consequences, now and in the future, of current actions have to be taken into account in judging the adequacy of measures to control radiation risks”.

1.4. Overall approach and structure of the report

The processes involved in setting discharge limits and authorization conditions are illustrated in Figure 1. These processes are presented as discrete steps for ease of presentation, but it is recognized that, in reality, they represent an iterative procedure. Furthermore, the level of detail involved in each part of the process may vary amongst types of source and different Member States. Quality assurance of all parts of the process is an important consideration, although this term is not explicitly referred to in this diagram.

Each process identified in Figure 1 is described in succeeding sections of this report. Examples of current approaches adopted in Member States are presented in boxes throughout the text.

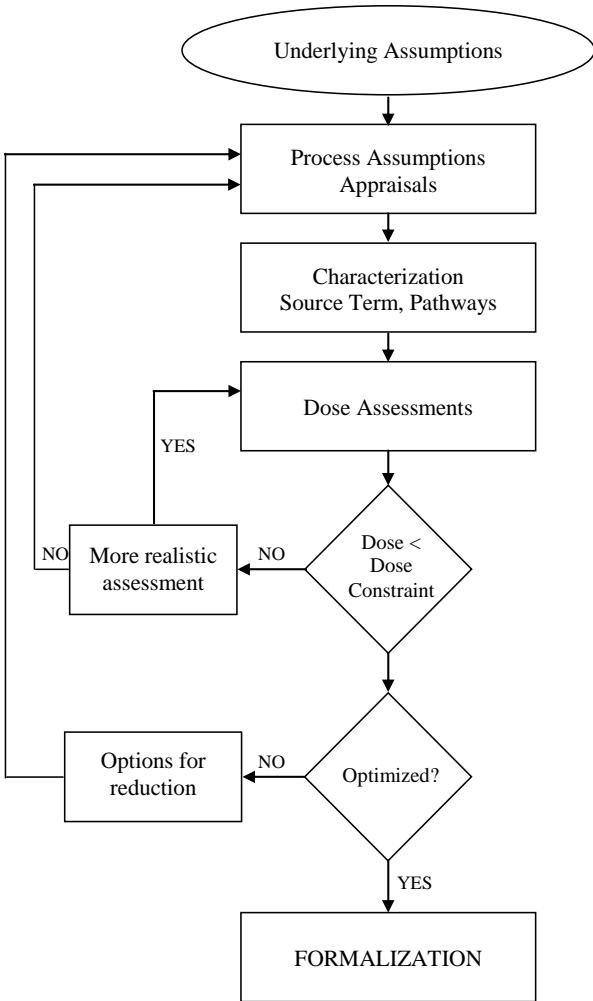


Fig. 1. Illustration of the procedure for setting discharge limits authorization conditions.

This report has been structured to follow this general flow of considerations and information as follows:

- Section 2, immediately following this introduction, provides an overview of issues related to the characterization of discharges and identification of exposure pathways.
- Section 3 explores issues related to the assessment of doses for comparison with dose constraints in the context of the regulatory control of discharges.
- Section 4 includes an overview of optimization, including identification of the types of issues influencing optimization.
- Section 5 provides a discussion of features of authorizations, including the forms of discharge authorization, practical considerations in setting discharge limits and conditions.
- Section 6 provides some background on NORM related issues and Section 7 outlines some of the emerging issues relating to protection of the environment.
- Section 8 provides brief summary and conclusions.

For illustrative purposes, the questionnaire distributed to Member States, in order to collate information about current practices in discharge control, is included as the Appendix. The summary of the responses to this questionnaire, and subsequently provided information from Member States, is presented in the Annex. Finally, a list of the contributors to drafting and review is provided at the end of the report.

TABLE 1. NORMALIZED DISCHARGES FROM NUCLEAR POWER STATIONS (AVERAGE FOR THE YEARS 1990–1994) [10]

Type of Nuclear Power Station	Normalized discharges (Bq/(GW(e)a))						
	Gaseous				Liquid		
	H-3	C-14	Noble gases	I-131	Particulates	H-3	Other
PWR	2.3×10^{12}	2.2×10^{11}	2.7×10^{13}	3.0×10^8	2.0×10^8	2.2×10^{13}	1.9×10^{10}
BWR	9.4×10^{11}	5.1×10^{11}	3.5×10^{14}	8.0×10^8	1.8×10^{11}	9.4×10^{11}	4.3×10^{10}
GCR ²	4.7×10^{12}	1.4×10^{12}	1.6×10^{15}	1.4×10^9	3.0×10^8	2.2×10^{14}	5.1×10^{11}
HWR	6.5×10^{14}	1.6×10^{12}	2.1×10^{15}	4.0×10^8	5.0×10^7	4.9×10^{14}	1.3×10^{11}
RBMK	2.6×10^{13}	1.3×10^{12}	1.7×10^{15}	7.0×10^9	1.4×10^{10}	1.1×10^{13}	5.0×10^9
FBR	4.9×10^{13}	1.2×10^{11}	3.8×10^{14}	3.0×10^8	1.2×10^{10}	1.8×10^{12}	4.9×10^{10}

TABLE 2. NORMALIZED DISCHARGES FROM NUCLEAR REPROCESSING PLANTS (AVERAGE FOR THE YEARS 1990–1994) [10].

Discharge mode	Normalized discharges (Bq/(GW(e)a))							
	H-3	C-14	Kr-85	Sr-90	Ru-106	I-129	I-131	Cs-137
Gaseous	2.4×10^{13}	4.0×10^{11}	6.3×10^{15}	–	–	1.0×10^9	9.0×10^7	8.0×10^7
Liquid	2.7×10^{14}	8.0×10^{11}	–	2.0×10^{12}	2.1×10^{12}	3.0×10^{10}	–	1.0×10^{12}

² Includes AGRs.

2. CHARACTERIZATION OF DISCHARGES AND IDENTIFICATION OF EXPOSURE PATHWAYS

As outlined in the Safety Guide on the Regulatory Control of Discharges [1], the first stage in performing an assessment of the potential impact of a radioactive discharge to the environment is the characterization of the nature of that discharge, in terms of:

- Industrial process or activity and supporting assumptions;
- Radionuclide composition;
- Chemical and physical form of the radionuclides (related to behaviour in the environment);
- Routes of discharge and discharge points, including discharge characteristics such as stack height, exit velocity, exit temperature, maximum and average discharge rates;
- Total amount of various radionuclides expected to be discharged in one year; and
- Expected time pattern of discharge, including the need for and likelihood of enhanced short-term discharges.

For installations using unsealed sources, such as hospitals and research laboratories, discharges may be assessed on the basis of the estimated throughput, or the number of procedures, with allowance made for radioactive decay. For nuclear facilities, discharges may be estimated from a consideration of the design and actual previous or proposed operating characteristics. For existing facilities, information will already exist that may be reviewed to support this process. Tables 1 and 2 provide average normalized discharges (discharges per unit of electricity produced) for different types of nuclear power plants and reprocessing plants for the period 1990 to 1994 [10].³

For new facilities, it may be possible to make an assessment based on knowledge of similar facilities elsewhere. In either case, it is generally necessary to understand the way in which particular effluents are produced to assess the relationship between discharge and operational parameters, such as production figures, and the potential effect that waste treatment or abatement techniques may have on the amount discharged.

In order to assess the impact of a given discharge to the environment, it is necessary to assess the dispersion and accumulation of the radionuclides in environmental materials. Given that authorizations are based on a prospective assessment, an environmental modelling approach is essential. Dispersion models allow the activity concentration of a radionuclide in the air or water medium, into which it is discharged, to be assessed as a function of time and distance from the source. Environmental transfer information may then be used to assess activity concentrations in other environmental media (e.g. sediment or food products) based on time-varying or equilibrium assumptions. The bioaccumulation characteristics will depend on the chemical and physical properties of the radioactive material discharged. Dispersion and transfer parameters are outlined in more detail in Safety Reports Series No. 19 [11].

The level of realism required in estimating the transfer of material from one environmental compartment to another will depend upon the type of facility under consideration, the nature

³ Updated data could be published by UNSCEAR in its next report under preparation at the moment of the preparation of this publication.

of the discharge and the availability of information. The half-life of the radionuclides discharged will also have an influence on the assessment approach adopted. For example, it will be necessary to take account of the accumulation in the environment in undertaking an assessment of the impact of discharging long-lived radionuclides.

In Safety Reports Series No. 19 [11], the proposed screening dose assessment approach is based on the use of simple transfer parameters that take account of a number of environmental processes, and implicitly assume a state of equilibrium between the concentration in water or air and other environmental materials. Such an approach is likely to be appropriate for a number of facilities where the application of annual averages is suitable. Other approaches may be more appropriate for batch, or short-term releases, and are in development in some Member States.

Once the concentration of discharged radionuclides in environmental materials has been estimated, the routes by which ‘receptors’, such as representative members of the public, may come into contact with the discharged material may be identified. The critical group⁴ is generally the focus for assessments for authorization purposes, and a schematic diagram of exposure pathways is given in Figure 2. There are two main categories of exposure:

- External exposure from radionuclides present in the air or in material incorporated in for example soils or sediment;
- Internal exposure from the inhalation or ingestion of radionuclides present in air or incorporated in water or foods respectively.

The relative importance of different exposure pathways will be dependent upon the magnitude of the discharge, the route of discharge, the physical and chemical characteristics of the radionuclides discharged and the characteristics of the radioactive decay. Table 3 lists the most important exposure pathways for a number of radionuclides associated with discharges from a range of establishments.

This process may also involve an assessment of the probability of occurrence of each discharge and exposure scenario. The scenarios of relevance to this report are those that may be reasonably predicted to occur as part of normal operation; accident scenarios are outside the scope of authorization considerations. In practice, this process will involve consideration of the relative frequency and consequences associated with different operational conditions that might lead to elevated levels of discharge. Reasonably foreseeable conditions of relatively low consequence would be considered in allowing for operational flexibility in setting the regulatory discharge level.

⁴ The term ‘critical group’ is used throughout this report on the basis that it is primarily based on current practice. The implications of ICRP Publication 101 [12], on assessing dose of ‘the representative person’ are discussed in Section 3.

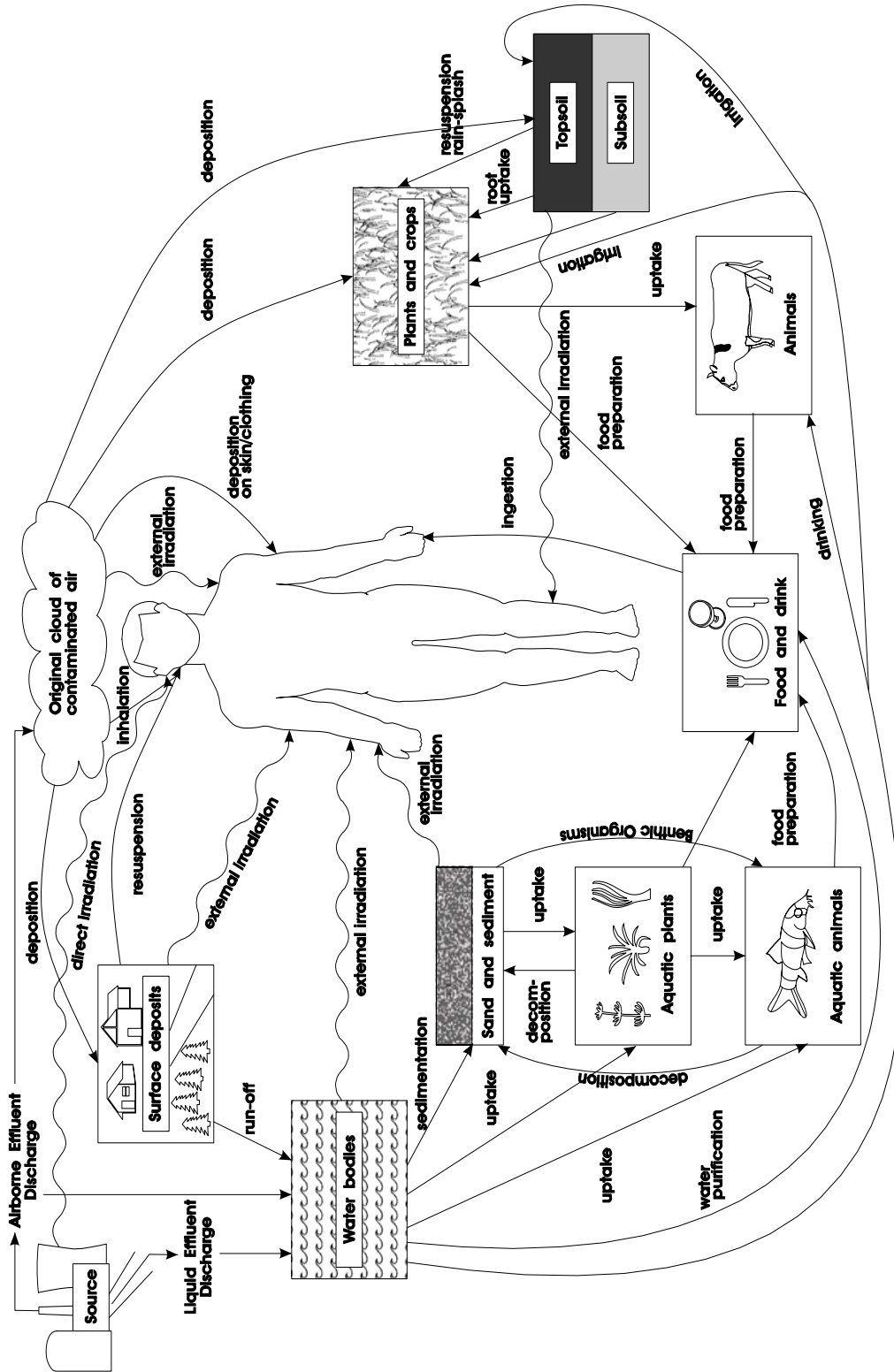


Fig. 2. Main potential exposure pathways for discharges in the atmospheric and aquatic environments.

TABLE 3. EXAMPLES OF EXPOSURE PATHWAYS FOR KEY RADIONUCLIDES DISCHARGED TO THE ENVIRONMENT [13, 14]

Radionuclide	Important exposure pathway
<i>Discharges to atmosphere</i>	
H-3	Ingestion of food and inhalation of plume
C-14	Ingestion of foodstuffs
P-32	Ingestion of foodstuffs
Ar-41	External irradiation from plume
Co-57/Co-60	External irradiation from deposited activity and ingestion of food
Kr-89	External irradiation from plume
I-131	Ingestion of foodstuffs (milk)
Cs-137	Ingestion of foodstuffs and external irradiation from deposited activity
U-238	Inhalation of plume
Pu-238/Pu-241	Inhalation of plume
U-238+	Inhalation of plume
U-235+	Inhalation of plume
Th-228+	Inhalation of plume
Ra-228+	Inhalation of plume and ingestion of foodstuffs
Ra-226+	Inhalation of plume and external irradiation
Pb-210+	Ingestion of foodstuffs
Po-210	Inhalation of plume and ingestion of foodstuffs
<i>Discharges to aquatic environment</i>	
H-3	Ingestion
C-14	Ingestion
P-32	Ingestion
Co-60	Ingestion and external irradiation from deposited activity
Sr-90	Ingestion
Ru-106	Ingestion and external irradiation from deposited activity
I-131	Ingestion
Cs-137	Ingestion and external irradiation from deposited activity
Pu-239	Ingestion
U-238+	Ingestion of water
U-235+	Ingestion of water
Th-228+	External irradiation
Ra-228+	Ingestion of water and fish
Ra-226+	Ingestion of water and fish
Pb-210+	Ingestion of fish
Po-210	Ingestion of water and fish

3. DOSE ASSESSMENTS FOR COMPARISON WITH DOSE CONSTRAINTS

Assessments of doses to members of the public for authorization purposes are generally based on an identified or hypothetical critical group. This group has traditionally been broadly defined as those members of the public likely to receive the highest exposure from a given source. In 2006, ICRP revised its recommendations on the assessment of doses to members of the public in ICRP Publication No. 101 [12]. In this publication, ICRP recognized the need to revise the critical group concept to address the range of approaches used to assess doses⁵ to members of the public for comparison with dose constraints, including the application of hypothetical assumptions for prospective assessments. In such assessments, it is important to

⁵ Limits and constraints relate to the sum of the effective (or equivalent) doses from external sources and the committed effective (or equivalent) dose from intakes in the specified time period (e.g. a single year).

take account of potential accumulation in the environment over the operational lifetime of the practice. As a consequence, a change in nomenclature was recommended. However, the characteristics underlying the selection of the ‘representative person’ — reasonableness, sustainability and homogeneity — are similar to those recommended previously to define critical groups; The ‘representative person’ concept is still to be incorporated in international guidance and therefore the term ‘critical group’ is retained below, where discussing existing national experience. However, the first impression is that this new concept represents a change of terminology, which is unlikely to have major practical implications.

Collective doses may also be assessed during the authorization process. A screening methodology for calculating collective dose as a function of radionuclide and discharge, is provided in Safety Reports Series No. 19 [11]. The EC has also published guidance on the calculation, use and presentation of collective doses for routine discharges which deals with, among other things disaggregating collective dose into different components, with the aim of providing a basis for decision-making and risk communication [15]. However, Member States’ experience suggests that critical group doses generally influence authorization decisions to a far greater extent and collective doses are not discussed further in this section as a result.

The approaches used to identify the critical group differ in detail amongst Member States. The critical group (or representative person) may be defined on the basis of generic or site-specific information. A generic assessment implies the use of conservative assumptions regarding the location or habits that bring members of the public into contact with the radionuclides discharged, often based on national experience and data (e.g. habits may be defined on the basis of a high percentile of the national or regional distribution). This generic approach may be considered to represent a hypothetical ‘most exposed’ or representative person.

A site-specific assessment is likely to utilize parameters (for occupancy and consumption) gathered from local sources, possibly to represent groups of the population whose habits are not sufficiently represented by national information. References [1] and [11] provide detail on the use of such models; reference [1] provides a procedure for determining the level of assessment required, while reference [11] contains a generic screening approach, based on generally conservative assumptions.

Within Europe, it is important to note that Article 45 of the European Union’s Basic Safety Standards (Council Directive 96/29/EURATOM [16]) requires that ‘Member States’ competent authorities ensure that estimates of doses from practices subject to prior authorization shall be as realistic as possible for the population as a whole and for reference groups” [16]. In 2002, the EC published a report with a view of developing a common methodology on the harmonization of approaches for assessing doses to members of the public [17]. The focus of the report was on retrospective assessment, rather than the prospective assessments, but parts of this guidance are relevant to the present report. The EC report emphasizes the importance of having a good understanding of local conditions around the installation being assessed, while also recognizing the fact that the effort expended in achieving realism should be commensurate with the radiological significance of the source concerned. For example, it is suggested that a detailed survey of local consumption rates may not be justified where doses are of the order of a few $\mu\text{Sv/a}$. Furthermore, it is suggested that uncertainty/variability analysis may not be warranted if ‘best estimate’ doses are of the order of $10 \mu\text{Sv/a}$ [17].

Experience of Member States

Both hypothetical and realistic critical groups are used. In some cases the critical group is defined for the whole practice or facility, in others for a particular exposure pathway from the given source. The critical group may consist of a single individual or of a group of people; in the latter case there is a general requirement that people in the group have similar habits or that the exposure to the individuals from a given source is evenly distributed. Sometimes the generally cautious approach of assuming that hypothetical critical groups reside permanently at the site fence or at the boundary of an exclusion area around the site is used, especially for assessment of doses due to direct radiation from the facility, or at the location with the highest dose rates or activity concentration in the area around the facility.

Estimated critical group doses are then compared with the regulatory criteria to ensure compliance. This is often an iterative process and the detailed application will depend upon the national practices; when using dose considerations, some regulatory bodies choose to express these limits as doses to members of the critical group, whereas others may choose to impose the limits at the site boundary. These techniques can be equally valid because all of these quantities can easily be related to each other. The choice may therefore be one of Member State preference, or based on the requirements of other aspects of the overall regulation of the facility, such as the methods to be used to demonstrate compliance.

Experience of Member States

The use of a circumstantial higher dose criterion of 5 mSv/a, included in Reference [1] was not applied in practice and was considered to be unacceptably high to form the basis of setting discharge limits, even for ageing nuclear facilities. This implies a need to update the Safety Guide.

Should the postulated discharge result in doses that are above the applicable dose constraint, further dose calculations would be appropriate to consider whether the application of more realistic assumptions would give a different result. If the result is confirmed, then the practice would not normally be authorized. In exceptional circumstances, for example relating to existing facilities that cannot comply, some exceptions may be made [1].

Generic dose assessments can be used to establish numerical values that can then be used for comparison with dose criteria, particularly for non-nuclear industries. In this situation, conservative assumptions are used to give assurance that the regulatory criteria will be met. The advantage of the generic approach is that it provides clear requirements to both the regulator and the licensee and that similar technical solutions can be applied to similar facilities. Further, due to the fact that the generic assessments use simplified models and generic data, this methodology has significant cost advantages compared to site-specific assessments. The primary disadvantage is that the operational requirements placed as a result may be more stringent than would otherwise be the case.

The use of generic assessments is particularly useful for assessing the impacts from facilities such as hospitals and research laboratories. In such cases, the development of detailed site-specific assessments is unlikely to be warranted due to the fact that the discharges from such facilities are usually very low. A generic approach also may be used as the first stage in a dose assessment process, which may be followed by a more site-specific realistic assessment if the preliminary dose assessment yields a high result that warrants further consideration.

For nuclear facilities, the assessed doses from the use of generic assessments are more likely to approach the regulatory criteria (e.g. dose constraint) and therefore a more detailed site specific assessment may be needed. A site-specific assessment is generally required for nuclear facilities, even if the doses under normal conditions are low. This is a consequence of the potential for enhanced doses and the level of regulatory supervision expected for such facilities

A site-specific approach provides the potential for a more realistic assessment of the impact associated with discharges from a site. It may include more detailed consideration of not only the habits of the critical group (or representative person) but also the characteristics of the discharge. This allows the development of a more detailed understanding of the contribution of a complex series of discharge routes to critical group doses, which may be used to prioritize specific control measures. This has the advantage that facility specific risks are quantified and an optimum option can be selected. In cases where there is large variation in site-specific parameters, a site-specific assessment may be the only option.

Experience of Member States

Dose assessments are often conducted in a manner that is nuclide specific and based on unit discharge. In some Member States the dose per annum per unit release is derived, sometimes called reference release factor. This allows for determinations of optimization solutions that take account of the actual releases on a nuclide specific basis.

4. OPTIMIZATION

The practical application of the optimization principle in the context of public exposure is a subject of on-going debate. In practice, the extent to which formal optimization techniques are applied depends upon the operational status of the facility involved and the potential doses and risks involved. Many options may lead to an increased arising of solid radioactive waste and a corresponding trade-off between reduced public and occupational doses and risks. There could also be safety considerations such as an increased risk of accidental releases which need to be taken into account as part of the optimization process [12].

Different considerations will also be involved in optimization of proposed and existing facilities, as outlined below:

- The design stage of a new facility is likely to involve complex decisions and processes that may require formal decision-aiding techniques to be used. At this stage, there may be a broad range of possible designs and there is the potential to construct the facility to reduce waste arisings (including discharges) and thereby reduce potential occupational and public doses.

- During the operational stage, the options for reducing public exposures are more restricted, due to the more limited possibilities of changing the process or activity under consideration to reduce radioactive waste than during design and, in practice, reduction in effluents is often based on an evaluation of the technical options available.

Experience of Member States

Optimization of public protection for on-going discharges is often undertaken in an interactive way between the regulatory body and the operator. Regulatory bodies require optimization and may verify that it has been implemented, while operators may propose and design, as well as implement, the optimized option.

Not all options will require a formal quantitative optimization assessment. The Safety Guide [1] recommends a screening procedure based on collective dose. Data and models given in Safety Reports Series No. 19 [11] allow an estimate to be made of the collective dose commitment in man Sv arising from discharges in a year. This may then be added to an estimate of the relevant collective dose from occupational exposure to provide an estimate of the total collective dose. If this value is less than 1 man Sv, it is probable that there is no need to carry out an extensive formal optimization study [18]. However, there is some question regarding the extent to which collective doses are used for this purpose in practice among Member States.

Experience of Member States

Collective dose calculation is used for occupational radiation safety reasons and, while it is calculated in some Member States for public doses from discharges, it is not generally calculated explicitly for the purpose of optimization.

In one Member State, for example, collective dose is used to assess the effectiveness of liquid and gaseous effluent treatment systems used in power reactor designs. The regulatory agency applies a cost-benefit ratio of \$200,000 (US) per man Sv.

Formal optimization assessment and a screening procedure based on collective dose are not routinely performed for facilities such as hospitals or university research units, where discharges are likely to be significantly lower than any dose constraint or limit set by the regulatory body

A more formal optimization assessment is required for activities that would result in a collective dose greater than 1 man Sv/a, or under other circumstances where the regulatory body has deemed it necessary. This will involve consideration of alternative options for storage, treatment and/or redesign, and their individual attributes, including capital, operating and maintenance costs, the implications for waste management, and the effect on individual and collective doses for both the public and workers. Social and political considerations may also be evaluated. The application of the optimization principle was the subject of a recent ICRP publication [12], which included the recommendation that collective dose matrices should be used to take account of the range of individual doses and the scale (local, regional

or global) over which they arise. The application of these recommendations is a subject of review.

Protection can be considered to be optimized when, from among the management options that satisfy the dose constraint condition, the one chosen is that for which radiation doses are as low as reasonably achievable, economic and social factors being taken into account [4, 2].

The Safety Guide [1] addresses optimization in terms of traditional radiological protection and human health. However, in recent years, international and national organizations have considered protection of the environment in more depth. Some consideration on the explicit protection of the living environment is discussed in this report in Section 7.

4.1. Features of a management option

Consideration of management options includes the evaluation of requirements for design and operational features, storage and treatment, and prevention of spills. For new facilities, protection can be optimized through the design, and construction for the operational, and decommissioning stages of the facility. Once a facility has been constructed and operation has begun, there are fewer options available to optimize. However, during operation there may be opportunities to review options for the management of discharges and re-authorization when major changes in operation are proposed. The management option may then consist of storage, treatment (abatement), redesign of the facility, or backfit or upgrade of the existing facility or system design features.

The optimal control method will be dependent on the waste stream and the radionuclides involved. This approach has resulted in the development of abatement or storage systems which retain materials to be discharged to allow for short-lived radionuclides to decay, and systems and methods, such as filtration and precipitation, which concentrate and contain materials to be discharged eventually converting them into solid waste for storage. Examples of abatement techniques for discharges from nuclear installations are provided in Table 4, based on information provided in Reference [19].

TABLE 4. EXAMPLE ABATEMENT TECHNIQUES SUGGESTED AND DISCUSSED IN REF. [19].

Liquid abatement	Gaseous abatement
Chemical precipitation	Electrostatic precipitation
Ion exchange	Cyclone scrubbing
Reverse osmosis	Chemical adsorption
Ultrafiltration	HEPA filtration
Evaporation	Cryogenics
Hydrocyclone centrifuging	Decay tanks
Cross-flow filtration	

Experience of Member States

Options to control discharges from non-nuclear facilities such as hospitals and research facilities are often limited, for example to the prevention of spills, exhaust air filtration, and decay in storage. Liquid discharges are generally routed through sanitary sewer systems, following decay storage, in some cases.

4.2. Decision aiding techniques

Decision aiding techniques may be employed to facilitate the optimization process. The advantage of formal decision aiding techniques is that they allow each of the elements involved in making a decision to be explicitly identified. The most common decision aiding techniques discussed in the literature are cost benefit analysis (CBA) and multi-attribute analysis (MAA), although there can be others. The IAEA has already discussed decision-aiding techniques to some extent elsewhere [20].

As stated in the Safety Guide [1], the objective of using CBA to optimize protection is to identify the level of protection that minimizes the sum of the cost of protection and the cost of radiation detriment. The cost of the health detriment is assumed to be proportional to the collective dose. In order to apply CBA to the optimization of protection, the cost of protection and the cost of radiation detriment are expressed in monetary terms. The estimation of costs of protection is in principle a straightforward procedure, although considerable complexities may arise when detailed costs of plant, materials, energy and labour need to be considered. Assigning a cost to radiation health detriment requires a judgement of the value of avoiding the deleterious effects of radiation exposure, which involves a complex ethical challenge.

In some cases, the regulatory body may exercise judgment on the possible need to assign different costs to categories of the collective doses that occur over different time periods, especially when a practice leads to environmental contamination by long lived radionuclides and therefore to inter-generational exposures. As a consequence, there may be different considerations for discharges from a nuclear facility than from a radiopharmaceutical production plant, primarily due to the different characteristics and half-lives of the radionuclides concerned. The consideration of trans-generational and trans-boundary exposure will also be influenced by ethical considerations and the principles of radioactive waste management.

The main limitation of CBA is that it requires explicit valuation of all factors in monetary terms. This tends to restrict the range of factors that may be included in the optimization process. MAA does not necessarily require such explicit valuation. It is therefore possible to take more qualitative factors into account and such approaches are more flexible as a result. For the radiological impact, for example, additional factors such as equity in time and space, risk perception of the public and accident potential can be taken into account using multi-criteria methods. Other considerations that may also be included are: technical factors such as the flexibility and redundancy of a proposed installation or process, its development status, and the extent of technical support or of the research and development effort.

Experience of Member States

At present, for the purpose of public protection formal CBA and MAA are not widely employed in the consideration of on-going operations. Many Member States do, however, use a balance of costs and benefits to decide what technology to require for plant operations and discharge abatement. Further issues, such as public acceptability, government policy and pressures for progressive reduction, are then considered with the aim of producing a further step in reducing discharge limits.

In one Member State, for example, an applicant for a reactor license is required to include in the design of liquid and gaseous effluent treatment systems items of reasonably demonstrated technology, that when added sequentially to a treatment system in order of diminishing benefit return, can for a favourable cost-benefit ratio effect reduction in doses to populations within a 80-km radius of the proposed reactor. The regulator applies a cost-benefit ratio of \$200,000 (US) per man Sv.

4.3. Examples of considerations influencing the optimization process

Social and political factors will influence the decision on the optimized level of discharge. In particular, factors including public perception, political awareness, and potential consequences are relevant and likely to be different for discharges from nuclear facilities than from non-nuclear facilities such as hospitals. The effects on future generations, the ability to control the exposures, and the amount of information available for making informed decisions may also be considered. The need to accommodate and balance the requirements of seemingly contradictory policies will also need to be considered (for example the requirements to minimize discharges — with associated requirements for waste treatment measures that will increase the arisings of solid waste — and the principle of waste minimization).

The factor that is of most importance will be dependent on site-specific attributes and also on the political and social pressures within a country. A list of such considerations is outlined below, in no particular order:

Waste minimization: It is generally agreed that wastes should not be created unnecessarily and therefore waste minimization should be a consideration in any optimization assessment. The principle takes account of solid, liquid and gaseous wastes in combination and separately. It is also concerned with reductions in both activity concentration and volume of waste.

Cost: The cost of a management option will have an influence on decisions. Capital, operational and maintenance costs should all be taken into account.

Proportionality: The requirement that regulator ‘safety requirements’ shall be commensurate with risk and that regulation shall be prioritized in terms of the relative severity of the problem.

Worker versus public dose: A management technique will affect the dose commitment to members of the public and workers. Storage and treatment will often reduce the dose to the public in the near-term. It is necessary to consider the potential increase in occupational dose associated with any storage effluent treatment options.

Effluent discharges versus solid disposal: Government policies, final disposal preferences or stakeholder pressures may result in the preference of one waste stream over another. It is preferable to discharge effluent at times, in a form and manner that minimizes the radiological effect on the environment and to the public. For radionuclides that are persistent in the environment or have a high radiological impact, it may be more appropriate to adopt a strategy of concentrate and contain through the use of abatement techniques.

Inter-generational considerations: The impact on future generations of doses arising should be taken into account, especially for long-lived radionuclides.

Transboundary considerations: Transboundary effects refer to the movement of released radioactive materials across national boundaries. Transboundary effects may extend far beyond the national boundaries of the originating country when activity is entrained into atmospheric and oceanic currents or rivers.

Different states may impose different restrictions on the levels of radioactive materials permitted to be discharged to the environment, and this may cause difficulties in cases where significant transboundary effects occur or are expected to occur as a result of the operation of the facility. It would therefore be prudent to reach agreements on the handling of such effects at an early stage of the process of establishing authorized discharge limits. A range of such regional agreements have been established that address such transboundary considerations (including Article 37 of the EURATOM Treaty [24] and the OSPAR Convention [22]).

Implications of Regional and International Conventions: e.g. Conventions to prevent marine environment pollution like OSPAR, HELCOM, London (Waste Dumping) may involve additional requirements, that need to be included as part of the optimization process. An example is given below.

Experience of Member States

Over the last decade, there has been an increasing focus, particularly in Member States in Europe, on the application of Best Available Techniques (BAT).

The application of BAT to the nuclear sector has been promoted, for instance, by commitments related to the OSPAR convention [22]⁶. Within this convention, Contracting Parties are committed to apply Best Available Techniques (BAT) and Best Environmental Practice (BEP) including, where appropriate, clean technology, in their efforts to prevent and eliminate marine pollution. As defined in Appendix 1 of the OSPAR Convention BAT “means the latest stage of development (state of the art) of processes, of facilities or of methods of operation which indicate the practical suitability of a particular measure for limiting discharges, emissions and waste” [23]. BEP is defined as “the application of the most appropriate combination of environmental control measures and strategies”.

BAT is effectively a different approach to optimization that focuses on techniques and technology rather than impact. This approach has been widely applied to the control of non-radioactive pollutants, and was introduced as a key principle in the Integrated Pollution Prevention and Control (IPPC) Directive 96/61/EC [21], and is being increasingly applied to the control of radioactive pollutants, for example through commitments made in the context of the OSPAR convention. Within the context of IPPC, BAT is defined as follows:

- **‘best’** in relation to techniques, means the most effective in achieving a high general level of protection of the environment as a whole;
- **‘available techniques’** meaning those techniques developed on a scale which allows implementation in the relevant class of activity under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced within the State, as long as they are reasonably accessible to the person carrying out the activity;
- **‘techniques’** includes both the technology used and the way in which the installation is designed, built, managed, maintained, operated and decommissioned.

Involvement of interested parties: Many regulatory bodies involve local and regional groups in the decision-making process, particularly when considering effluent discharges from a nuclear installation. The benefits and risks are then discussed and the regulatory bodies aim to demonstrate that the optimal management option has been proposed. Such discussions allow openness, transparency, and involvement. Furthermore consultation with the public and potentially affected parties is a policy requirement for such environmental decisions in several

⁶ The OSPAR Convention is the current legal instrument guiding international cooperation on the protection of the marine environment of the North-East Atlantic (see <http://www.ospar.org>).

Member States, and supported by the Aarhus Convention [25].⁷ Local, regional, national and international groups may all wish to be involved in the decisions because of the actual and perceived implications.

Feasibility: Several management options are likely to be considered when assessing optimization. Each option should consider practical feasibility of implementation e.g. existing facilities will have less scope for waste minimization etc than newer plants and therefore some options may not be feasible. In addition to practical feasibility, political and social feasibility should be considered.

Degree of uncertainty: Each option may involve a number of uncertainties. Some forms of uncertainty can be reduced through further assessment and comparison with existing best practice and previous experience.

Other factors: Where appropriate, a regulatory body may choose to consider other factors, such as chemo-toxicity of radionuclides, safety issues and limits for non-radioactive contaminants.

5. DISCHARGE AUTHORIZATION

The previous sections of this report provided guidance and examples of international experience on characterizing the discharges from the facility, identifying the exposure pathways, calculating the resulting doses, and optimizing the discharges. Decisions regarding the design of a new facility or changes in an existing facility concerning the types of discharge treatment systems and techniques to be used are made, as part of the optimization process. This process provides an indication of the lowest discharge levels (and associated doses) that can reasonably and economically be achieved for the facility under consideration. The next step would typically be to determine the authorized discharge limits to which the facility would be required to comply. According to the Safety Guide [1], these limits:

“... should reflect the requirements of a well designed and well managed practice and should provide a margin for operational flexibility and variability.”

The following sections provide some guidance on achieving this goal and for setting discharge limits in general.

5.1. Forms of discharge authorization

5.1.1. *Dose limits and limits of radioactive material discharged*

There are a number of ways in which authorized discharge limits can be set based on limiting either dose or quantity of radioactive material discharged from the facility. In most cases, the choice is a matter of preference on the part of the regulatory body, as well as the manner in which the regulatory body requires licensees to demonstrate compliance.

⁷Aarhus Convention, Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (see <http://www.unece.org/env/pp/>)

Some regulatory bodies prefer dose because it is viewed as a more fundamental quantity and one that underlies the system of limitation of discharges. Setting limits in terms of quantities discharged, on the other hand, is viewed by other regulatory bodies to reflect more closely the quantity that is to be controlled and measured, and is therefore more closely connected to the actions that the registrant or licensee must take to control discharges.

Expressing limits in terms of dose or quantity of radioactive material discharged does not represent a fundamental difference, but rather one of preference, because dose and quantity are directly proportional for any given site, and one can be converted to the other without difficulty. However, while a quantity of radioactive material is a measurable magnitude, dose to members of the public is always based on an assessment.

Discharge limits expressed in terms of dose are generally based on the limitation of individual doses. Collective doses are rarely used for limiting discharges based on experience among Member States.

Discharge limits specified as doses

Choosing to specify the limits in terms of dose will require some additional decisions to be made regarding the application of:

- a single or multiple dose limits or constraints; and
- site or individual source-related limits.

The regulatory body may decide to set a single limit based on the effective dose and one or more equivalent organ doses. In the case of facilities that discharge radioiodine, for example, it may be adequate to specify limits in terms of the equivalent dose to the thyroid for pathways leading to internal exposure. In general, setting limits in terms of a single dose value will be appropriate only for those facilities that discharge few radionuclides. For cases in which a mix of many radionuclides is discharged, and especially where there is no constant correlation between the amounts of each type of radionuclide discharged, using one dose limit may not be adequate.

Experience of Member States

When more than one dose value is used, some regulatory bodies adopt the approach to specify one limit for the effective dose, one for the equivalent dose to the thyroid, and another one for the equivalent dose to any other organ or organs.

The location at which the dose is to be specified must also be defined. One approach is to require that the doses be specified for the critical group. This approach has the advantage that this group has already been identified, when assessing the impact of site discharges, and therefore little additional effort is required. The disadvantage of this approach is that the limit is that it will be subject to changes in the group, or their habits.

Some regulatory bodies therefore prefer to specify the dose limits at the site boundary, which is the boundary within which the licensee exerts complete access control, and from which the public is normally excluded or, if not entirely excluded, would not normally spend significant

amounts of time. Specifying the limit in this manner will require that the limits are such that the dose to the actual critical group will not be exceeded as long as the site boundary limit is not exceeded.

In some cases, the dose limits will be specified as the dose to any member of the public. This is generally the same quantity as the dose at the site boundary, because that is the location of the closest approach to the facility for any member of the public.

Experience of Member States

The examples given above are primarily on limitation of critical group or individual doses. It is rare that discharge limits include limitations on collective dose. However, in one case the regulatory body gives restrictions on specific annual normalized collective dose per unit of productivity or radioactivity inventory, for different groups of facilities, and those constraints do not change depending on the practice.

Limits on radioactive material discharged

The limits on quantities of radionuclides discharged are usually specified at the point of discharge, such as the stack for airborne discharges, and the discharge pipe for liquid discharges. This choice of location is usually the point at which measuring or sampling equipment is located. If the discharges are made in batches, rather than continuously, then analysis of samples from each batch before discharge will serve the same purpose for demonstrating compliance as does measuring the activities at the points of discharge.

Discharge limits may, in some cases, be set indirectly by using an operational parameter that is directly related to the levels of discharge, as a surrogate for the discharges themselves. For example, a facility engaged in xenon studies will discharge xenon in proportion to the number of studies conducted, and the regulatory body may decide to impose limits on the number and rate of studies conducted rather than on the airborne discharges. This approach has the merit of much greater simplicity and ease of implementation, and achieves the desired control purposes. This approach is generally available only for relatively simple operations, because the increasing complexity of a facility diminishes the direct link between operating parameters and actual discharges.

5.1.2. Radionuclide grouping

When discharge limits are specified in terms of quantity of radioactive material discharged, separate limits are usually specified for different radionuclides, or groups of radionuclides. Exceptions are cases in which the facility discharges only a few radionuclides, such as a hospital using only iodine or Tc-99m. However, even in situations where a mixture of radionuclides is discharged, it is unusual to set limits on each individual radionuclide, because such a practice will usually be cumbersome and unnecessary, in which case one limit on total activity released may be used. For example, these groups are chosen to reflect one of the following:

- the feasibility of measuring one or more radionuclides within the group;
- indicators of plant performance;
- contribution to dose.

For larger facilities that may discharge a variety of radionuclides, limits are generally imposed on groups of nuclides that share relevant characteristics, although limits may also be imposed on specific radionuclides that are deemed to be of special significance. For example, airborne discharges for nuclear plants are often grouped as follows: noble gases, halogens or iodine isotopes, and particulates. This grouping reflects dosimetric considerations: noble gases result in external exposure to the whole body, iodine isotopes result in thyroid doses, and particulates usually present a potential inhalation or ingestion hazard to all of the organs and tissues of the body. They also reflect different ways of sampling and quantifying the discharges. The grouping may also be extended to include gross alpha and gross beta activities.

Grouping of radionuclides is also useful in situations in which members of selected radionuclide groups arise together, and therefore the occurrence of one indicates the presence of the others in the group usually, although not always, in fairly fixed proportions. Such grouping has the merit of achieving simplicity in both the formulation of the limits as well as their implementation. The radionuclide of the group that is most easily detected at the desired sensitivity is often used in specifying the discharge limit for the group.

In some cases, a regulatory body may impose limits on specific radionuclides that provide early indications of changes in the operational status of the facility, or that may make an exceptionally high contribution to the total offsite dose. When limits are specified for groups of radionuclides, the practice is usually to set the limit for the group on the basis of the characteristics of the most radiotoxic radionuclide of the group.

5.1.3. *Site or facility specific limits*

Discharge limits, whether specified in terms of dose or quantity of radioactive material released, may be specified either for the whole site, for each unit within the site, or even for each discharge point, such as stack or pipe. A unit in this context means an identifiable entity that generates airborne or liquid wastes. For example, at a large hospital, there may be a nuclear medicine facility, a waste treatment facility, and an incinerator, each of which has its own discharge points and each of which may be considered as a separate and independent unit on which discharge limits may be imposed. At a large reactor site, each unit may be a nuclear reactor. In nearly all cases, regulatory bodies impose a site limit, whether or not individual unit limits are imposed, but in some cases regulatory bodies impose only a site limit, with no limits on individual units. When a site limit alone is used, without limits on individual units, the discharge from each unit is still expected to be optimized. The site limit in such cases serves as a cap for future development at the site. An additional, new unit will add to the overall discharge from the site, but the total would be expected to remain within the site limit. An alternative approach is to use a national limit per nuclear site below which optimized lower site levels are defined. This individual site-level can be increased if new facilities are added, on condition that the national limit is not exceeded.

Site limits alone, as well as site plus unit limits, are both used, and the choice is a matter of the preference and experience of the regulatory body, as well as the ease of implementation, especially in situations in which the units on the site share discharge treatment equipment.

5.1.4. Time interval for demonstrating compliance

The basic interval over which compliance is expected to be shown is almost always one year, usually a calendar year, although a rolling 12 month period is also used. The advantage of the latter is that it is believed to permit closer supervision of the facility by the regulatory body, but it is administratively more cumbersome to implement.

Although annual discharge limits are almost invariably used and are considered as the primary means of regulatory control, some regulatory bodies view one year as too long a period over which is to demonstrate compliance. One concern is that the validity of the assumptions used in setting annual discharge limits may not be applicable for short-term discharges.

Parameters are typically chosen to be representative of annual averages. For example, the prevailing wind direction and speed, the degree of stability of the atmosphere, and the dietary habits applied are usually annual averages. In the absence of discharge authorizations for periods shorter than a year, it is at least theoretically possible that the facility may discharge a significant fraction of its annual allowance over a short duration, or a series of short durations, with significantly different radiological impact. For example, if a significant proportion of the discharge occurs during a period of exceptional atmospheric stability, the radioactive material would not be dispersed as much as the annual average calculations would indicate, thus leading to higher doses. Short-term limits are therefore often specified in addition to the annual limits. The short-term limits also allow the regulator to more closely monitor the facility's performance, and to take action as appropriate should operations fail to meet the short-term limits. Short-term limits are generally higher than the pro rated value for the applicable duration, to allow for operational flexibility (see text box below).

Experience of Member States

As an example, a calendar quarter limit may be one half of the annual limit, and an instantaneous release rate limit may be 30–50 times the average annual discharge rate.

A variety of short-term limits have been used, but the most common are limits over a period of a calendar quarter. In addition to quarterly limits, some regulatory authorities also impose limits on the instantaneous discharge rate. This latter is normally expressed as the maximum allowable concentration of radioactive material being discharged, measured either at the point of discharge or at the site boundary. These rate limits may be imposed on each discharge point, or for the site as a whole if applied at the site boundary.

Some regulatory authorities consider exceeding the shorter-term limits and discharge rates not as a violation of basic requirements, but as triggers for a reporting requirement. The operator in such cases is usually required to report the occurrence to the regulatory body, with an explanation of why the limit was exceeded and what measures have been taken, or are to be taken, to prevent recurrence or minimize its probability. However, this is not always the case, and some authorities consider exceeding even the shorter-term limits as violations of regulatory requirements that subject the registrant or licensee to penalties.

5.2. Setting authorized discharge limits — operational flexibility

Based on the optimized discharge levels or operational experience the regulatory body will set authorized discharge limits. Exceeding limits will normally initiate regulatory action. There is therefore a need to allow for operational flexibility, and anticipated fluctuations in performance, in setting discharge limits in order to avoid unnecessarily frequent violations of regulatory requirements that would result in significant and needless expenditure of resources, negative public perception, and frequent interference with the operation of the facility.

According to the Safety Guide [1], authorized discharge limits are set higher than the optimized levels (see Figure 3) — although within the specified dose constraints — by an amount sometimes referred to as ‘headroom’ (or allowance for operational flexibility). How much operational flexibility (or headroom) should be permitted is a matter of judgment on the part of the regulatory body, but at a minimum it must allow for what would be anticipated under normal operating events. These events include plant conditions that lead to a temporary increase in discharge levels of relatively short duration, usually hours to days, but are not classified as an incident or accident. For example, in the case of a nuclear medicine department, the event may be a number of patients seen that is significantly higher than average. For other types of operation, it may be a temporary failure of an effluent treatment system. Previous experience with the facility in question or other similar facilities can provide useful information on the minimum allowance for flexibility that should be permitted.

Some regulators set this at a level that is the minimum indicated by experience, or by past performance of this particular facility. Specific guidance cannot be provided to assist in this choice; it will be determined by the framework of national policy and commitments made through international agreements. The major point, however, is that sufficient allowance is made for operational flexibility to allow for normal operational variations for the type of facility under consideration.

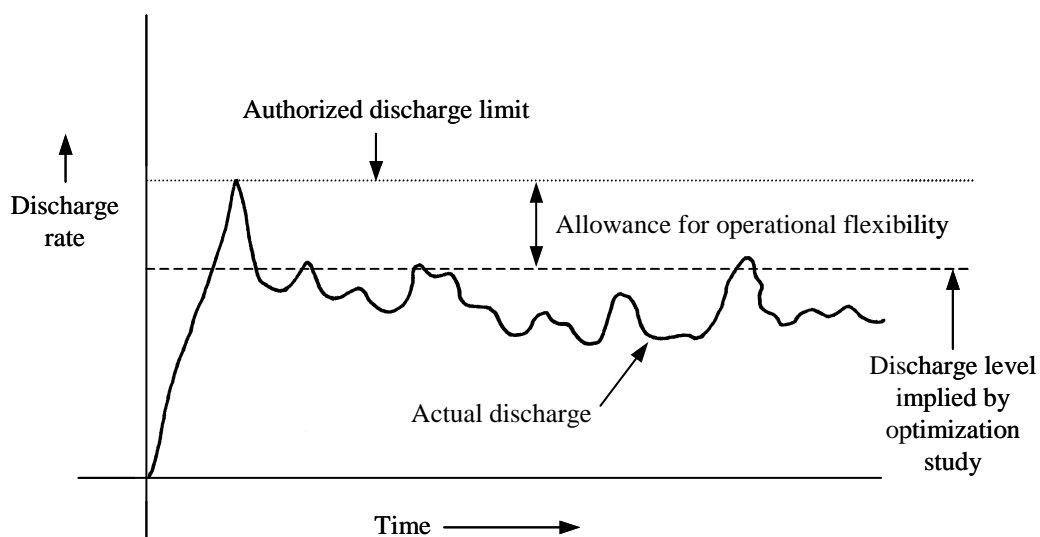


Fig. 3. Illustrative representation of the relationship between optimized and authorized discharge levels.

5.3. Period of authorization validity

Some regulatory bodies issue discharge authorizations that have a limited period of validity. At the end of the period of validity, authorizations are reviewed, and updated, if necessary, based on current information. There is no standard period of validity; it may vary from two to three years up to five or more years. The appropriate period is generally selected by the regulatory body based on, for example, the likelihood of the occurrence of changes at the site and its surrounding environment that may affect the bases on which the discharge authorization was initially issued. Some regulatory bodies have the legal possibility to review and update the authorizations if necessary and do not apply a defined limit on the validity of the discharge authorization.

It is normal to require facilities to obtain approval from the regulatory body before making any changes that may affect doses or the safety of operations. However, the accumulation of such changes over a period of time may produce a qualitative change in safety level that can only be detected through a complete review of the overall operation. The period of validity will also be influenced by the degree of ongoing review and supervision provided by the regulatory body, and the breadth and depth of such ongoing reviews. In some cases, such ongoing reviews are of such a depth and scope that they constitute, in themselves, a facility review.

In some cases, the period of validity of the authorization may be equal the expected design life of the facility. Such facilities would normally have stringent ongoing review and audit requirements imposed in their authorization, such as, for example, periodically reviewing whether there have been any significant changes in operation or in dose assessment factors such as the demographics and land use in the areas surrounding the facility. This should ensure that the location and composition of the critical group and factors such as the locations of dairy farms, vegetable gardens, population centres, dietary habits, and other factors that enter into the calculation of the dose to the critical group and the collective dose for the site, have not altered or are taken into account. Any significant changes are generally required to be reported to the regulatory body, the doses are recalculated, and the authorized limits adjusted accordingly.

5.4. Compliance and operational requirements

It is an operational requirement upon an operator to comply with the discharge authorization. An operator is often required to have a management system and the resources to achieve compliance. A list of the issues generally dealt with under compliance and operational requirements is given below:

Monitoring: The regulatory body could specify the requirements for monitoring in the discharge authorization, depending on the type of facility. The level of monitoring required is generally expected to be commensurate with the potential hazard, as indicated in the Safety Guide [1]. Hospitals, for example would not require the same level of monitoring as nuclear power plants. However, a regulatory body may request a facility to conduct effluent monitoring as part of its registration.

Experience of Member States

A method for setting discharge limits uses factors that allow for explicit consideration of the individual components that contribute to operational flexibility [26]. The method starts with the value of the average annual discharge from the plant for the past 5 or so years, D , if the plant authorization is being renewed, or for a similar facility in the case of a new authorization. D should not include releases caused by unusual events, such a steam generator pipe leak, that temporarily raised the facility's discharge levels. D is then multiplied by a factor, F , to allow for normal and expected deviations from average performance. A value of 1.5 for F has been suggested, but this value would be chosen by the regulatory authority based on its assessment of probable normal facility variations. The discharge limit, DL , would then be given by:

$$DL = D \times F$$

Additional factors may be included to allow for anticipated developments at the site. These may include the following:

T: a factor to allow for probable increases in the facility's performance level, for example increases in the number of patients treated per year;

A: a factor to allow for changes due to plant aging. Some authorities are of the opinion that plant aging should not, in itself, be a sufficient reason to permit increases in discharge levels, and therefore would set this factor to unity;

B: a factor to allow for possible changes in facility processes that may result in increased discharge levels, such as, for example, the development of medical diagnostic tests that use larger amount of radioactive material per test.

In addition to the above multiplicative factors, other factors may be added to allow for additional activities that may be undertaken at the site, such as construction of additional units, decommissioning activities during operation of the facility, and the use of new technologies to reduce the levels of emissions from the site. Taken together, these additive factors will be represented by X to yield the following expression. The factor X is also useful in that it permits flexibility in regulating discharge levels from some sites that engage in temporary activities that may cause their discharge levels to rise for short durations, such as a few months to several years. An example is a site at which legacy spent fuel is to be reprocessed, raising its discharge levels for the duration of this processing. The value of X may then be selected to make allowances for this unusual activity, at the end of which X may be reset to zero or to its pre-activity value.

$$DL = D \cdot F \cdot T \cdot A \cdot B + X$$

The DL calculated by the above expression will yield an estimate of a discharge limit appropriate for this type of facility, and will include the necessary operational flexibility (headroom) to allow for fluctuations during routine operations as well as likely developments at the site that may take place before the end of the discharge authorization review cycle. The advantage of using the approach is that it explicitly forces consideration of each element that contributes to the authorized headroom, and allows each element to be considered and set separately from the other elements.

It is recommended that monitoring for nuclear facilities includes effluent and environmental monitoring [1]. The regulatory body would normally agree that satisfactory measuring techniques are employed and maintained by the operator. The majority of countries monitor effluent discharge from the source or at the site boundary (it may be specified in the discharge authorization).

Effluent monitoring allows the regulatory body to check the discharges against the annual and shorter-term limits to ensure there are no anomalies. Monitoring of the environment demonstrates that the levels are below or at the discharge level and may validate the model assumptions. However it is also a mechanism for checking that there have not been any unexpected discharges. It serves to reassure the public that there is no accumulation of radioactive material in the environment. The monitoring strategy should be sufficient to cover all relevant exposure pathways and allow for evaluation of doses to the critical group. Some Member States specify lower limits of detection for effluent and environmental monitoring. More information on strategies for effluent monitoring (also called, ‘source monitoring’) and environmental monitoring to control the radionuclides discharges under the conditions of authorized practices is provided in an IAEA Safety Guide [27].

Reporting: There is generally a requirement on operators to report discharge activity and volumes as a condition of the authorization. The requirement on reporting usually includes:

- *Routine reporting:* involves compiling and retaining records that indicate the total activity of the discharges, and the time and date when discharges occur. For continuous discharges, a time period may be specified. Discharge data (often quarterly and annual) are usually required to be reported by regulatory bodies.
- *Event reporting:* It is usual for a regulatory body to require an operator to record any unusual events, It is recognized that fluctuations in discharges occur, however, should a large fluctuation be greater than a specified notification level, the operator is required to inform the regulatory body. Notification levels can be pro rata limits of the annual limit or higher, for example a quarterly notification level of 25–50%.
- *Record keeping:* a regulatory body usually requires an operator to retain records for extended periods of time, or until allowed to dispose of by the regulator.

Quality assurance: Generally an appropriate quality assurance programme should be in place for all aspects of the discharge authorization. Quality assurance procedures are particularly important for monitoring programmes to ensure that they are implemented properly [1, 27].

Non-compliance: Measures taken by the regulatory authority to address issues of non-compliance are not discussed in detail in this report, since they depend on the legal framework in place to regulate radioactive discharges, at the national level. Satisfactory reporting of non-compliance with notification levels is generally sufficient for the anticipated fluctuations during normal operation. However, a breach of a discharge limit usually requires the operator to justify the circumstances that lead to the breach. The operator may also be required to investigate the incident, implement appropriate mitigation actions to limit the consequences, corrective actions to prevent the incident occurring in the future and any other action the regulator deems necessary.

6. NORM INDUSTRIES CONSIDERATIONS

A number of Member States have experience of NORM residues and radioactive discharges coming from different industrial activities. The following industries have been identified as the major generators of NORM: in-land and offshore oil and gas extraction, surface and underground mineral mining, milling and processing facilities e.g., phosphates processing (HCl and H₂SO₄); titanium dioxide (for pigments); production of rare earth metals, thorium and titanium, production of abrasive and refractory materials, zirconium sands for ceramics; geothermal energy production, coal industry (combustion and mining); aluminium, copper and iron industry, alum shale products, water treatment facilities relying on ground water. A range of possible sources of discharges of naturally occurring radioactive materials (NORM)⁸ is presented in Table 5 [28].

The mentioned industries release radioactive materials to the environment mainly liquid discharges and solid wastes and in some cases plant stack and vent emissions and fugitive dust emissions from material stockpiles. These releases are associated, for instance, with produced water, sludge, scales and ashes. In some cases, solid wastes are disposed of on land. From the radiological point of view, some of these releases constitute a protection and regulatory issue to be solved.

TABLE 5. ACTIVITIES THAT MAY LEAD TO NORM CONTAMINATED RESIDUES [28]

Mineral ores and extracted materials		Other processing/manufacturing
Aluminium (bauxite)	Rare earths	Water treatment
Copper	Tin	Sewage treatment
Fluorospars	Titanium	Spas
Gypsum	Tungsten	Paper and pulp
Iron	Vanadium	Ceramics manufacture
Molybdenum	Zircon	Paint and pigment manufacture
Phosphate	Coal (and coal ash)	Metal foundry facilities
Phosphorus	Oil and gas	Optics
Potassium (potash)	Geothermal energy	Incandescent gas mantles
Precious metals (gold, silver)	Uranium and thorium	Refractory and abrasive sands
		Electronics manufacture
		Building materials

⁸ Material containing no significant amounts of radionuclides other than naturally occurring radionuclides, such as primordial radionuclides (K-40, U-235, U-238 and Th-232) and their radioactive decay products. It includes materials in which the activity concentrations of the naturally occurring radionuclides have been changed by man-made processes. These are sometimes referred to as technically enhanced NORM or TENORM and, as a result, the term NORM is sometimes used in contrast with TENORM, i.e. to refer only to materials in which the activity concentrations have not been technologically enhanced.

At the time of preparation of the present report, some countries have no regulations to control discharges of NORM. Others only regulate such discharges on the basis of their chemical toxicity rather than their potential radiological impact. A few Member States have developed regulations that include radionuclide discharge limits, permitted ambient radiation exposures rates, liquid and gaseous concentrations, and requirements to undertaken environmental related monitoring programmes. The radiological criteria for exemption, clearance, decommissioning or disposal of residues of NORM solid radioactive waste and criteria for release of control for contaminated sites and equipment are also considered in some related national regulations.

Many countries are in the process of evaluating whether it is necessary to produce or improve their regulations for the control of radioactive discharges related to NORM industries. While there is currently a variety of regulatory approaches for the control of NORM discharges the value of a more harmonized approach is recognised. The IAEA is establishing a work programme to this effect, which focuses on elaborating and addressing the relevant issues. Further information on NORM industries may also be found in different publications [28, 29].

Experience of Member States

Options to manage NORM discharges may be limited due to:

- The magnitude of the processes;
- The large investments required for the installation and operation of liquid waste treatment facilities as well as for reducing discharges into air;
- The availability of options to dispose of solid wastes resulting from air and waste water treatment;
- Other discharge limitation requirements already imposed due to the presence of non-radioactive contaminants.

7. ENVIRONMENTAL PROTECTION CONSIDERATIONS

Radiological risk assessment and management of radionuclides entering or present in the environment are generally based on human health considerations alone, on the basis of the following statement from the 1990 Recommendations of the International Commission on Radiological Protection (ICRP): “The Commission believes that the standard of environmental control needed to protect man to the degree currently thought desirable will ensure that other species are not put at risk...” [2, 30].

This approach is considered to have been appropriate also in protecting non-human species in most exposure scenarios, particularly in situations of controlled radioactive discharges to the environment during normal operations — which is in the scope of this report. Most notably, there is an absence of any evidence of obvious deleterious effects in other species from exposure to environmental radiation due to controlled releases of man made radionuclides.

However, questions have been raised concerning the universal applicability of the above statement. Furthermore, the increasing awareness of the vulnerability of the environment to human activities, and the need to be able to demonstrate the level of its protection against industrial pollutants (*inter alia* radioactive materials), has been reflected in new and developing international policies, legal instruments and agreements [30], beginning with the Declaration of the United Nations Conference on Environment and Development (1992) [31].

The International Conference on the Protection of the Environment from the Effects of Ionizing Radiation, which took place in Stockholm (2003), encouraged the development of an international framework for environmental radiation protection to control radioactive releases to the environment by explicitly taking into account the protection of species other than humans. The findings of this conference provided the basis for the IAEA's Plan of Activities on the Radiation Protection of the Environment, which was accepted by the IAEA General Conference in 2005⁹. The objectives of the IAEA's Plan of Activities are to promote collaborative work by relevant international organizations that enhance current approaches in radiation protection of the environment and provide assistance to IAEA Member States in their efforts to protect the environment.

The IAEA programme of work in this field has been and continues to be based on the Plan of Activities. This included the establishment of an international coordination group which was set up comprising representatives of the international organizations active in this area (notably the ICRP, UNSCEAR, IUR, EC and NEA) and representatives of IAEA Member States with particularly well developed work programmes in this area. This group continues to provide the basis for international cooperation and coordinated international work.

Within this coordinating group there is consensus on carrying on an iterative review process to determine the need for, and if necessary, the form and content of, additional or revised standards in line with the IAEA Safety Fundamentals [5] where the following fundamental safety objective (in terms of both environmental and human protection), is defined as follows:

“to protect people and the environment from harmful effects of ionizing radiation”

Within this framework, it was concluded that, in this review process, account must be taken that:

- Radiation is one of many environmental stressors, probably relatively minor if compared to others.
- There is a need to understand the implications of any proposed improvement on the current system of regulation and to test the practical adequacy thereof.
- The process of reviewing IAEA Safety Standards does not necessarily mean major standard revisions.
- There are expectations in connection with the ICRP results regarding the definition of a ‘system for protection of the environment’.

During 2007, the ICRP approved the revised fundamental recommendations on the protection of man and the environment against ionizing radiation. ICRP Publication [3] includes a chapter entitled, ‘Protection of the Environment’ where the relevant acknowledgements, conclusions and recommendations regarding protection of the environment are presented.

At this stage the ICRP does not propose to set any form of ‘dose limits’ with respect to environmental protection. Furthermore, the ICRP emphasized that the proposed recommendations in this field constitute a preliminary approach to fill a conceptual gap in the system of radiological protection and, a framework to progress the acquisition of knowledge

⁹ See <http://www.iaea.org>.

and information which could be used in the future to define a system of protection of the environment, complementary with the existing systems to radiation protection of humans.

ICRP is working on the elaboration of the set of hypothetical entities derived on the same grounds and for the same purpose as the reference person with defined anatomical, physiological, and life-history properties that can be used to relate exposure to dose, and dose to effects, for that type of living organism (e.g., reference animals and plants). In their discussions, ICRP remarks that other relevant information necessary to be considered in any decision process where reference animals and plants (RAPs) could be applied are, for example, the type of exposure situation, the size of the area affected, the status of the population, the fraction of a population exposed, and the legal framework within which management action are taken. The publication of the report of ICRP on RAPs is expected during 2009.

Experience of Member States

The US DOE has established a Biota Dose Assessment Committee (BDAC) which has developed a DOE Technical Standard that provides a graded approach for evaluating radiation doses to aquatic and terrestrial biota. The DOE Technical Standard provides a methodology for demonstrating compliance with DOE dose limits, and with findings of the International Atomic Energy Agency (IAEA) and National Council on Radiation Protection and Measurements (NCRP) regarding doses, below which deleterious effects on populations of aquatic and terrestrial organisms have not been observed.

A web site has been set up to provide a central access point to support the needs of BDAC members and to provide the public with BDAC-related information, activities, and available products concerning biota dose evaluation methods, radio-ecological research, and standards. The BDAC Standard may also be downloaded from this site. Furthermore, the RESRAD-BIOTA code is available for general use as a companion tool for implementing DOE's Graded Approach to Evaluating Radiation Doses to Aquatic and Terrestrial Biota (DOE Technical Standard DOE-STD-1153-2002) [32].

The BDAC approach has been applied to several DOE sites over the last few years. More information may be obtained from:

<http://homer.ornl.gov/nuclearsafety/env/bdac/>

Experience of Member States

In the UK, a methodology has been developed to fulfil Environment Agency obligations under habitats regulations, including the review of all existing authorizations and consents to ensure that no existing authorized activities result in adverse effects on the integrity of identified European conservation sites. The approach — outlined in Environment Agency R & D Publication No. 128 — was published in 2001 [33]. This approach has been implemented as a simple spreadsheet tool and is based on a reference organism approach. The review of various sites authorizations has been completed.

8. SUMMARY AND CONCLUSIONS

This report provides an overview of the practical aspects of setting discharge limits and authorization conditions. It includes a description of the main processes involved in setting discharge authorizations and presents examples of current practice drawn from both nuclear and non-nuclear industries. It summarizes the international experience on optimization of discharges and the setting of authorized discharge levels, based on questionnaires completed by a limited number of Member States and on discussions at a Technical Committee Meeting held in 2003 and 2008. These discussions yielded some interesting conclusions regarding the practicalities of setting discharge limits which may have an influence on the way in which future guidance is framed.

The interpretation of the optimization principle and its application to the control of discharges is usually not the quantitative formalized process based on human health and ALARA that might be implied by the IAEA Safety Guide [1], the ICRP recommendations [2] and many national regulations. Decisions regarding discharge controls and limits are generally made on the basis of expert judgment.

The Member States present at the Technical Committee Meeting in 2003 do not generally apply formal cost-benefit or multi-attribute decision aiding techniques in setting discharge limits. Indeed collective dose assessments and a quantitative evaluation of the potential cost of health consequences are rarely employed. Critical group assessments are used as the primary measure of the potential impact of discharges, with the level of assessment complexity depending on the potential level of dose predicted or societal interest.

Many factors are taken into account in setting discharge limits — particularly the public dose implications and the appropriateness of different abatement technologies. In general terms the overall regulatory approach to setting discharge limits can be considered as an establishment of a reasonable balance between the individual (or critical group) doses implied, and a consideration of the possible dose and cost implications of alternative abatement techniques. This approach is adopted for both the nuclear and non-nuclear industries although with different levels of complexity and for different reasons.

There are also differences in the way in which discharge limits are set in the nuclear and non-nuclear industries due to the difference in the size of the facilities and characteristics of the discharge, public perception and the potential consequences of accidental situations. In the case of the nuclear industry, societal pressures have tended to result in discharge levels being reduced to levels below those that would have been defined by a quantitative interpretation of optimization. This has led to a greater focus on the feasibility and effectiveness of further technological advances in making discharge control decisions. For nuclear installations, site-specific assessments of critical group doses are generally performed, while for non-nuclear sites more generic assessments are often considered to be sufficient.

In non-nuclear industries, the level of complexity implied by quantitative decision-aiding techniques is generally not warranted in view of the generally low dose and risk implications of such practices. The value of expanding the scope of developing practical guidance for small users was highlighted.

In the future, there would be value in providing more guidance on the application of optimization and techniques for discharge control, particularly in relation to small users and NORM industries. The inclusion of environmental radiation protection considerations and the potential for definition and use of environmental concentration levels, in controlling discharges under normal conditions, will warrant further consideration. It is important to recognize the importance of an overall approach that balances the whole range of different factors that are relevant to controlling discharges.

Appendix

EXPERIENCE OF MEMBER STATES

This Appendix summarizes experience in setting radioactive discharge authorizations in Member States. Information provided in the Appendix was collected through the responses to a questionnaire and material presented at the Technical Committee Meeting held from 11 to 15 July 2003 and subsequent revisions provided by the competent authorities in advance of and during a Technical Committee Meeting held between 1 and 5 September 2008.

1. Argentina

Discharge authorizations are required for some relevant facilities operating in Argentina, typically: nuclear power reactors, research reactors and important isotope production facilities. The International Basic Safety Standards [4], ICRP 60 recommendations [2], the IAEA Safety Fundamentals [5] and supporting Safety Standards are used as a basis for radiological protection regulations and practices in Argentina.

The annual dose limit for a member of the public is 1 mSv. Constraints are used at the design and operation stages of the facility, and are set by the Nuclear Regulatory Authority (ARN in Spanish). For members of the public the constraint is 0.3 mSv, it applies to the critical group and does not change depending on the practice. It is not required to demonstrate that the systems are optimized if the critical group dose does not exceed 0.1 mSv and if the collective dose does not exceed 1 man Sv per year. This approach is therefore usually adopted for small facilities. There are not different dose constraints for gaseous and liquid release modes.

Regarding radioactive discharges, older facilities are expected to be operated to the same standards as those of new facilities. As it is common in some practices, in particular nuclear power reactors, some of Argentina's discharges cross national borders, i.e. radionuclides of global and regional impact, such as C-14 and H-3, are released in normal operation and no special measures are taken to address this issue because, in the optimization process, local, regional and global collective doses are considered.

When assessing doses from facilities, Argentina conducts generic or site specific modelling depending on the facility. Generic models are sufficient for small practices but larger facilities like nuclear power reactors, research reactors and large isotope production facilities require site-specific dose assessments. When assessing doses, a hypothetical critical group is considered, and is defined at the design stage as the maximally exposed individuals due to routine releases during the period of operation of a given facility.

The regulator requires discharges to be optimized. This is defined as finding a control option such that (for public exposure) the individual doses, the number of people exposed and the likelihood of incurring exposures (where these are not certain to be received) are all kept as low as reasonable achievable. In the optimization of discharges, cost benefit analysis, expert judgment and common sense are considered. When collective dose is used within the optimization process, a monetary value of US \$10,000 per man Sv is adopted.

There is not an explicit policy requirement to encourage the generation of solid waste over discharges to the environment. This happens naturally as result of the restrictions set by discharge control standards.

Discharge limits are currently specified on an annual basis in terms of activity at the release point. Each facility has a separate limit but the critical group dose due to the combined discharges of all facilities must comply with the dose constraint. In addition to the annual

limits, there are quarterly and daily limits which are 30% and 1% of the annual limit, respectively. Exceeding short-term limit starts regulatory actions to identify its causes but does not constitute a violation of regulations that would lead to penalties. Maximum discharge activity rates from the site are not considered.

Any authorizations issued are renewed periodically, every 5 or 10 years, depending on the type of facility. Effluent monitoring of discharges is required for nuclear power reactors, fuel fabrication facilities, research reactors and large isotope production facilities. In addition, nuclear power reactors and other facilities, such as research reactors require environmental monitoring. Air, water and soils samples are taken and the artificial nuclides investigated are those expected to be the main contributors to the critical group and population doses.

Limits of detection are not specified but it is requested that they must be sufficiently low as to assure the quantification of a small fraction of the discharge limit for each relevant radionuclide. The licensee must send a monthly or quarterly report to the regulator with the activity of specific radionuclides released in the period for each mode of release. Quality assurance procedures are required to be applied by each operator and the ARN carries out audits, independent measurements of effluent samples, inter-comparisons of laboratory measurements and environmental monitoring in some cases.

Oil and gas extraction, mining and milling facilities (and some underground mines) in Argentina give rise to discharges containing naturally occurring radionuclides. For example, the oil and gas industry discharges produced water with sludge and paraffin. At present, these discharges are not regulated in relation to their radioactive content and the relevant authority for such radioactive discharges is not clearly defined. The future approach for regulating such discharges is being considered by the government and industry, with the technical advice of the Nuclear Regulatory Authority, which has, since 2005 been carrying out a study to evaluate the impact of NORM in industries (including measurements and scenario assessments).

2. China

In China, there are nuclear power plants and fuel enrichment facilities in addition to non-nuclear users such as research reactors, irradiators, radiopharmaceutical companies and isotope production facilities. The discharges of radioactive substances to the environment are regulated by the Department of Nuclear Safety and Radiation Environment Management of the Ministry of Environmental Protection (MOEP) under the Law of China on Prevention and Control of Radioactive Pollution and its implementing regulation as well as the basic standard — Basic standards for protection against ionizing radiation and for the safety of radiation sources (GB 18871-2002) . The basic standard is based on the International Basic Safety Standards [4], ICRP 60 recommendations [2], the IAEA Safety Fundamentals [5] and their supporting Safety Standards, as well as the experiences of practices in China. One typical experience is that the environmental protection facilities should be simultaneously designed, constructed and put into operation with the main process installations. Sometimes it is called ‘3-simultaneous principle’. This means optimization of discharges is considered in both the design and construction phases as well as operation.

The characteristics of discharges, exposure pathways, dose assessments and optimization are the consideration in setting authorized discharge limits. The authorized discharge limits (both dose limit and activity limit) are set by MOEP, the values are lower than those set by the related standard (Table 6). Under the authorized discharge limits, management discharge limits are set by the operators, but the limits must be less than the authorized discharge limits and should be reported to MOEP.

TABLE 6. RECOMMENDED DOSE LIMITS IN PLANNED EXPOSURE SITUATIONS

Type of limit	Occupational	Public
Effective dose	20mSv/a, averaged over defined periods of 5 years	1 mSv/a (in special circumstances, a higher value of effective dose could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv per year)
Annual equivalent dose in:		
Lens of the eye	150mSv/a	15 mSv/a
Skin	500mSv/a	50 mSv/a
Hands and feet	500mSv/a	–

TABLE 7. AUTHORIZED LIMITS OF RADIOACTIVE DISCHARGES TO THE ENVIRONMENT FROM PWR NPP IN NORMAL OPERATION

Discharge	Radionuclides	Authorized limits [Bq/PWR per year]
Airborne	Noble gas	2.5×10^{15}
	Radioactive iodine	7.5×10^{10}
	Particulates (half life $\geq 8d$)	2.0×10^{11}
Liquid effluent	H-3	1.5×10^{14}
	Other radionuclides	7.5×10^{11}

There are authorized discharge limits for a number of specific and groups of radionuclides. For nuclear power plants, the upper value for dose constraint received by the public is set to 0.25 mSv/a by the national standard Regulations for environmental radiation protection of nuclear power plants (GB 6249-86). Under this dose constraint, the discharge quantity limits are also set by GB 6249-86, shown in Table 7. In the review version of GB 6249-86 (GB 6249-200x), the derived discharge activity concentration limits are expected to set as 3700 Bq/L for NPP in shore, 370 Bq/L for NPP in inland.

Discharge limits for the facilities related to uranium enrichment, fuel fabrication, reprocessing of spent fuel as well as uranium mining and milling are given by the national standard Authorized limits for normalized releases of radioactive effluents from nuclear fuel cycle (GB 13695-92).

Discharge limits for other facilities like research laboratories and radiopharmaceutical companies are expressed as the annual average concentration of gaseous and aerosol radionuclides in the public environment as a result of discharge should not exceed 1/150th of the derived air concentration (DAC). The effective dose received by the critical group as a result of liquid discharges can only be a small proportion of the annual dose limit for the public (1mSv).

Low-level liquid waste (with activity concentrations less than $4.0E+06$ Bq/L defined as a low-level liquid waste) is discharged through ‘tank discharge’. The location of discharge, the total discharge activity and concentration must be authorized by MOEP. If the effluent contains long-lived radionuclides (half life greater than 30 years), the operator is not permitted to discharge to closed lakes. The use of seeping wells, seeping pits, natural crevices, limestone caves or other means of discharge of liquid radioactive waste is prohibited by the State.

Low-level liquid waste can not be discharged through a generic sewage pathway unless the flow rate of sewage is higher 10 times greater than the liquid discharge rate, and the total

discharge activity per month is not allowed to exceed 10 ALI_{min} (ALI_{min}: the minimum Annual Limit of Intake from either inhalation or ingestion), discharge activity at any time is not allowed to exceed 1 ALI_{min}. It is necessary to flush the pipeline using water after liquid discharge.

MOEP has established a radiation environmental monitoring network including a central monitoring station, several regional stations and 30 provincial monitoring stations. They independently carry out the monitoring responsibilities, and report directly to MOEP. In China, all practices unless those are excluded and exemption, are required to implement effluent monitoring and environmental monitoring according to the basic standard (GB18871-2002) and technical criteria for radiation environmental monitoring (HT/61-2001).

Quality assurance is required by the basic standard (GB18871-2002) and is an integral part of programmes for source monitoring, environmental monitoring and individual monitoring. Detail requirements are given by the national standard General requirements of quality assurance program for effluent and environmental radioactivity monitoring at nuclear facilities (GB 11216-89).

3. Czech Republic

In the Czech Republic, the Decree No. 307/2002 Coll. on Radiation Protection determines that the radionuclides may be discharged into the environment only if the radionuclide discharge is justified and prescribes a set of conditions for discharge without any authorization from the State Office for Nuclear Safety (SUJB — Czech Nuclear and Radiation Protection Regulatory Authority). The conditions are set on the basis of international recommendations. Discharges from nuclear facilities must be authorized.

If a collective effective dose might exceed 1 man Sv or the exposure in a critical group might exceed one twentieth of the general limits during a radionuclide discharge, the optimization of radiation protection shall be demonstrated by a quantitative study. Such a study would include evaluation of the benefits and risks of the procedure being chosen and a comparison with possible alternatives.

The dose constraint for a total discharge of radioactive substances from a practice is an average effective dose of 250 µSv per year for a member of a critical group of public, for nuclear power plants (200 µSv for airborne discharges and to 50 µSv for watercourse discharges). Nuclear power plants are required to perform an optimization process and, on the basis of its results, the SUJB sets authorized discharge limits for the NPP. The authorized discharge limits are site specific. Current authorized limits for NPP Dukovany are 40 µSv for airborne discharges and 6 µSv for watercourse discharges; and for NPP Temelín 40 µSv for airborne discharges and 3 µSv for watercourse discharges.

Moreover, general pollution limits for watercourse discharges are set by a governmental order in the term of activity per unit volume. From these limits, a warning (investigation) and alarm (intervention) levels for discharges are derived for application during monitoring programmes, which are also authorized by the SUJB. In this way, a uniform discharge during a year can be ensured.

The monitoring of discharges is introduced at all workplaces where a disposal of radionuclide contaminated substances is carried out by a controlled discharge or where a release of significant amount of radionuclides into the environment is possible. The monitoring includes both the balancing measurement of all radionuclides which significantly contribute to

exposure of public and continuous measurement of representative radionuclides which can quickly indicate deviations from normal operations. The NPP's report the amount of discharged radionuclides to the SUJB monthly, quarterly and annually.

In the authorized monitoring programmes, among other things, the warning and alarm levels and measures in the case of exceeding them, measuring methods, measuring instruments, and detection limits are specified.

The discharge process is regularly inspected by the SUJB inspectors; the authorization is time-limited. QA procedures are applied on the discharge process.

4. France

According to the 2006-686 Act of 13 June 2006 concerning transparency and security in the nuclear field, known as the 'TSN Act', discharge authorizations are required for nuclear facilities in France, which include nuclear power reactors, research reactors, fuel enrichment facilities, fuel fabrication facilities and large research laboratories.

Apart from the TSN Act, the Public Health Code and the Labour Code One, set basic standards for the health protection of the population and workers against the risks of ionizing radiation. This legislation is based on internationally adopted rules, whether regulations or community directives such as Council directive 96/29/EURATOM dated 13 May 1996. It is also based on a variety of norms, standards and recommendations, such as recommendations from ICRP, or the standards issued by the IAEA, in particular the International Basic Safety Standards for Protection against Radiation and for the Safety of Radiation Sources (Safety Series No. 115) [4].

The 26 November 1999 Decree specifies the content of discharge permits of nuclear installations. This Decree prescribes that the nuclear installation shall be designed, operated and maintained so as to limit the emission in the atmosphere and the discharge of liquid effluents. This Decree prescribes that the limits shall be based on the best available technologies at affordable cost and the specific characteristics of the site environment. France is a Contracting Party of the OSPAR Convention and the 26 November 1999 Decree prescriptions are consistent with the PARCOM Recommendation 91/4 which concerns the use of BAT 'to minimize and, as appropriate, eliminate any pollution caused by radioactive discharges from all nuclear industries'.

The choice between effluent discharges and production of waste is the result of an optimization process specific to effluents, after efforts made to reduce by-products generated by nuclear activities. Hence, in certain circumstances discharge may be preferred for reasons which include safety considerations (including increase risk of accidents), radiation protection of workers, intergenerational considerations, technical feasibility, etc.

In all cases, the trade-offs between the containment of substances or their dispersal and the abandonment, for safety and radioprotection reasons, of certain reduction at source or treatment options must be made clear by licensees.

The use of BAT is checked in practice by national and international benchmarking as appropriate as well as the operational experience of the facility and of similar facilities. BAT is based on the selection of technology options, at the design stage, as well as organisational best practices at the operational stage. Limits specified by the authorities include headroom to allow for anticipated fluctuations and to take account of uncertainties. Every contribution to

headroom has to be justified. Headroom should not take into account releases resulting from incidents/accidents or even mal-operations.

As a general principle, old facilities are expected to be operated to the same discharge standards as those used for new facilities, unless operators justify that they cannot reach such standards.

Transboundary concerns are taken into account by following the EURATOM Article 37 procedure before the granting of the discharge permit by the French Authorities. France is also a Contracting Party of the OSPAR Convention and has submitted every 4 years their report on progress achieved in France in the implementation of BAT in nuclear industry facilities.

Dose assessments are performed to make sure that the potential impact of the limits of radioactive discharges is very low. Doses are assessed for real critical groups (named 'reference groups' according to the European Directive 96/29) defined as existing most exposed groups of population. Realistic consumptions rates and living habits of the identified reference groups are usually considered. Direct radiation from the facility should be added, if any, to the radiological impact of the discharges. Collective dose assessments are not required. The protection of the environment is not considered independently of protection of humans, although one objective of the environment monitoring is to survey concentrations in biota.

No decision aiding technique is preferred. Expert review is currently used; in particular technical review by the experts of the French technical support organisation IRSN (Institut de Radioprotection et de Sûreté Nucléaire) is generally used as an input by the French Safety Authorities.

A short-lived, low- and intermediate-level radioactive waste disposal facility (CSFMA) is readily available to operators. As clearance is not authorised in France, a very low-level radioactive waste disposal facility (CSTFA) is also available.

Discharge limits are specified in permits in terms of discharged activity in the atmosphere and in the water. For large sites with different types of facilities (e.g. research centres with a range of reactors and laboratories or site with different types of industrial or research facilities), limits for airborne effluents are specified for each facility and limits for liquid effluents are specified for each outlet. For sites with several facilities of the same kind (e.g. nuclear power stations with several PWR reactors), limits are usually specified for the site. Limits for the La Hague reprocessing plant are specified for the site, which include two very similar facilities (UP2-800 and UP3-A). All permits include at least annual limits, but shorter term limits are also usually specified: monthly limits (usually one sixth of the annual limit) and/or daily limits (specified after case-by-case investigations). These shorter term limits are specified for the same unit or site as the annual limits. Exceeding a short-term limit constitutes a violation of regulations that may call for penalties.

Permits are granted for an undefined period of time but are reviewed by the Authorities as appropriate. As a matter of fact, all discharge permits have been reviewed for ten years or are in the process of being reviewed. The application of BAT to specify the annual limits entailed a drastic reduction of most of them. Examples of the reduction factors for annual limits of nuclear power reactors and the La Hague reprocessing plant are given in Table 8 (radionuclide grouping refers to previous permits).

TABLE 8. EXAMPLES OF THE REDUCTIONS IN DISCHARGE LIMITS ASSOCIATED WITH APPLICATION OF BAT REQUIREMENT IN FRANCE

Facility Type	Discharge Route	Radionuclide Group	Reduction factor
For 900 MW(e) reactors	Airborne discharges	noble gases + tritium	28
		halogens + aerosols	23
	Liquid discharges	tritium	1.4
		other radionuclides	2.3
For 1300 MW(e) reactors	Airborne discharges	noble gases + tritium	32
		halogens + aerosol	34
	Liquid discharges	tritium	1.3
		other radionuclides	2.6
For the La Hague reprocessing plant	Airborne discharges	gas (other than tritium)	1
		tritium	15
		halogens + aerosols	9
	Liquid discharges	tritium	2
		other radionuclides	12
		alpha emitters	10

The 26 November 1999 Decree specifies the grouping of radionuclides for the annual limits. Such limits should be specified, as appropriate, for:

- Airborne effluents: tritium, carbon 14, noble gases, iodine, other beta-gamma emitters, alpha emitters,
- Liquid effluents: tritium, carbon 14, iodine, other beta-gamma emitters, alpha emitters.

Note in particular that all facilities which produce/handle carbon 14 and discharge detectable levels of this nuclide in liquid or airborne effluents, have to set up a monitoring programme for this nuclide. Moreover, limits on specific nuclides are also specified, as appropriate (e.g. limits on uranium discharges for nuclear cycle facilities).

Dose constraints are not used for radiation protection of the public. However, the 26 November 1999 Decree prescribes that the concentration of nuclides or groups of nuclides in the atmosphere (for the airborne discharges) and in the river or sea water (for liquid discharges) may be limited as appropriate. Most permits include such limits, which are specified according to the corresponding annual limit and site-specific dispersion considerations.

The 26 November 1999 Decree requires the operator to immediately notify and report to the Authorities on any incident or maloperation which concern discharge operations, such as: leaks from tanks or pipes, unplanned release, abnormal increase of the activity or other parameter of the discharged effluents, non availability of tanks, deterioration of filters, exceeding alarm thresholds, reduction of air flow in main stacks, breakdown of flow or activity measurement devices, significant increase of the radioactivity in the environment in the vicinity of the facility.

As a general principle, the discharge permits specify permanent source monitoring so as to verify that annual and shorter term limits are complied with at any time. Permits specify also as appropriate the continuous measurement of beta activity (airborne effluents) or gamma activity (liquid effluents) with alarm at specified thresholds. When the threshold is exceeded, concerted discharges should be automatically stopped.

The 26 November 1999 Decree requires a comprehensive monitoring of the environment which includes:

- For airborne discharges: continuous measurement of gamma radiation at the site fence and at different locations in the vicinity of the facility, measurement of the concentration of specified nuclides or groups of nuclides, monitoring of the activity in the rain water, monthly monitoring of grass and milk, annual monitoring of the upper layers of soil and of local food production.
- For liquid discharges: measurement of the activity per unit volume in river or sea water downstream, monitoring of sediment, fauna and flora, monitoring of groundwater within the site fence and in the vicinity of the site.
- Detection limits are usually not specified within the permits. Results of effluent and environment monitoring are recorded in registers which are sent periodically (usually monthly) to the Safety Authorities.

The 29 January 2008 Decision No 2008-DC-0095 of the Autorité de Sûreté Nucléaire (French Nuclear Safety Authority), among other things, specifies technical rules for the discharge of radioactive effluents from hospitals and clinics. This Decision specifies that the concentration of the nuclides discharged to sewers shall be less than 10 Bq/L, or 100 Bq/L for the effluents from rooms of patients treated with I-131.

5. Germany

The facilities that operate in Germany are both part of the nuclear industry and non-nuclear industry, such as nuclear power reactors, fuel enrichment facilities, radiopharmaceutical companies and isotope production facilities. All of these practices require authorization. The recommendations upon which regulations are based are from ICRP Publication 60 [2] and EURATOM Directive [16] and therefore the annual dose limits applied are an annual effective dose of 1 mSv, a dose to the lens of the eye of 15 mSv, and a dose to the skin of 50 mSv. Constraints are used for combined releases, and are the same for all practices and include annual effective dose of 0.3 mSv. In addition, annual limits on organ dose exist and lie within the range 0.3–1.8 mSv.

The decision to justify a practice is based on consideration of the most important alternative technological processes for installations underlying the Environment Impact Statement according the Ordinance on the procedure for licensing of installations. Older facilities are expected to operate to the same standards as newer facilities.

Some discharges from Germany cross their national borders. However, there are no special measures in place to take account of this. Germany does have to submit details of such discharges to the EC under Article 37 of the EURATOM Directive 96/29 [16].

Generic model assessments are deemed to be sufficient when calculating doses for hospitals and research laboratories only. All other facilities require site-specific dose assessment models. Radiopharmaceutical companies are not required to assess doses at all. During the optimization process, hypothetical critical groups are considered. The critical group is defined as the most exposed person of the public, for direct radiation from facility that is permanently at the fence of installation, or for receiving releases from the facility, permanently at the location with highest activity concentration in the surroundings.

The principle of minimization is used in Germany in preference to optimization, according to the ordinance on the protection against damage and injuries caused by ionizing radiation. When determining discharge levels, BAT, occupation exposure and decision aiding techniques are not considered. Protection of the environment is explicitly considered independently of protection of humans through an Environmental Impact Statement (written by the licensee and accepted by the regulator). In line with the minimization principle, there is a policy that encourages generation of a waste form according to the Safety Standard of Nuclear Safety Standard Commission.

Discharge limits are specified in terms of activity at the point of release (the stack in many cases). If a site has several independent facilities, it is dependent upon the authorization body whether they have separate limits or whether only a site limit is set. The limits are annual. However, there are also quarterly, monthly, and daily limits that are higher than the pro-rata value according to time. There are also maximum rates of activity that can be released. The breach of a short-term limit is not a violation of the regulations but would require the licensee to declare and abolish the cause of the breach. Quarterly and annual reporting of nuclide specific values of activity release are reported. The authorization body must be notified if limits are exceeded.

Effluent monitoring is required for all facilities, and environmental monitoring is required for most, the exceptions being hospitals, radiopharmaceutical companies and research laboratories. Monitoring includes measurement of the activity concentrations of specific radionuclides, such as, beta-emitting radionuclides, gamma-emitting radionuclides including I-131, alpha-emitting radionuclides and isotopes of uranium, plutonium, americium, curium and strontium, for particulates, noble gases, H-3 as water vapour, and C-14 as CO₂.

Limits of detection are specified for devices for continuous measurement of the activity concentration of particulates, noble gases (Xe-133) and gaseous compounds of I-131. Thresholds for measuring and reporting radioactive discharges of alpha- and gamma-emitting radionuclides and isotopes of strontium, in particulate form, and of gaseous compounds of isotopes of strontium are also specified.

Regular reporting is required, usually quarterly, but at a minimum, annually. QA procedures are followed. Review of authorizations occurs periodically if stated in the authorization and renewal occurs in case of major changes of installation, process or operator.

6. Hungary

All practices falling under licensing obligations require a discharge authorization, which includes nuclear power reactors and research reactors as well as other facilities. Other facilities operating in Hungary include: research laboratories, irradiators, hospitals and radiopharmaceutical companies. Justification is a basic requirement of the Decree of the Minister of Health 16/2000 (VI: 8.) on radiation protection. The regulation of radiation protection is based on the International Basic Safety Standards [4] and ICRP Publication 60 [2]. The annual dose limit for members of the public is therefore an effective dose of 1 mSv.

Dose constraints are set by the Chief Medical Officer's Office and change with the practice, for example: 90 µSv/a for nuclear power plants (NPP), 100 µSv/a for the research reactor in Budapest and the Isotope Institute Ltd (split 50%–50%), 50 µSv/a for the training reactor and 30 µSv/a in other cases. The constraints are for combined releases from the site and older facilities are expected to operate to the same standards as new facilities. The Decree 15/2001. (VI: 6.) of the Minister of Environment regulates radioactive releases into the air and into the

water in connection with the application of atomic energy, as well as their control. These regulations apply also to the discharges from Paks NPP into the Danube.

Dose assessment modelling is conducted for nuclear power plants, research reactors and isotope production facilities (site specific) and irradiators, research laboratories and hospitals (generic). Real critical groups are used when assessing doses from NPP, research and training reactors. The critical group is defined as a group of persons whose exposure originating from a given source is of acceptably even distribution and represents the individuals who are most exposed to that radiation.

The nuclear safety codes, issued by a Governmental decree, include the Safety Requirements for the Operation of Nuclear Power Plants. This requires the following:

“The operating organisation shall regulate radiation protection activity appropriately, in accordance with effective laws and regulations. A fundamental requirement for radiation protection regulations is that they shall include activities and responsibilities by means of which it can be ensured that:

- (a) the justification of the activity entailing radiation exposure are checked,
- (b) the radiation exposure of the operating staff, the quantity of radioactive materials emitted to the air from the facility, and the radiation exposure of the population related to operation are kept within regulatory limits,
- (c) maintain the radiation exposure level of the operating personnel and the population, as well as radioactive emissions, as low as reasonably possible.”

Collective dose is the criterion used in the planning of radiation protection at the Paks Nuclear Power Plant. In the planning of radiation protection, a monetary value of 25,000 HUF per man mSv (150,000 US\$ per man Sv) is used for employees. The monetary value is not used in relation with discharges. The concept of BAT and formal decision aiding techniques are currently not applied and occupational exposure and decommissioning are not considered in the optimization process for discharges. In addition, protection of the environment is not explicitly considered (separately from the protection of humans). The policy governing discharges does not encourage the generation of one waste over another.

Discharge limits are specified in activity from the point of release per annum for normal operation. Only a site limit applies, there are no separate limits for each facility on site and there are no shorter-term limits or maximum rates of release. The period of validity of a discharge authorization is indefinite. If there is a breach of a discharge limit, regulatory investigation will begin. Exceeding a short-term limit does not call for penalties. Effluent monitoring and reporting are requirements of the authorization and occurs at all sites. Environmental monitoring is only required at nuclear power and research reactors and isotope production facilities. Radionuclides that are monitored are noble gases, iodine, aerosols and some specific nuclides from nuclear facilities. Limits of detection of 1 Bq/kg for gamma-spectrometric analyses and tritium determination, 0.1 Bq/kg for measurements of beta-emitting radionuclides and 0.01 Bq/kg for alpha-spectrometry are applied. Confidence in the results obtained is achieved through the use of accredited laboratories. Reporting of discharges is required annually for all facilities. Additional monthly and quarterly reporting is required for the nuclear power plant; in the event of an abnormal occurrence additional monitoring is required. Nuclear facilities are also obliged to notify the authority, when 30% of the annual limit is reached.

7. India

Nuclear industries in India mainly consist of uranium and thorium extraction, fuel fabrication, reactor operations, production and use of radioactive isotopes. Low-level radioactive waste generated from operation, maintenance and decommissioning of nuclear and radiation facilities are disposed off to the environment as per approved practices. Atomic Energy Regulatory Board (AERB) has been entrusted with the responsibility for ensuring safety of the occupational workers, members of the public and the environment from undue radiation exposure.

The disposal of radioactive wastes is governed by the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules 1987. These Rules were promulgated under the Atomic Energy Act to have a uniform national policy for management of radioactive wastes in accordance with international practices. Chairman, AERB is the Competent Authority to enforce these rules.

As per the Rules, it is mandatory for every nuclear facility to obtain an authorization from the Competent Authority for disposal/ transfer of any radioactive waste. The radioactive wastes can be disposed/transferred only in accordance with the terms and conditions specified in the authorization. Further, the Rules also stipulate the requirements related to record keeping, reporting, inspection of records and facilities, and environmental surveillance. Procedures for issuance of authorization, inspection and enforcement of the provisions of the above Rules have been laid down.

For implementing the provisions of the Rules, more detailed regulations are specified in the Safety Code on Radioactive Waste Management. The Safety Code specifies the requirements to be met in the management of radioactive wastes by nuclear and radiation facilities. It also specifies the requirements for radiation protection aspects in design, construction and operation of waste management facilities and the responsibilities of different agencies involved. The safety guides prepared under the Safety Code by AERB give guidelines for achieving the safety requirements for safe management of radioactive wastes and environmental monitoring. At a given site, facility specific disposal schemes for radioactive solid, liquid and gaseous wastes to the environment should be established and approved by the regulatory body prior to the commencement of operation.

The control of exposure to a member of public in all normal situations is exercised by the application of controls at the source. AERB, in line with the recommendations of International Commission on Radiological Protection (ICRP), has prescribed an annual effective dose limit of 1 mSv for members of the public, at the site boundary of a nuclear facility for normal operating conditions. The dose limit of 1 mSv applies to a site as a whole, which may comprise of a number of nuclear facilities. The main governing principles for effluent releases are source control, application of dose limit and releases as low as reasonably achievable (ALARA).

The regulatory body usually sets dose constraints (apportionment of dose limit) for monitoring compliance with dose limit for the public. In the concept of dose apportionment, the primary dose limit of 1 mSv per year for a member of the public is apportioned among the various facilities operating and planned at the site, among atmospheric, aquatic and terrestrial pathways and also among radionuclides which are specific to the installation. A fraction of the dose limit is kept as a reserve for future expansions of the facilities at the site. The dose apportionment is based on techno-economic and practical considerations and past experience. In the dose apportionment, it is felt prudent to utilise only 70–80% of the effective dose limit for each site leaving 20–30% as reserve for future facilities.

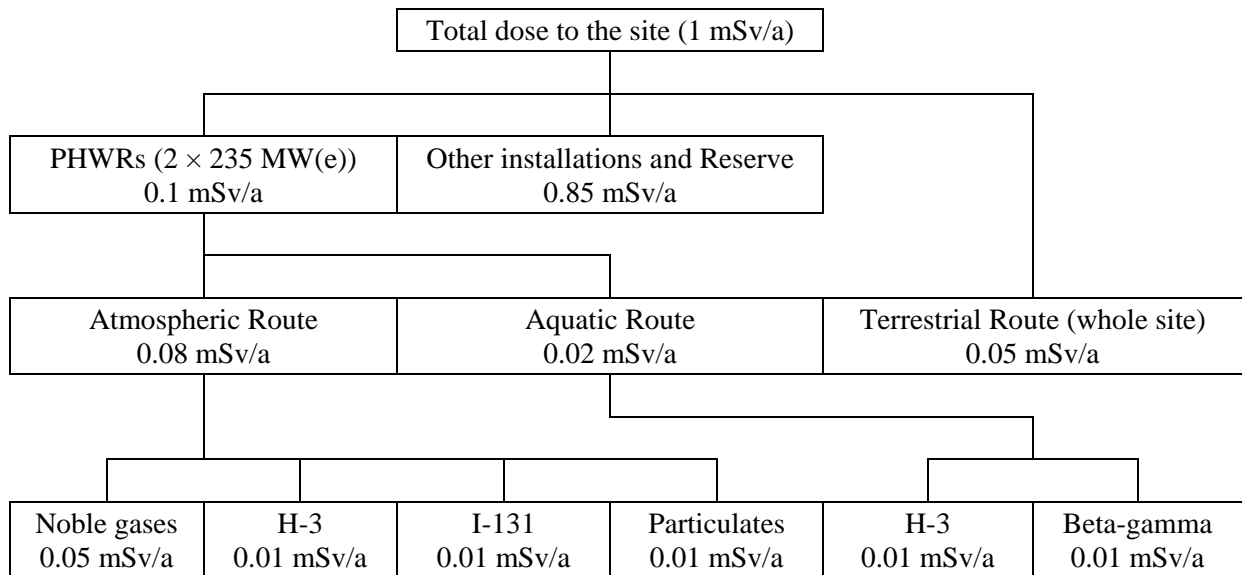


Fig. 4. Example of dose allocation when establishing discharge limits in India.

The discharge limits of radioactive effluents from a nuclear power plant (NPP) are derived based on the dose apportioned for different pathways and radionuclides, as illustrated in Figure 4. The apportioned doses are translated into annual discharge limits and specific concentrations of various radionuclides based on standard environmental models. In addition to the annual limits set, there are also daily dose limits and maximum rate of release limits for specific activity and discharge rate. These discharge limits form part of technical specifications for operation of the NPP. Site-specific parameters are used for deriving the discharge limits wherever possible. In the absence of such data, values recommended by IAEA are used. Activity discharge limits apply at the point of release, which is the main outfall for liquids and the stack for gases.

Based on operating experience of similar plants, and to achieve as low as reasonably achievable (ALARA) releases, only a fraction of the discharge limits are prescribed as authorised limits issued under the Rules. The authorised limits are specified such that the actual releases may be about 50%, the margin being provided to cater for operational exigencies. The general philosophy of multi-tier restrictions is adopted while determining the authorised limits for discharges from an installation so that the dose to the members of the public is within the dose apportioned and the releases are ALARA.

Radioactive waste should be characterized, monitored, segregated, treated and conditioned, as necessary, prior to disposal. The facility should assess the adequacy of controls on release of activity into the environment and demonstrate compliance with the regulatory requirements. In case the discharges exceed the authorised limits, the facility should report to the regulatory body within the stipulated period. The facility also needs to implement approved environmental monitoring and surveillance programme for the identified exposure pathways to meet the requirements set by the regulatory body.

There are provisions in the Atomic Energy Act to penalise the operator in case of contravention to the terms and conditions of the authorization. Also, the authorization can be suspended and restrictions on operation can be imposed. Authorizations are issued for a period of 3 years, then reviewed and renewed as appropriate. The regulator is informed of discharges through reporting and notification from the operator, which is a condition of the

authorization. Reporting is on quarterly and annual basis for NPPs and annual for all other facilities. The reporting consists of data from the effluent and environmental monitoring programmes in place. Effluent monitoring is required at all major facilities, including hospitals, and environmental monitoring is required at all nuclear fuel cycle facilities. Specific radionuclides are monitored, including Sr-90, Cs-137, Cs-134, H-3, Co-60, Pu-239, Pu-241, Rn-220, and Rn-222.

The regulatory body ensures that the dose actually measured or estimated to a member of the critical group is lower than the prescribed constraints (or apportionment) provided for an installation releasing radioactive materials. The actual releases from older facilities are much lower than the authorized limits, which are generally conservative. New facilities are given lower discharge limits by taking advantage of design changes reducing releases. India does not have discharges that cross national borders. The estimated doses to members of public are of the order of 2–5 μSv per year, which is negligible compared to natural radiation.

When assessing doses, hypothetical critical groups are considered and are defined as group of members of public receiving highest dose through the given pathway from the given source. The critical groups are used in site-specific assessments of nuclear power reactors and research reactors.

The regulator requires discharges to be minimized, which means that compared to the electricity produced, the detriment due to releases should be small. Concentrate and contain is a preferred philosophy of waste management wherever feasible. The wastes generated during decommissioning are considered for regulatory clearances. When setting discharge limits BAT is not explicitly considered but activity levels, treatment options, mode of release and operating costs are taken into account. Protection of the environment is not considered independently of protection of humans.

A proper regulatory control mechanism has been established in India with adequate legal framework to control the generation and regulate the disposal of radioactive wastes. It ensures adequate protection of the public and the environment with respect to radiological safety. It has also provided adequate assurance and confidence to the public that the operation of NPPs and associated nuclear facilities are being carried out in a safe manner.

8. Ireland

Ireland does not have nuclear power facilities but it does require discharge authorizations for uses of radioactive material in the non-nuclear industry, namely, hospitals, university research laboratories, isotope production facilities and irradiators. The authorizations are valid for a period of 1 or 2 years depending on the licensee's activities. The regulation of discharges from these facilities is based on the recommendations of ICRP Publication 60 [2]. The effective dose limit applied is 1 mSv in a 12 month period. Dose constraints set by the Radiation Protection Institute of Ireland are also used and are the same for all practices: exposed workers: 1 mSv/a; all others: 0.3 mSv/a. This applies to all releases from a site, and in practice there are no authorizations for gaseous releases. Discharges occur to sewers and to the marine environment. All facilities, regardless of age must comply with the same discharge standards. As the industry is non-nuclear, the justification of practices is addressed through international acceptance, previous experience of similar situations, and safety considerations.

The only dose assessment that occurs is on a site specific basis for hospitals and takes account of a real critical group likely to receive the highest dose. At present, practices are required to minimize discharges and occupational doses are taken into account. However, for hospitals,

an optimization policy is currently being drafted in the case of patient excreta. Financial cost and dose adverted would be taken into account. BAT is not considered at present. However, there is currently a review to determine whether BAT is applicable.

Discharge limits are set for the activity concentration at the point of release and are set for the site as a whole, not for different facilities. There are short-term (daily) limits for in vitro applications (based on EURATOM Directive 96/29) [18] and the use of monthly limits for in applications is currently being drafted. Any breach of a license condition is an offence, which is prosecutable and subject to fine. Routine discharges of H-3, C-14, Tc-99m and I-131 to the sewers must be reported on an annual basis. There is no other effluent or environmental monitoring required as part of the authorization. Any laboratory measurement procedures are accredited under ISO 17025.

9. Republic of Korea

There are a number of nuclear power reactors and nuclear fuel cycle facilities in the Republic of Korea, in addition to non-nuclear industrial users of radioactive materials (research reactors and laboratories, isotope production facilities, irradiators and hospitals). Licensees are required to have the discharge facility, discharge monitoring system, sampling and analysis system. Authorizations are valid for the facility's life, but can be re-issued if regulatory requirements are changed. The International Basic Safety Standards [4] and the recommendations of ICRP [2] are the basis for radiological protection regulations. The annual limits are an effective dose of 1 mSv/a and an annual dose equivalent of 15 mSv/a to the lens of the eye and 50 mSv/a to hands, feet and skin. Dose constraints are used but they change depending on the practice. The dose constraints shown in Table 9 are applied to the major nuclear facilities such as nuclear power reactors, research reactor, fuel cycle facilities including nuclear fuel fabrication facility, in the Republic of Korea.

TABLE 9. DOSE CONSTRAINTS APPLIED FOR MAJOR NUCLEAR FACILITIES IN THE REPUBLIC OF KOREA

Release Type	Dose Contribution	Dose Constraint
Gaseous effluents	Air absorption annual dose by gamma rays	0.1 mGy/a
	Air absorption annual dose by beta rays	0.2 mGy/a
	Effective dose from external exposure	0.05 mSv/a
	Equivalent dose to the skin	0.15 mSv/a
	Organ equivalent dose from particulates, H-3, C-14 and iodine	0.15 mSv/a
Liquid effluents	Effective dose	0.03 mSv/a
	Organ equivalent dose	0.1 mSv/a
Site dose constraint for multiple units (for all pathways)	Effective dose	0.25 mSv/a
	Equivalent dose to the thyroid	0.75 mSv/a

There is no formal requirement to justify practices. Older facilities operate to the same discharge standards as new facilities. The only dose assessment required in the Republic of Korea is site specific for nuclear power reactors, fuel fabrication facilities, research reactors and isotope production facilities. Hypothetical critical groups are considered, based on any individual who is located at the exclusion area boundary (EAB) with maximum food consumption.

Discharges are required to be minimized and the impact to the environment is to be as low as reasonably achievable. BAT is not considered in this process and is not considered to be part

of optimization. Occupational exposures and decommissioning are considered when minimizing discharges. Protection of the environment is not addressed independently of protection of humans.

Discharge limits are set for both dose and activity levels. Dose is specified for total aqueous discharge and for radionuclide group within gaseous discharges. For activity releases, the limits occur at the point of release. An effluent control limit is set for each independent facility and the dose constraint is set for each independent unit as well as for the whole site. Dose constraints are set on an annual basis and effluent control limits are set on a weekly basis (or a quarterly basis if possible). Shorter-term limits are set only for nuclear power plants, where 50% of the annual limit per calendar quarter is permitted. There is a concentration release rate limit stated on emission control limit (ECL).

A breach of a discharge limit requires the licensee to submit a special report, including the corrective actions and the reason for violation. Routine reporting is required as well as event reporting. The licensee shall report the total activity and volume of wastes discharged on a quarterly basis. Effluent and environmental monitoring are required for nuclear power reactors, research reactors, isotope production facilities and fuel fabrication facilities. Hospitals and research laboratories are only required to monitor effluent. Specific radionuclides are required to be monitored depending on nuclear facilities; that includes gamma-, beta- and alpha emitting radionuclides, and H-3, on a continuous basis, and gamma-emitting radionuclides, gross beta, gross alpha, periodically. A summary of monitoring activities undertaken in the Republic of Korea is provided in Table 10.

TABLE 10. SUMMARY OF MONITORING ACTIVITIES OF LIQUID RADIOACTIVE EFFLUENTS FROM NUCLEAR POWER REACTOR IN THE REPUBLIC OF KOREA

Release modes	Sampling frequency	Minimum analysis frequency	Type of Activity Analysis	Lower Limit on Detection (Requirement) (Bq/mL)
Batch releases (Tanks) Waste Monitor Tanks Laundry Waste Tanks Steam Generator Drain Condenser Drain	Each batch	Each batch	Principal gamma I-131	0.0185 0.037
	One batch per month	Monthly	Dissolved or entrained gases	0.37
	Each batch	Monthly composite	H-3	0.37
			Gross Alpha	0.0037
	Each batch	Quarterly composite	Sr-89, Sr-90	0.00185
Continuous Releases Steam Generator Blowdown Condensate Polisher Regeneration Wastewater Condenser Pit Sump	Continuous	Weekly composite	Principal gamma I-131	0.0185 0.037
	Monthly grab sample	Monthly	Dissolved or entrained gases	0.37
	Continuous	Monthly composite	H-3	0.37
			Gross Alpha	0.0037
	Continuous	Quarterly composite	Sr-89, Sr-90	0.00185

10. Malaysia

Malaysia does not have a nuclear power industry. Radioactive materials are used in medicine and in the mineral processing industry. There is also one small research reactor. The regulation of activities involving radioactive materials is based on the International Basic Safety Standards [4].

The public dose limit used is 1 mSv/a, the worker dose limit is 50 mSv/a. The dose constraint is 0.3 mSv/a. Formal optimization does not occur and BAT is not considered. However, the operators in the mineral industry are required to submit a radiological impact assessment to the regulator.

Operational environmental monitoring is required on a monthly basis for large facilities, and less frequently for smaller facilities. There is one discharge route to the South China Sea where activity levels are slightly higher than background. No special measures are in place to take account of this.

11. Mexico

Mexico requires authorizations of all practices involving the use of radioactive or nuclear material. This includes: a nuclear power station, research reactor, research laboratories, and non-nuclear users, such as radiopharmaceutical companies, isotope production facilities and irradiators. The decision to justify a practice is made in the context of a cost benefit analysis.

The basis for radiological protection of authorized facilities is the International Basic Safety Standards [4] and ICRP 26 [34], in addition to the US Code of Federal Regulations and US Nuclear Regulatory Guides. As a result of the regulations, the current annual dose limit is 5 mSv/a. Dose constraints are not used. Older facilities are expected to conform to the same standards as new plants.

Generic dose assessment models are sufficient for all facilities except for nuclear power reactors, which require site specific modelling. Real critical group assumptions are used, and the critical group is defined as 'members of the public (of a specific age) that receive the highest dose through a particular pathway'. Collective dose is not considered in the optimization process.

Discharges are required to be optimized, and therefore discharges should be as low as reasonably possible. There is not a policy in force to encourage generation of one waste type over another. Best available techniques are not used when determining discharge levels, although different techniques are evaluated on the basis of the lowest values for environmental discharges. No formal decision aiding techniques are used and occupational exposures, protection of the environment and decommissioning are not considered within the optimization process.

At the present time, both dose limits (5 mSv/a for the critical group at the site boundary) and activity limits (of total discharge at the site boundary) are used. Limits apply to the site as a whole, regardless of the number of facilities that are on that site. For nuclear power plants, the limits are based on annual and quarterly limits. For non-nuclear facilities, annual limits are considered to be sufficient. No other short-term limits are imposed. There are maximum concentration limits of released activity. The discharge authorizations are periodically renewed, on average every 2 years. A breach of an authorization condition within the period of validity does constitute a violation that calls for penalties to be imposed. One license condition relates to monitoring and reporting of radionuclides within discharges. Both effluent and environmental monitoring are required from all sites, for total activity, not specific radionuclides, although limits of detection are specified for particulates, tritium and radioactive iodine. Reporting at nuclear facilities is required on an annual and semi-annual basis, including quarterly information. Reporting at non-nuclear facilities is required.

12. Netherlands

There are both nuclear power facilities, including a central facility for treatment of liquid waste and conditioning and storage of solid waste, and non-nuclear uses of radioactive materials in the Netherlands. The regulation is based on European Council Directive 96/29 EURATOM [16]. The justification of practices is a structured process whereby the responsible ministers provide a list of practices or categories of practices regarded as justified (positive list) and a list of practices or categories of practices regarded as not justified (negative list). If a new practice is not on the positive list, the application for authorization must address the justification.

The annual dose limits is 1 mSv effective dose; 15 mSv and 50 mSv dose equivalent to lens of the eye and skin, respectively. In addition to dose limits, an annual dose constraint of an effective dose of 0.1 mSv/a to members of the public from all sources of exposure and all installations from an establishment is used. This was set by the responsible ministers in the Radiation Protection Decree (BS2000) that came into force March 2002. The constraint applies to total exposure, including exposure to external radiation.

Authorizations are valid for an indefinite period. However, the licensee can be requested to renew his application for authorization. Authorizations of discharges from practices explicitly require removal of radioactive contamination from air and waste water as far as it is reasonably achievable. At present, old facilities are allowed to operate under the authorization obtained under previous legislation but become subject to new regulations when their authorization has to be reviewed. The effect on regulation of discharges of new legislation mainly pertains to discharges from NORM industries. As with other European Member States, any discharges that cross national borders are subject to notification under Article 37 of the EURATOM treaty. Discharges have not caused problems to neighbouring countries, as the maximum doses close to the facilities are already very low.

Site-specific dose assessments are required for nuclear power reactors, radiopharmaceutical companies, research reactors, isotope production facilities and fuel enrichment plants. Generic assessment is sufficient for hospitals and research laboratories, using both hypothetical and real critical group dose assessment.

Discharges are required to be optimized, which means reducing discharges with BAT to levels such that resulting exposures are considered to be ALARA by competent authorities. No formalized decision aiding techniques are used, simply accumulated experience and expertise. Collective doses and assigned monetary values do not in practice play a role in optimization of discharges. Decommissioning is also not considered in optimization of discharges. Protection of the environment is not considered explicit to protection of humans.

Discharge limits are specified in terms of activity concentration in a calendar year. However, the acceptability of the limit depends on the resulting dose to the highest exposed members of the public outside the establishment. The activity is measured at the main release points of the facility and some short-term limits can be imposed in addition to the annual limit. In specific cases, limits on aerial discharge rates of the relevant radionuclides from specific installations are derived on the basis of the authorized annual discharge limits. They are expressed in Bq/m³ not to be exceeded for a prolonged period. Any breach of short-term limits can result in a formal warning or prosecution in court.

Routine quarterly and annual reporting of effluent and environmental monitoring is required. The radionuclides measured depends on the facility. In addition to monitoring of discharges

by licensees and environmental monitoring by some licensees several state laboratories operate environmental and food monitoring programmes. Any waste treatment and discharge condition that seriously deviates from the conditions specified in the authorization has to be reported to the competent authorities. Limits of detection are specified based on German regulations. Effluent monitoring by the main licensees is checked by independent state laboratory analysis; QA is standard issue at annual meetings of main licensees with the state laboratory and the Environment Inspectorate

13. Norway

There is no nuclear industry in Norway, but there are two research reactors and non nuclear industry, based on uses radioactive materials and including NORM industries. These include among others hospitals, radiopharmaceutical companies, research laboratories and the petroleum industry.

All activities that lead to radioactive discharges require an authorization from the Norwegian Radiation Protection Authority (NRPA). The NRPA have established requirements on:

- Justification;
- Radiation protection officers;
- Competence, instructions and procedures;
- Risk assessment, physical protection and emergency preparedness;
- Shielding and technical safety requirements;
- Classification and marking of the workplace;
- Personal dosimetry;
- Regulation of discharges;
- Order to investigate and carry out countermeasures;
- Requirements for storage;
- Requirements as to treatment, storage and final disposal of radioactive waste.

A new radiation protection regulation entered into force in Norway in 2003, Regulations No. 1362 of 21 November on Radiation Protection and Use of Radiation. With some exceptions it was implemented the following year. This induced changes to the regulation of radioactive waste.

The regulation of radiological protection is based on ICRP Publication 60 [2] and the International Basic Safety Standards [4]. The annual dose limit for members of the public is therefore an effective dose of 1 mSv. A dose constraint is included in the Regulation Act of 0.25 mSv, and the limit is rarely used. All facilities conduct site specific modelling of dose and hypothetical critical groups are used for dose assessment purposes.

Norway is signatory of the Espoo Convention, and therefore includes neighbouring authorities in public inquiries that are concerned with discharges that may cross national borders.

All undertakings are required to use the best available techniques (BAT) in order to avoid discharges to the environment, or to keep them at the lowest possible level. The OSPAR definition of BAT is used in this context. No specified decision aiding techniques are employed. Discharges are optimized on the basis of the requirements mentioned above. Monetary values for the man Sv has only been used in connection with assessment of actions taken after for instance Chernobyl accident, then the monetary value attributed to the man Sv

is 600 000 NOK (95 000 US\$). There is a policy which encourages generation of solid waste in preference to discharges into the environment, on condition that this is not achieved at the expense of occupational doses. Solid waste facilities for low-level activity are available for waste from some activities. There is, for instance, a repository for radioactive waste from the petroleum industry and a repository for low and intermediate level waste from the research reactors, industry and research. Protection of the environment is considered independently of protection from humans.

For the research reactors, the discharge limits are specified in terms of dose, but activity limits are also provided to trigger notification to the NRPA. For other facilities, the discharge limits are given in terms of activity. The activity concentration at the point of release for each discharge route is used. The annual discharge limits given in terms of dose relate to the predicted dose to the most exposed member of the public and the total discharge, while the activity limits for notification are specified for each nuclide. Authorizations are usually valid for 5 years, but short-term limits are issued when dealing with time-limited work programme.

Effluent monitoring is required for all facilities, while environmental monitoring is required for some facilities, for example the repositories for radioactive waste from the petroleum industry and from research reactors. Annual report of monitoring results is required and in the event of an accident. The radionuclides to be measured are specified depending on the facility concerned.

14. Slovenia

In Slovenia, only nuclear installations and mining and milling facilities require discharge authorizations. However, there are other facilities that use radioactive materials including research reactors and laboratories and hospitals. The International Basic Safety Standards [4], ICRP Publication 60 [2] and EC EURATOM Directive 96/29 [16] are used as a basis for radiological protection regulations. The annual dose limit is 1 mSv (exceptionally 5 mSv with the condition that the average value of 1 mSv in several years must not be exceeded). Dose constraints, set by the Ministry of Health and the Ministry of Environment, are used and they change depending on the practice: for nuclear power plants the annual dose constraint is 0.05 mSv/a for discharges and 0.2 mSv/a for direct external radiation from the site. A single dose constraint for combined releases from a site is applied. Limits for liquid radioactive discharges (excluding H-3, noble gases and C-14) are 200 GBq on an annual basis and 80 GBq quarterly. Discharge limits for H-3 are 20 TBq/a and 8 TBq per quarter.

The principle of minimization governs the regulation of discharges. Optimization and BAT are not currently defined or applied in Slovenia. When considering minimization, decision-aiding techniques do not play a part and decommissioning, occupational exposure and protection of the environment, independent of protection of human beings, are not taken into account.

The discharge limits are set based on total doses to the critical group and activity released from point sources for liquids and the site boundary for gaseous effluents, all of which are set on an annual basis with additional short term limits for noble gases weekly and quarterly and for liquid discharges on a quarterly basis.

The authorizations are issued for an indefinite period of validity. Any breach of the authorization is considered to be a violation that can call for a penalty. In such instances, the discharges are to be reported to the regulatory body (in addition to routine reporting). Both effluent and environmental monitoring are required for facilities other than hospitals and

research laboratories. These discharges only require effluent monitoring. Radionuclides monitored are specified as: noble gases, H-3, C-14, iodine, particulates in gaseous effluents and noble gases, gamma emitting radionuclides (including Co-60, Cs-137 and I-131) and H-3 in liquid effluents. Limits of detection are also specified. Discharges from the Krško NPP cross the border with Croatia and therefore environmental monitoring is extended into Croatian territory. Quality assurance takes the form of written procedures for sampling, and measurements, record keeping calibration of equipment, consideration of the uncertainty of results estimated and reported and compulsory participation in international inter-comparison.

15. Spain

Discharge authorization is required for the following practices: the radioactive facilities with scientific, medical, agricultural, commercial and industrial aims; the generation of nuclear power, including the entire cycle of related activities from the mining and processing of radioactive ores to the operation of nuclear reactors and the fuel fabrication, and radioactive wastes repositories. Regulation is based on the International Basic Safety Standards [4], ICRP 60 [2] and other EU Directives.

An annual effective dose of 0.3 mSv/a to most exposed members of the public has been established by the Nuclear Safety Council (CSN) as dose constraint. Although that value is not formally included in the Spanish legislation, it is taken into account when operational limits to control the radioactive effluents released from those installations are set. In general, the operational limits represent a percentage of the value established as Dose Constraint. This constraint is applied to the combined releases from a site.

According to the Spanish regulations on Health protection against ionizing radiation, a justification is required from operators when applying for an authorization. Authorizations are granted by the Ministry of Industry, Tourism and Trade after a mandatory and binding report issued by the CSN.

Old facilities are expected to be operated to the same standards as those used for the new facilities. During operation, licensees are required to develop a continuous safety assessment programme (CSA) taking into account the evolution of the standards, the progress in technology (BAT), and the operational experience. Licensees are also required to perform a periodic safety review (PSR) programme on a ten yearly basis. The documentation submitted and the results of the evaluation performed by the CSN are taken into account in the renewal of the operating permits.

Portugal and Spain share several river courses and specific agreements are in place regarding these. Periodic meetings information exchange and on radiological environmental surveillance are organised.

Dose assessments are undertaken on the basis of specific modelling for all the fuel cycle facilities. Generic modelling is used to set the activity discharge limits for radioactive facilities. Critical groups are defined according to ICRP Publication 60 [2]. Hypothetical groups are used for verification of compliance with the authorised limits, and data for actual groups are used for the estimation of the impact on the members of the public.

According to the Spanish regulations, doses to the public due to the radioactive discharges must be as low as reasonably achievable taking into account economic and social factors (ALARA). BAT is considered according to its definition in the OSPAR Convention but this concept is not considered as part of the optimization process and has not been used in

determining discharge levels. Occupational exposures are taken into account when specific techniques are selected using BAT. The environmental is assumed to be protected through the protection of humans.

CSN requires that radioactive waste treatment systems are designed in accordance with the generic design objectives given by the USNRC. These design objectives give rise to the release limits that represent a percentage of the dose constraint.

Spain does not have a policy that encourages generation of a type of waste in preference to others. The economical and technological provisions for dismantling must be presented by operators when permits for the construction and operation of a facility are requested.

Discharge limits for nuclear fuel cycle facilities are specified in terms of doses to the public while they are set in terms of activity for the radioactive installations. A limit on discharges giving rise to 0.1 mSv/a to the most exposed member of the public is defined for fuel cycle facilities (from liquid and gaseous discharges), with the exception of the low and intermediate waste repository, which was licensed with the criterion of zero liquid releases and a dose limit for the gaseous effluents is 0.01 mSv/a.

For non nuclear facilities, which discharge liquid effluents into the sewer system, the authorised limits are:

- 10 GBq/a for H-3; 1 GBq/a for C-14; and 1 GBq/a for the summed activity of other radionuclides.
- For individual discharges, the activity concentration of a radionuclide must not exceed 1 ALI calculated for an adult. If more than one radionuclide are present, then:

$$\sum_n \frac{A_n}{ALI_n} \leq 1$$

These limits are applied at the release point and apply to each facility at the site.

Discharge limits are set on annual basis (of twelve consecutive months for the fuel cycle installations and for calendar years for non nuclear installations). Instantaneous limits, derived on the basis of maximum concentrations of released activity for liquids and dose rates for gaseous emissions that give rise to an effective dose of 5 mSv/a that are used as trigger points for the monitors. For the fuel cycle facilities, the period of validity of authorization is ten years, as established in the operation permits.

Exceeding short-term limits does not constitute a violation of regulations that calls for penalty. If an instantaneous limit is exceeded, the release rate must be immediately restored to within the authorised limit and, according to the CSN Nuclear Safety Instruction IS-10, a notification is to be submitted to the CSN within one hour and a special report within 30 days.

For the fuel cycle installations, when the authorised discharge limit is exceeded a notification to the CSN has to be submitted within 24 hours according to the CSN Nuclear Safety Instruction IS-10, and a special report has to be submitted within 30 days according to the Technical Specifications. This report shall identify the cause for exceeding the limit and define the corrective actions to be taken to assure that subsequent releases will be in compliance with the limit.

Effluent and environmental monitoring is required for fuel cycle facilities. Operating permits establish the radioactive effluent controls program (PROCER) and the environmental monitoring program, as part of the technical specifications. The PROCER, includes the release limits and, among other aspects, the sampling and analysis programme required to verify compliance with the release limits, the location of radioactive effluent sampling and the frequency of analysis, the radionuclides to be detected and the lower limits of detection required are established. The radionuclides to be monitored depend on the release route and the type of installation.

Information on radioactive discharges and environmental monitoring are reported on monthly and annual basis. To this end, the CSN has elaborated specific Safety Guides, where the frequency and information to be submitted by the nuclear power plants is specified. Other nuclear installations send similar information, adapted according to their specific characteristics. A specific electronic file is also provided every month for input into the CSN effluents database.

The quality assurance of the radioactive discharge and environmental data is verified by means of evaluations, inspections and independent analyses according to specific technical procedures elaborated by the CSN. As an independent check of the sites' monitoring, independent environmental monitoring (PVRAIN) is also carried out by the CSN that comprises about 5% of the PVRA, and the sampling locations, procedures, dates of sampling and analyses replicate as far as possible those of the operators.

Spanish industries include some that involve the discharge of naturally occurring radioactive materials including: phosphate processing (HCl and H₂SO₄); titanium dioxide (for pigments); zirconium sands for ceramics; coal industry; aluminium, copper and iron extraction (for copper) and processing and limited levels of oil & gas extraction. Discharges from these industries are considered to be negligible and they are regulated according to their potential toxic rather than radiological impacts, on the basis of discussions with the industry. An environmental monitoring program is in place. However, radiological aspects are expected to be taken into account in future. A regulation was approved by the CSN on the 31 October 2007 and presented to the parliament, but has not yet been approved.

16. Sweden

Discharge authorizations are required for identified practices from the Swedish Radiation Safety Authority (SSM) for both nuclear and non-nuclear facilities. The regulation of discharges is based on International Basic Safety Standards [4], recommendations from ICRP [2], the EU Basic Safety Standards and other EU directives, such as 96/29 [16]. The annual effective dose limit to members of the public is 1 mSv/a (SSI FS 1984:4). Dose constraints set by the SSM are used and may vary between practices; for example a dose constraint of 0.1 mSv/a is set for combined releases from nuclear facilities (with an investigation level set at 0.01 mSv/a) located in the same geographically delimited area. For some practices and work activities activity limitation is in place.

Justification of nuclear facilities is a decision taken by the Government; other licensed facilities are basically justified by the SSM. In principle, older facilities are subject to the same discharge standards and ALARA is applicable, however, the BAT concept may apply differently to older facilities.

Some discharges cross national borders and are subject to the requirements of the EURATOM 96/29 Article 37 and Espoo Conventions.

Site-specific dose assessments are modeled for many facilities, including nuclear power reactors, research reactors, isotope production facilities and fuel fabrication plants. Realistic critical groups are used in the models.

The limitation of radioactive releases of radioactive substances from nuclear facilities is based on the optimization of radiation protection (ALARA) and is achieved by using the best available technique (BAT). It is the responsibility of the operator to suggest the techniques that may be considered BAT (technical, social and economical elements) and for SSM to examine and approve. The monetary value may vary between different applications. Particular nuclear entrepreneurs may use higher monetary values than proposed by the regulatory bodies. Protection of the environment is considered independently of protection of humans, using the BAT principles (so far only for nuclear power reactors). Decommissioning is not included in optimization considerations for nuclear facilities.

Discharges are currently set using annual dose to the critical group from total discharges from nuclear sites and activity from the point of release over shorter time periods for non-nuclear sites. The dose investigation level for nuclear sites is 0.01 mSv per month. The regulations are reviewed periodically

Exceeding a short-term limit does not constitute a violation of regulations that calls for penalties. The first step is conducting better, more realistic dose calculations. If the dose constraint (0.1 mSv/a for nuclear facilities) is exceeded, action is required. Effluent and environmental monitoring is required for all practices that require monitoring. Some practices do not require any monitoring, e.g. hospitals. During monitoring, a number of different radionuclides are considered. The detection limits shall be such that compliance can be shown to the dose in 0.01 mSv/a.

For nuclear facilities, reporting on discharges to air and water is on a semi-annual basis. Information reported includes nuclide specific activity and doses to individuals in critical group), as well as on environmental monitoring.

17. United Kingdom

In the United Kingdom, all practices making disposals or discharges to air and, water or land require a discharge authorization, except those practices which are exempted from regulatory control. Regulations give effect to the Council Directive 96/29 EURATOM (Basic Safety Standards) [16]. UK practices include both non-nuclear users and a full nuclear cycle, with the exception of uranium mining. The UK is currently actively promoting the construction of new nuclear power stations.

The annual effective dose limit is 1 mSv/a, with dose constraints of 0.3mSv/a from any new source and 0.5mSv/a from a single site (which may cover a number of facilities). However actual doses are very much lower than this. The constraints for application to potential new nuclear power stations is currently under discussion.

Justification of a practice is a decision taken by the relevant Government Department. The disposal of radioactive waste in the UK is regulated by the environment agencies, with separate Agencies for England and Wales, Scotland and Northern Ireland. The HSE (Health and Safety Executive) is separately responsible for worker safety and other issues, including security and safeguards.

Optimization is required in the UK and is a key aspect of the regulatory regime. For nuclear facilities this involves both options appraisal and selection of the best (i.e. least polluting) option and minimization of releases from the selected option. These steps are currently termed best practicable environmental option (BPEO) and best practicable means (BPM). These terms are being replaced in England and Wales by best available techniques (BAT) although the current terminology is being retained in Scotland and Northern Ireland. We regard this as primarily a change in terminology, to align it better with European usages. However, BAT does give clearer emphasis of the need to adopt good (global) practice, a key Government requirement in the context of the construction of new nuclear power plants in England and Wales.

A range of factors are considered in the optimization process, including worker dose, cost and others (non-radiological, environmental impacts, security and social and economic impact, good practice). Optimization for small users is generally by adoption of relevant good practice. Optimization includes addressing both the technology used to control discharges and the operation and maintenance of the facility, including operators' management arrangements for the control of the facility in general and their ability to comply with permit conditions in particular. The choice of formal decision aiding techniques is open to the operator.

Generic dose assessment is sufficient for non-nuclear facilities. Nuclear facilities require site-specific modelling using hypothetical and real critical groups and collective dose assessments.

Authorized limits are expressed in terms of disposals of radionuclides and are based on what the operator can achieve through optimization of the facility, with headroom for the normal fluctuations and events expected during the lifetime of the facility. Limits are expressed in terms of radionuclides and activities released, on the basis that this is what the operator controls and can monitor on an ongoing basis. Limits are set on an annual basis but shorter-term limits may be set for control and notification purposes. There are no statutory requirements regarding the details of limit-setting. Any exceedance of the authorised limits and any failure to use BAT are regarded as breaches of permit conditions, regardless of the degree of resulting radiological impact.

The UK has developed a strategy for radioactive discharges as part of its obligations under the OSPAR convention. A revised version is under consultation and covers both gaseous and liquid discharges, from nuclear and NORM industries. This strategy seeks a progressive and substantial reduction in discharges so as to meet the OSPAR convention target that discharges add close to zero to historical levels of radioactivity in the NE Atlantic. This obligation may require lower levels of discharges than that resulting from traditional optimization considerations.

18. United States of America

In the United States of America, the use and distribution of radioactive materials and operation of nuclear power and research reactors are regulated by the United States Nuclear Regulatory Commission (NRC), the Environmental Protection Agency (EPA), and State agencies. Any practice that results in the generation of radioactive wastes or involves liquid and gaseous effluent releases into the environment, requires a discharge authorization defined in an operating permit or license. Authorizations can be issued by the NRC, EPA, or the responsible State agency. Regulators from Federal and State agencies have different, but complementary regulations. Within the United States of America, there are facilities operating at all stages of the nuclear fuel cycle and non-fuel cycle facilities, including radioisotope

production facilities, medical and academic institutions, industrial facilities, mineral mining and processing, and research and development laboratories. These facilities are operated primarily by commercial entities, but a few Federal and State Agencies are also authorized users in specific instances. The basis for regulations in the USA, primarily, is ICRP Publication 26 [34]. However, some parts of ICRP Publication 2 [35], ICRP Publication 60 [2] and the International Basic Safety Standards [4] are also used. The regulatory process requires that any application for the use of radioactive materials is justifiable. It is implemented through laws, regulations, and regulatory guidance, with decisions made by regulators from agencies that have regulatory responsibilities.

The dose limit used by the NRC is an effective dose of 1 mSv/a, while the EPA considers risks, within a set range (1×10^{-4} to 1×10^{-6}). Constraints are applied, at times with specific restrictions, by regulatory agencies, depending on the type of practice being regulated. The EPA sets separate constraints for gaseous and aqueous releases. Older facilities are expected to conform to discharge standards of new facilities. The NRC sets separate constraints, or imposed license conditions defining operational criteria, dependent on the type of facility or practice.

Site specific dose assessments are required for nuclear fuel cycle facilities; for all other facilities, generic dose assessments are generally sufficient, but may be augmented depending on the type of practice. In assessing doses, members of the critical group are used in some applications, but not others. For example, the NRC uses maximally exposed individuals in assessing routine compliance with liquid and gaseous effluent releases from nuclear power plants and research and test reactors. If they are used, real groups are considered based on a review of local demographics, such as when demonstrating compliance with the EPA's environmental radiation standards.

Federal and State regulatory agencies require that all discharges be optimized under the ALARA principle. The risk of stochastic health effects is the primary criterion when determining optimization; however, acceptability can also be taken into account. Best Available Technique is not applied by the NRC but the EPA does consider it when setting discharge limits. The NRC, for example, requires an applicant for a reactor license to include in the design of liquid and gaseous effluent treatment systems items of reasonably demonstrated technology, that when added sequentially to a treatment system in order of diminishing benefit return, can for a favourable cost-benefit ratio, effect reduction in doses to populations within a 80 km radius of the proposed reactor. The NRC uses collective doses for optimization and applies a cost-benefit ratio of \$200,000 (US) per man Sv. These factors amongst others (including occupational exposure and decommissioning) are considered in cost benefit analyses or in multi-attribute analyses. The EPA, however, does not consider collective dose or occupational exposure and does not use any formal decision-aiding techniques. The EPA and NRC consider protection of the environment, in addition to the protection of human health, but apply different approaches in regulatory implementation.

Discharge limits are currently set in terms of radioactivity levels or discharge rates and doses. For radioactivity, the resulting concentrations are measured at the boundary of the unrestricted area to determine total discharges; for dose, the limit can be specified in terms of critical group doses, highest exposed individual, or at the site boundary. The EPA also considers risk. Usually the limits apply to individually permitted or licensed facilities on a site; while in other instances the limits may be applied to the site as a whole. The EPA also uses annual dose limits, but can also issue lifetime limits. The EPA also imposes maximum activity levels and

discharge rate limits, depending on the type of facility. Such limits may include yearly total activity releases (Bq/a).

The NRC imposes annual dose limits to members of the public and concentration limits on liquid and gaseous effluents released into the environment. The dose limit is 1 mSv/a, and the regulations include a dose constraint of 0.1 mSv/a for gaseous effluent releases for facilities other than nuclear power plants and research and test reactors. For power plants and research and test reactors, the NRC limits are:

- (1) The total annual quantity of all radioactive materials released from each reactor to the atmosphere will not result in an estimated annual external dose from gaseous effluents to any individual in unrestricted areas in excess of 0.05 mSv to the total body or 0.15 mSv to the skin.
- (2) The total annual quantity of radioactive materials released from each reactor to the atmosphere will not result in an estimated annual air dose from gaseous effluents at any location near ground level which could be occupied by individuals in unrestricted areas in excess of 0.01 cGy for gamma radiation or 0.02 cGy for beta radiation.
- (3) The total annual quantity of radioiodines, carbon-14, tritium, and all radioactive materials in particulate form released from each reactor at the site in effluents to the atmosphere will not result in an estimated annual dose or dose commitment from such releases for any individual in an unrestricted area from all pathways of exposure in excess of 0.15 mSv to any organ.
- (4) The total annual quantity of all radioactive materials released from each reactor to surface water bodies in unrestricted areas will not result in an estimated annual dose or dose commitment from liquid effluents for any individual in an unrestricted area from all pathways of exposure in excess of 0.03 mSv to the total body or 0.1 mSv to any organ.
- (5) The total annual quantity of all radioactive materials released from the site and contribution from all sources of external radiation to unrestricted areas will not result in an estimated annual dose in excess of 0.25 mSv to the total body, 0.75 mSv to the thyroid, and 0.25 mSv for any other organ.

The NRC can also impose maximum activity discharge rates or concentration limits. Such limits are imposed to define instantaneous discharge rates for noble gases. For liquid effluent discharges, a factor of 10 is applied to concentration limits defined under Title 10, Part 20, Appendix B, Table 2 [36], concentration limits. In both instances, operators implement these requirements by defining and setting alarm set-points for effluent monitoring instrumentation, which when exceeded would terminate releases. Exceeding a limit as specified in an authorization or license condition would normally result in a regulatory finding and penalties, depending on the severity of the regulatory infraction. Routine reporting requirements and corrective actions are mandated by both Federal and State regulations.

Environmental and effluent monitoring is required at all types of facilities, except for hospitals (only require effluent monitoring) and irradiators (which require no monitoring). Specific radionuclides are monitored, such as tritium, iodine, caesium, and noble gases. Lower limits of detection are required; they differ depending on the type of sampling, environmental media and the radionuclide or group of radionuclides being monitored. Reporting is required on an annual and semi-annual basis. Federal and State regulations also specify reporting requirements following inadvertent and accidental releases of radioactivity. Reporting requirements are defined by grouping of events, based on the magnitude of releases or potential for doses to members of the public.

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Annex

QUESTIONNAIRE SENT TO MEMBER STATES

Questionnaire completed by (full name):	
Organization/Institute contact details (in full):	

BASIC RADIATION PROTECTION

1. What practices do you require to have discharge authorizations?

2. Indicate which of the following facilities are operating in your state:		
<input type="checkbox"/> Nuclear power reactors	<input type="checkbox"/> Fuel enrichment facilities	<input type="checkbox"/> Isotope production facilities
<input type="checkbox"/> Research Reactors	<input type="checkbox"/> Research laboratories	<input type="checkbox"/> Irradiators
<input type="checkbox"/> Fuel fabrication facilities	<input type="checkbox"/> Radiopharmaceutical companies	<input type="checkbox"/> Hospitals and clinics

3. Do you use, as a basis for your radiological protection regulations and practices:			
<input type="checkbox"/> International Basic Safety Standards	<input type="checkbox"/> ICRP-26	<input type="checkbox"/> ICRP-60	<input type="checkbox"/> Other (please specify)

4. What is the annual dose limit on the effective dose, or effective dose equivalent, for a member of the public?

5. Are constraints used?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
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6. If constraints are used, are they the same for all types of practices, or do they change with type of practice?		
<input type="checkbox"/> All the same	<input type="checkbox"/> Change with practice	<input type="checkbox"/> N/A

7. If constraints are used, what are their values and who set them?

8. Are separate constraints set for gaseous and aqueous releases or is a constraint related to combined releases from a site?

9. How is the question of justification of a practice addressed?

10. Are old facilities expected to be operated to the same discharge standards as those used for new facilities? If not, how do they differ?

11. Do the discharges from any of your facilities cross national borders. Are any special measures taken to address this issue?

DOSE ASSESSMENT

1. Do you conduct generic or site specific modelling for the following facilities?	Generic	Site Specific
Nuclear power reactors	<input type="checkbox"/>	<input type="checkbox"/>
Radio-pharmaceutical companies	<input type="checkbox"/>	<input type="checkbox"/>
Research Reactors	<input type="checkbox"/>	<input type="checkbox"/>
Isotope production facilities	<input type="checkbox"/>	<input type="checkbox"/>
Irradiators	<input type="checkbox"/>	<input type="checkbox"/>
Hospitals and clinics	<input type="checkbox"/>	<input type="checkbox"/>
Research laboratories	<input type="checkbox"/>	<input type="checkbox"/>
Fuel fabrication	<input type="checkbox"/>	<input type="checkbox"/>
Fuel enrichment facilities	<input type="checkbox"/>	<input type="checkbox"/>

2. Do you use critical groups?

Hypothetical
 Real
 N/A

3. How do you define a critical group?

OPTIMIZATION

1. How do you define optimization of discharges?

2. How do you define Best Available Techniques (BAT)?

3. Do you consider the application of Best Available Techniques (BAT) an optimization process?

Yes

No

4. Do you use Best Available Techniques (BAT) in determining discharge levels?

Yes

No

5. Do you require discharges to be:

Optimized

Minimized

6. What criteria do you use to determine optimization?

7. Do you use the collective dose, man-Sv in optimization? If so, what monetary value do you assign to a man-Sv?

8. What decision aiding techniques do you use, or require to be used, when optimizing discharges?

9. Do you have a policy that encourages generation of solid waste in preference to discharges into the environment, or vice versa?

10. Are solid waste (low-level) facilities readily available to registrants and licensees at reasonable a cost?

Yes

No

11. Do you consider occupational exposures when optimizing discharges?

Yes

No

If yes, do you assign the same monetary values to occupational and public doses and collective doses, or are they weighted differently?

12.	Do you consider protection of the environment independently of protection of humans?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
If yes, what name do you give to these efforts? What criteria are used to determine if adequate measures have been taken to protect the environment?			

13.	Is decommissioning considered as part of optimization or separately?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
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SETTING DISCHARGE AUTHORIZATION
--

1.	Are your discharge limits specified in terms of dose, activity, or both?		
<input type="checkbox"/>	Dose	<input type="checkbox"/>	Activity
<input type="checkbox"/>		<input type="checkbox"/>	Both

2.	If discharge limits are specified in terms of dose, what dose is specified (e.g. to the critical group, at the site boundary, to the highest exposed member of the public, etc)?

3.	If discharge limits are specified in terms of activity, at what location is the limit applied (e.g. at the point of release, at each stack or discharge pipe, at the site boundary, etc)?

4.	If discharge limits are in terms of dose, is the dose specified for each group of radionuclides and for each discharge route, or for the total discharge?

5.	If the site has several independent facilities (e.g. several reactors, a hospital and an incinerator, etc.), does each have a separate limit and if so, how are these related to the site limit?

6.	Is the basic limit set on an annual basis? If not, what time period is used?

7.	Are there short term limits imposed on discharges in addition to annual limits (e.g. quarterly, monthly, weekly, etc.), and if so how are they related to the annual limit?

8.	Are there limits on the maximum rate of discharge of activity from each unit or from the site?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
If yes, what form do these limits take (e.g. maximum concentration of released activity, maximum dose rate, etc.)?			

9.	Do you issue authorizations for an indefinite period of validity, i.e., for the facility's life facility, or do these have to be renewed periodically? If so, what are the renewal periods? Does this differ with the type of authorization?

COMPLIANCE AND OPERATIONAL REQUIREMENTS
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1.	Does exceeding a short-term limit constitute a violation of regulations that calls for penalties ?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
If not, what action is expected?			

2.	Are there general conditions related to the discharge authorization that require notification or reporting the regulatory authority?

3.	What effluent and environmental monitoring required?	Effluent Monitoring	Environmental Monitoring
	Nuclear power reactors	<input type="checkbox"/>	<input type="checkbox"/>
	Radio-pharmaceutical companies	<input type="checkbox"/>	<input type="checkbox"/>
	Research Reactors	<input type="checkbox"/>	<input type="checkbox"/>
	Isotope production facilities	<input type="checkbox"/>	<input type="checkbox"/>
	Irradiators	<input type="checkbox"/>	<input type="checkbox"/>
	Hospitals and clinics	<input type="checkbox"/>	<input type="checkbox"/>
	Research laboratories	<input type="checkbox"/>	<input type="checkbox"/>
	Fuel fabrication	<input type="checkbox"/>	<input type="checkbox"/>
	Fuel enrichment facilities	<input type="checkbox"/>	<input type="checkbox"/>

4.	Do you monitor specific radionuclides?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
If yes, which ones?			

5. Do you specify limits of detection?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
If yes, provide details.		

6. What type of reporting is required?

7. Do you follow QA procedures?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
If yes, provide details.		

6. What type of reporting is required?

ANY OTHER COMMENTS

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CONTRIBUTORS TO DRAFTING AND REVIEW

Amado, V.	Autoridad Regulatoria Nuclear (ARN), Argentina
Balonov, M.	International Atomic Energy Agency
Brember, P.	The Environment Agency, United Kingdom
Cabianca, T.	International Atomic Energy Agency
Cortés Carmona, A.	Comision Nacional de Seguridad Nuclear y Salvaguardias (CNSNS), Mexico
Chartier, M.	Institut de radioprotection et de sûreté nucléaire (IRSN), France
Chon, J.	Korea Institute of Nuclear Safety (KINS), Republic of Korea
Cindro, M.	Slovenian Nuclear Safety Administration, Slovenia
Clark, M.	United States Environmental Protection Agency, United States of America
Curti, A.	Autoridad Regulatoria Nuclear (ARN), Argentina
Czoch, I.	Hungarian Atomic Energy Authority (HAEA), Hungary
Dehmel, J-C.	United States Nuclear Regulatory Commission (USNRC), United States of America
Fegan, M.	Radiological Protection Institute of Ireland (RPII), Ireland
Frye, T.	United States Nuclear Regulatory Commission (USNRC), United States of America
Garraway, J.	The Environment Agency, United Kingdom
Gwynn, J.	Norwegian Radiation Protection Authority (NRPA), Norway
Guo, D.	Beijing Research Institute of Uranium Geology, China
Haegg, A-C.	Swedish Radiation Safety Authority, Sweden
Hamrah, B.	Atomic Energy Licensing Board (AELB), Malaysia
Korpela, H.	Radiation and Nuclear Safety Authority (STUK), Finland
Kerrigan, E.	Enviros Consulting Limited, United Kingdom
Krizman, M.	Slovenian Nuclear Safety Administration (URSJV), Slovenia
Linsley, G.	International Atomic Energy Agency
Moberg, L.	Swedish Radiation Protection Authority (SSI), Sweden
Mora, J.C.	Unidad de Protección Radiológica del Público y del Medio Ambiente, CIEMAT, Spain
Nilsen, M.	Norwegian Radiation Protection Authority (NRPA), Norway
Pather, T.	National Nuclear Regulator (NNR), South Africa
Petrova, K.	State Office for Nuclear Safety (SÚJB), Czech Republic
Proehl, G.	Helmholtz Zentrum München, Germany
Robinson, C. *	Enviros Consulting Limited, United Kingdom

* A Staff Member of the IAEA until 2003.

Ryan, T.	European Commission (EC)
Sagi, L.	KFKI Atomic Energy Research Institute (AEKI), Hungary
Sherbini, S.	United States Nuclear Regulatory Commission (USNRC), United States of America
Simmonds, J.	Health Protection Agency (HPA), United Kingdom
D. Telleria	International Atomic Energy Agency
Thomas, G.	Atomic Energy Regulatory Board (AERB), India
Tselane, T.	National Nuclear Regulator (NNR), South Africa
van Weers, A.	Nuclear Research & Consultancy Group (NRG), Netherlands
Vogl, K.	Bundesamt für Strahlenschutz (BfS), Germany
Wang, J.	Beijing Research Institute of Uranium Geology, China
Zerquera, J.T.	Centro de Protección e Higiene de las Radiaciones (CPHR), Cuba

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