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REVISED GUIDANCE ON THE PRINCIPLES FOR ESTABLISHING INTERVENTION LEVELS FOR THE PROTECTION OF THE PUBLIC IN THE EVENT OF A NUCLEAR ACCIDENT OR RADIOLOGICAL EMERGENCY

INTERIM REPORT ON THE DEVELOPMENT OF REVISED GUIDANCE
ON THE PRINCIPLES AND APPLICATION
OF INTERVENTION LEVELS OF DOSE

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EDITORIAL NOTE

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IN THE EVENT OF A NUCLEAR ACCIDENT OR RADIOLOGICAL EMERGENCY
IAEA, VIENNA, 1988
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FOREWORD

Measures to protect the public following an accidental release of radionuclides to the environment, and the timing for their introduction, will depend on the prevailing circumstances including the extent of the potential hazard. The projected levels of risk at which they are introduced can be defined quantitatively in terms of radiation dose, and are referred to, alternatively, as intervention levels of dose, "emergency reference levels" or Protective Action Guides. Their establishment is an important prerequisite in emergency planning, as it is upon these levels that any decision to implement protective measures during an accident should be based. The levels can also be expressed in terms of concentration levels in the environment or in foodstuffs; for example, Becquerels per cubic metre of air or per kilogram of a particular food category. These "derived intervention levels" represent the practical expression of the intervention levels of dose and can be determined for the range of potentially important radionuclides that could be released to the environment in the event of a nuclear accident.

By the end of 1985 guidance on the principles and procedures for setting intervention levels of dose had been developed and published by the Commission of the European Communities (1982), the International Commission on Radiological Protection (1984), the World Health Organization (1985) and the International Atomic Energy Agency (1985). This published guidance also included recommended numerical values for the upper and lower levels of dose on which to base the introduction of the key protective measures (sheltering, prophylaxis and evacuation) that may need to be implemented during the early stages of an accident. Although no internationally agreed values for derived intervention levels existed, the guidance identified the environmental measurements or materials for which they were needed, and the units to be used. Collectively, this guidance represented a general consensus on the principles for establishing intervention levels for the protection of the public in the event of a nuclear accident and a number of countries had specified intervention levels for use in conjunction with the emergency response arrangements applying to their major nuclear installations; several had also developed and published derived intervention levels for a range of radionuclides.

The accident at the Chernobyl Nuclear Power Plant on 26 April 1986 has had a major impact on the overall approach to emergency response planning, both at the national and international level, particularly as a result of the transport of radioactive material over long distances and its subsequent inhomogeneous deposition over very wide areas. The type of accident that could disperse readily measurable amounts of radionuclides across large areas of Europe, with detectable amounts over much of the Northern Hemisphere, had not been taken into account in any international guidance or national emergency response arrangements. These were aimed, primarily, at responding to relatively well defined releases originating from sources at specific locations within national borders rather than to the transboundary consequences from contaminants originating from outside the country. In particular, the published intervention guidance was directed towards the introduction of protective measures in the early stages of an accident when the main concern is avoiding non-stochastic effects and limiting the extent of stochastic risk to individuals.

The resulting actions taken by the various national authorities varied widely, ranging from simple reinforcement of their normal environmental monitoring programmes without the introduction of protective measures, to the banning of specified foodstuffs. The differences in approach, both between and within countries, with regard to levels at which the protective measures were introduced, cannot be explained either by the variation in contamination levels or the predicted radiological consequences. Certainly, a number of external factors appear to have influenced the decision, the more important of which were of a political or economic nature, rather than meeting radiation protection objectives. Moreover, there was a considerable misinterpretation of the existing radiation protection guidance; for example, mixing the rationale upon which intervention levels are based, with that relating to dose limits. This wide variation in response by national authorities, together with a lack of consistent and understandable advice to the public (particularly with respect to the potential contamination of food and the environment, and any resultant radiation doses and effects) undoubtedly caused much additional anxiety and unnecessary confusion.

Even in a major nuclear accident involving the release of large quantities of radioactive material into the atmosphere, the need for protective measures to limit the individual risk (e.g., sheltering, use of prophylactics, evacuation) will be restricted to within relatively short distances - probably not more than a few tens of kilometres - from the release point. However, because the released radioactive material will be diluted in the atmosphere and subsequently dispersed over wide areas, the major part of the collective dose to populations resulting from such an accident will, in general, be accumulated out to much greater distances. Although at these distances the individual dose levels will be substantially below those of concern for non-stochastic effects or for significant individual stochastic risk, the competent national authorities in those countries that lie along the route of the dispersed radioactive material will need to consider whether a reduction of the collective dose detriment for their populations is justified; for example, by introducing protective measures such as controls on food supplies and drinking water.

To avoid any future repetition of the confusion that arose from the widely varying post-Chernobyl response actions, particularly the major differences in the levels at which protective measures were initiated, several of the international and intergovernmental organizations were requested by their governing bodies to review the adequacy of their existing guidance on the application of intervention dose levels, together with the criteria upon which numerical values of derived intervention levels are based. In response to the recommendations of the International Nuclear Safety Advisory Group following the IAEA Post-Accident Review Meeting in August 1986, provision was made in the Agency's expanded nuclear safety and radiation protection programme for the development by the Agency (in collaboration with other relevant international and intergovernmental organizations) of additional guidance on intervention levels of dose and corresponding derived intervention levels appropriate to reducing the stochastic risk and collective dose equivalent, especially at distances beyond the immediate area of accident impact. To this end, an IAEA Advisory Group under the chairmanship of Dr. D. Beninson, Chairman of the International Commission on Radiological Protection, met in February 1987 to:

(i) review existing Agency guidance on intervention levels of dose and indicate whether, and if so, what, revision is required in relation to the primary intervention levels and their application;

(ii) consider whether, and if so, what additional guidance is required on limiting the stochastic risk and collective dose equivalent, particularly at long distances from the accident release point; and

(iii) consider whether, and if so, what, additional guidance should be developed on derived intervention levels.

The Advisory Group concluded that although the basic principles for the protection of the public, as set out in Safety Series No. 72, remain valid, further guidance on their application was necessary, particularly in the context of intervention associated with an accident having an impact over long distances and large areas, and extending over long periods of time. It therefore clarified and amplified several areas of the existing guidance, and commenced the development of further guidance in a number of specific areas of concern. A further meeting of the Advisory Group is scheduled for November 1988 at which it is planned to complete the text for a revised edition of Safety Series No. 72.

The purpose of this Interim Report, which is based on the report of the Advisory Group, is to present to a broader audience the initial conclusions and recommendations of the Advisory Group in order that they may be used in conjunction with the guidance currently presented in Safety Series No. 72, pending publication of the revised Safety Series, scheduled for late 1989.

The Secretariat invites comment on this Interim Report; these will be taken into consideration by the Advisory Group when developing their further guidance in this field and preparing the text for the revised edition of Safety Series No. 72. Comments should be addressed to the Department of Nuclear Energy and Safety, International Atomic Energy Agency, P.O. Box 100, Wagramerstrasse 5, A-1400 Vienna, Austria.

The Agency wishes to express its gratitude to the Advisory Group members who participated in the preparation of the report on which this document is based, and in particular to their Chairman, Dr. D. Beninson, and to Dr. G.N. Kelly of the United Kingdom Central Electricity Generating Board, who assisted the Secretariat in the development of this Interim Report.

CONTENTS

I. INTRODUCTION

GENERAL

101. The principles upon which to base the introduction of protective measures have been outlined in ICRP Publication 40 [1] and IAEA Safety Series No. 72 [2]. They provide the basis for radiation protection of the public following a nuclear accident. The experience gained as a result of the accident to Unit 4 of the Chernobyl Nuclear Power Plant in the USSR has indicated that these principles need to be clarified and amplified in several respects. In particular, because these principles were developed in the context of intervention within the general vicinity of the source of the accident, their applicability to an accident having an impact over long distances, upon large areas and populations, and extending over long periods of time, needs therefore to be addressed.

PURPOSE

102. In 1985 the Agency published guidance on the principles for establishing the primary intervention levels of dose at which measures for the protection of the public should be implemented, Safety Series No. 72. To enable the results of actual measurements in the environment and in foodstuffs to be readily compared with these primary levels, derived intervention levels are required. These levels are specified in practical quantities of measurements such as the concentration of a particular radionuclide in a particular foodstuff. Because the procedure for determining derived intervention levels must take into account a number of factors that are specific to those persons to whom the levels will apply, such as dietary habits, agricultural practices, etc., it is not possible to set realistic numerical values of derived intervention levels that will apply universally. In December 1986, in support of Safety Series No. 72, the Agency published Safety Series No. 81 "Derived Intervention Levels for Application in Controlling Radiation Doses to the Public in the Event of a Nuclear Accident or Radiological Emergency: Principles, Procedures and Data" [3]. Appropriate caveats are included in the text and tables to guide the user on the application and limitations of the numerical values provided.

103. In response to the recommendations of the International Nuclear Safety Advisory Group following the Post-Accident Review Meeting in August 1986, the Agency's Expanded Nuclear Safety Activities Programme included a requirement to review (in collaboration with other relevant international organizations) the Agency's existing guidance on intervention levels of dose and to consider the need to develop additional guidance relating to limiting the stochastic risk and collective dose, especially at long distances from the accident release point. An Advisory Group chaired by Dr. D. Beninson, Chairman of the International Commission on Radiological Protection, met in February 1987 to carry out this review. It took into consideration the concern of Member States regarding the potential transboundary consequences of an accidental radionuclide release, and the desire to seek international harmonization on the levels of radioactive contaminants, particularly for foodstuffs, above which protective measures may need to be introduced.

SCOPE

104. The Advisory Group were requested to re-examine the radiation protection principles upon which the current primary intervention levels of dose and corresponding derived intervention levels have been established, and to make recommendations on:

(i) the need for any modification of the existing Agency guidance in this field;

(ii) the need for any additional guidance on limiting the stochastic risk and collective dose equivalent (commitment), particularly at long distances from the accident release point;

(iii) the form that any additional guidance that may need to be developed as the results of (i) and (ii) above, should take; and

(iv) where, on the basis of the existing and any additional guidance on intervention levels of dose, further guidance should be developed on derived intervention levels, together with the criteria for such further guidance, including that relating to possible international harmonization on the levels of radioactive contaminants (particularly for foodstuffs) above which protective measures may need to be introduced;

with a view to publishing the recommendations as interim guidance prior to completion of the Advisory Group's work and publication of the revised edition of Safety Series No. 72, scheduled for 1989. In making their recommendations, the Advisory Group was requested to take into account any relevant work being carried out in this field by other international organizations. In this respect, a strong co-ordination has been maintained with the World Health Organisation in the development of their guidelines on Derived Intervention Levels for Radionuclides in Food [4].

II. BASIC PRINCIPLES FOR INTERVENTION AND THEIR ELUCIDATION

APPLICATION OF ICRP AND IAEA RECOMMENDATIONS

201. The recommendation of the International Commission on Radiological Protection (ICRP) and the basic radiation safety standards of the International Atomic Energy Agency (IAEA) as set out in ICRP Publication 26 [5] IAEA Safety Series No. 9 [6], respectively, clearly distinguish between two conditions of exposure. The first condition is one where the occurrence of the exposure is foreseen and can be limited by control of the source and by application of the Commission's system of dose limitation. The second condition is one where the source of exposure is not subject to control, for example, in accident situations, so that any subsequent exposure can be limited in amount, if at all, only by some form of intervention.

202. Under normal circumstances, where the first condition obtains, the three basic principles for radiation protection set out in ICRP Publication 26 will apply: Justification, Optimization and Dose Limitation. In the case of an accident during which the primary source has, by definition, been out of control, it is no longer appropriate to apply the normal dose limitation requirements specified in ICRP Publication 26. The principles of justification and optimization can, however, be applied to accidents in a manner analogous to their use in normal control of radiation exposure, except that in this case the control decisions involve protective measures, rather than the prior control of sources. For such circumstances ICRP Publication 40 and IAEA Safety Series No. 72 set out special principles by which dose limitation is achieved through the introduction of protective measures. These principles include consideration not only of stochastic and non-stochastic radiation risks, but also the risks to individuals that are inherent in the protective measures adopted.

203. The basic principles for planning intervention in the event of an accident have been formulated in ICRP Publication 40 [1] and Safety Series No. 72 [2] as:

(i) serious non-stochastic effects should be avoided by the introduction of protective measures to limit individual doses to levels below the thresholds for these effects;

(ii) the risk from stochastic effects should be limited by introducing countermeasures that achieve a positive net benefit to the individuals involved; and

(iii) the overall incidence of stochastic effects should be limited, as far as reasonably practicable, by reducing the collective dose.

204. In the immediate vicinity of the accident radiation exposure rates may be very high and it may be necessary to introduce protective measures under principles (i) and (ii) to avoid acute health effects or limit the stochastic health risk to the individual. This immediate area of the accident, which is unlikely to extend beyond a few tens of kilometres in radius, is referred to here as the "near field". In the event of a large accident the released radioactive material may extend over very large areas where the main concern will be the ingestion of radionuclides via the food pathway as the result of direct deposition or from imported contaminated foodstuffs. For these areas, referred to here as the "far field", the main concern is likely to be in meeting principle (iii) above; this presents significantly different problems for the relevant responsible public authorities than those associated with principles (i) and (ii).

205. Differing interpretations have been made of these principles and, in particular, with regard to the relative importance of the last two. In the remainder of this section and, to a lesser extent, in Section III, these principles are amplified and elucidated with the objectives of aiding their better understanding and their more consistent application in the future.

JUSTIFICATION OF INTERVENTION

206. Remedial measures, also known as protective measures or countermeasures, are intended to reduce the radiation risk from an existing source of exposure. Such remedial measures always entail some risks of their own and some costs which are related to the nature of the remedial measure and the prevailing circumstances. The decision to introduce a protective measure, therefore, should be based on a balance of the radiation risks averted and the risks and social costs resulting from the protective measure itself.

207. It is intrinsically difficult to express all components of the balance in compatible quantities, but the purpose of the balance is clear: to show that the exposed individuals are put in a "better" position by the remedial measure, in the sense that lower overall risks are achieved at a "reasonable" cost in financial and social terms. Various decision-aiding techniques are available to assist judgements in such complex areas. One (but by no means the only nor necessarily the best) technique that can be used to determine whether the introduction of a remedial measure would be justified is cost-benefit analysis, where the remedial measure would only be taken if it resulted in a positive net benefit. The problem can be conceptualized as follows, where the benefit is expressed as:

$$B = Y_O - [Y_I + R + X] \qquad (1)$$

where:

- B is the net benefit achieved by the protective measure;
- Y_O is the radiation detriment cost if the remedial measure is <u>not</u> taken;
- Y_I is the remaining radiation detriment cost if the remedial measure is carried out;
- R is the detriment cost consequent upon the risks introduced by the remedial measure itself; and
- X is the cost of the remedial measure and may comprise several components of both a tangible and intangible nature.

In practice it is difficult to quantify, in monetary cost, all the terms of Equation 1 and subjective value judgements, similar to those involved in most social and economic decisions, would often need to be made.

208. It is instructive to examine the components of the conceptual equation presented above. The radiation detriment terms, expressed as costs Y_O and Y_I, include the stochastic and non-stochastic health effects predicted to occur, and any additional health impact, not directly attributable to radiation exposure, such as anxiety. The costing of radiation induced health effects involves all of the difficulties inherent in the valuation of changes in the quality and expectancy of life; the latter is, however, a common and essential component of many socio-economic decisions, whether carried out explicitly or intuitively.

209. As an example, if it is assumed that the cost, Y, varies linearly with the expected number of effects then, conceptually, it can be expressed as:

$$Y = C_F N_F + C_{NF} N_{NF} + \alpha S + C_I \qquad (2)$$

where:

- C_F is the cost assigned to a non-stochastic radiation-induced death;
- N_F is the number of non-stochastic deaths;,
- C_{NF} is the cost assigned to a non-fatal non-stochastic effect;
- N_{NF} is the number of non-fatal non-stochastic effects;
- α is the cost assigned to unit collective dose;
- S is the collective dose; and
- C_I is the cost assigned to other health effects indirectly attributable to the exposure (e.g. anxiety), assumed here as dose-independent.

210. Equation 2 contains four additive terms: the cost of non-stochastic deaths, the cost of non-fatal non-stochastic health effects, the cost of stochastic health effects and the cost of health effects that are only indirectly attributable to the exposure and are assumed here to be independent of dose. As such, the expression is already a simplification, as all types of non-fatal health effects are grouped together and assigned a single cost per unit effect; the assignment of costs which were dependent on the individual level of dose or risk would be a further potential complication.

211. The detriment cost, R, associated with the risk from the protective measure itself may or may not be dependent on the prevailing radiation levels (e.g. high radiation levels may complicate the application of the protective measure) and, depending on the nature of the protective measure, may be dependent on the number of people involved to varying degrees.

212. The cost of the remedial measure, X, may have a significant component that is largely independent of the radiation level at which the action is introduced, and another component dependent on such a level, i.e.:

$$X = X_o + X(I)$$

These costs may include both tangible and intangible components. The more tangible components include, for example, the costs of disposing of contaminated food, compensation for restricted foodstuffs, etc.. Less tangible components might include a political and social perception of the need to implement protective measures, the harmonization of international trade, etc. Some of these less tangible components may have positive or negative costs and these aspects are discussed further in paras 235 and 604.

213. The relative importance of the various terms in Equation 1 will vary with the remedial measure being considered and the particular circumstances of an accident. In principle, in determining whether intervention is justified, due account must be taken of all of the terms and, where appropriate, of their component parts. It is unlikely, however, that, in any particular case, all of the terms will be significant in determining the overall balance and consideration can, in practice, be limited to the most important. The costs of the health detriment, Y, both with and without the remedial measure, will always be essential inputs to the balance. The costs of introducing the remedial measure, X, and those resulting from any additional risk it introduces, R, will be sensitive to the type of measure envisaged. In general, one or other is likely to dominate the overall cost attributable to the remedial measure. This situation can be readily illustrated by reference to two remedial measures, food restrictions and evacuation.

Cost of Remedial Measures

214. The risks to health of introducing food restrictions will, in general, be minimal other than perhaps to a few individuals with special dietary requirements or where there is no effective alternative supply. Consequently, the overall costs attributable to this remedial measure will be determined by the direct costs of restrictions which, among others, include the value of the lost produce, disposal costs and the costs of implementing and operating the control framework. Other, less tangible, factors connected for example with the perception of risk, the achievement of a harmonised international approach to restrictions, etc. may be additional important components of this cost.

215. For evacuation the situation is somewhat different because of the potentially significant additional risk which it introduces for those individuals affected; there may in addition be some health detriment associated with the stress of being moved from the family home and being separated from other family members. This risk will vary with the prevailing circumstances and with the individuals involved. Consequently, it is

difficult to draw general conclusions on the relative importance of the direct costs of evacuation and those associated with its risks and, unless there are indications to the contrary, both components will need to be addressed. In those cases where the risk component dominates the overall costs of the remedial measure, the balance in Equation 1 is simplified; it is then unnecessary to convert the various components to cost, the balance being determined directly on the basis of risk.

216. Some comment is warranted on the conversion of the various components to cost and on some of the factors implicit in the balance indicated by Equation 1. Where the overall costs of a remedial measure are essentially determined by the risks to health that it introduces, then the balance reduces to a simple comparison between the competing risks of the radiation averted and the remedial measure. Moreover, the respective risks are to the same individuals and the comparison is direct. Where the overall costs are determined, not by the risk component, but by the actual costs of the remedial measure, or other less tangible factors, the balance becomes less direct and more complex and, moreover, potentially subject to different outcomes depending on value judgements as to the weights accorded to particular components. In particular, it needs to be recognised that in these circumstances the risks may be borne by a different group from those bearing the costs; for example, the risks will be borne by those potentially exposed and subjected to the protective measure whereas, in many cases, the costs will be distributed across a much larger regional or national population.

OPTIMIZATION OF INTERVENTION

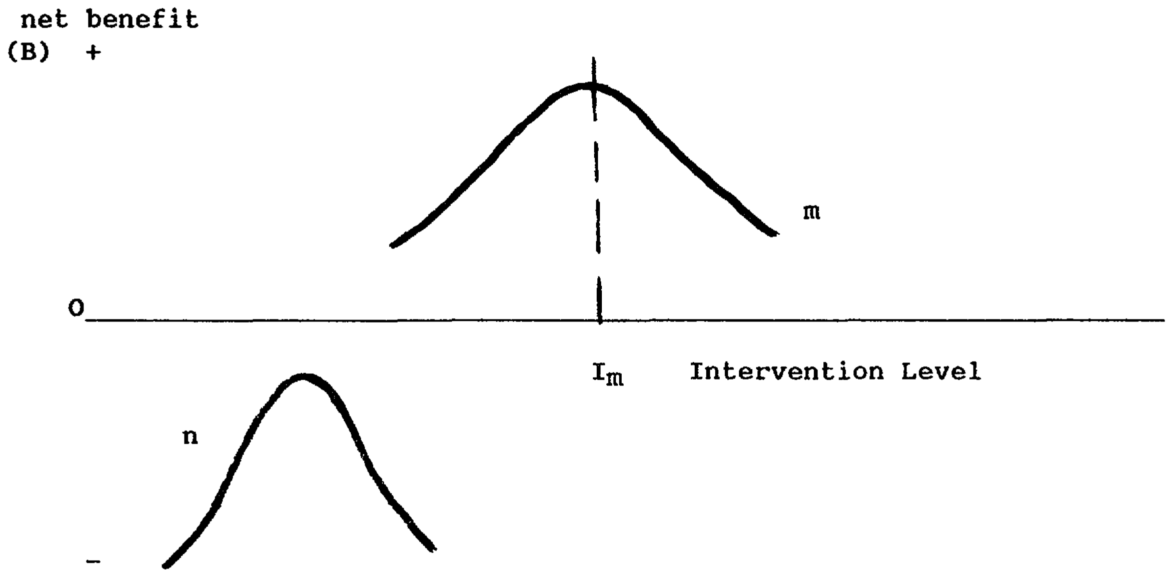
217. If intervention is contemplated, then the proper selection of the intervention level may optimize the situation, in the sense of maximising the net benefit. Assuming that the detriment cost, R, due to the risks from the protective measure itself, is independent of the intervention level, then the optimum intervention level is achieved when:

$$\frac{dX(I)}{dI} + \frac{d\,Y_I}{dI} = 0 \qquad (3)$$

where:

I is the intervention level.

218. It should be stressed that optimization of the intervention level is not a sufficient condition to confirm that the contemplated protective measure is justified; this will only be so if there is an overall benefit from its introduction (i.e. a positive value of B in Eq. 1). As many components independent of the intervention level enter into the ideal cost-benefit balance (which determines whether the action is justified) situations of the type indicated below may occur:



In case n, the introduction of the remedial measure would not be justified, even at the "best" value for the intervention level. The introduction of the protective measure would be justified in case m, and optimization would result in the selection of an intervention level, I_m.

219. Optimization assessments may be substantially simplified if only the stochastic health risk is relevant. In practice this will generally be so because the primary aim of intervention is to prevent the occurrence of non-stochastic health effects. Subject to the asumption that the cost per unit collective dose is independent of the levels of individual dose which it comprises (i.e. only the so-called α-term is relevant for optimization), in those cases where only the stochastic risk is relevant the optimizing condition can be expressed as:

$$\frac{dX(I)}{dI} + \alpha \frac{dS_I}{dI} = 0 \qquad (4)$$

where:

- $X(I)$ is that part of the protective measure cost which is dependent on the intervention level;
- α is the monetary cost assigned per unit collective dose; and
- S_I is the residual collective dose having applied the protective measure.

ILLUSTRATIVE EXAMPLES OF SIMPLIFIED OPTIMIZATION

220. Two examples of the application of this optimization approach are illustrated in the following. It should be recognized that a number of simplifying assumptions are made in the examples in the interests of presentation. The potential implications of these assumptions are discussed in paras 236-239.

221. In the first example consideration is given to the choice of intervention level for the relocation, and subsequent return, of people from contaminated areas. The approach is equally applicable to other situations where the intervention is fully effective while it is applied (i.e. there is no incurred dose during this period), and where both the collective dose and the cost of the protective measure are proportional to the number of individuals affected by the protective measure.

222. If the protective measure is applied to a group of N people, each experiencing the same dose conditions, for a time τ (during which individual doses are zero), and then removed, the cost, $X(I)$, and the remaining collective dose, S_I, can be expressed as:

$$X(I) = a N \tau \qquad (5)$$

$$S_I = N \int_{\tau}^{\infty} \dot{H}(t)\, dt \qquad (6)$$

where:

- a is the cost of the protective measure per person and per unit time; and

$\dot{H}(t)$ is the individual dose rate as a function of time if the protective measure is not applied.

The optimizing condition in Equation 4 can be expressed in terms of determining the optimum time for return, τ_{op}:

$$\frac{d\,X(\tau)}{d\,\tau} + \alpha\,\frac{d\,S_I}{d\,\tau} = 0 \qquad (7)$$

and, therefore, by substitution

$$\dot{H}_{op} = \dot{H}\,(\tau_{op}) = a/\alpha \qquad (8)$$

where:

$\dot{H}_{op}$ is the optimum value for the intervention level. (Although this is the optimum individual dose-rate for return of people to the contaminated area, a similar procedure can be applied for determining the optimum value for their initial withdrawal.)

It should be noted that the ratio, a/α, will, in general, be much less sensitive to geographical location than either a or α alone, because both quantities are likely to be similarly correlated to national wealth.

Foodstuff control considerations

223. The second example concerns the choice of intervention level to restrict the use of contaminated food [4]. Application of this methodology leads directly to an intervention level expressed in terms of the nuclide concentration in food (i.e., the derived intervention level for the particular foodstuff of concern). In this case the cost of the protective measure per person and per unit time, a, is given by:

$$a = b.\,V \qquad (9)$$

where:

b is the cost per unit mass of the foodstuff; and

V is the consumption per person and per unit time of that foodstuff.

The individual dose rate (more exactly the rate at which individual dose is committed), $\dot{H}$, is given by:

$$\dot{H} = A\ V\ H_E \tag{10}$$

where:

A is the activity concentration; and

H_E is the committed effective dose per unit intake by ingestion of the nuclide in question.

224. Substituting from Equations (10), (9), and (8), respectively, the optimized intervention level in the previous example (i.e. a/α) is seen to correspond to a derived intervention level of activity concentration, A_{op}, viz:

$$A_{op} = \frac{\dot{H}_{op}}{V\ H_E} = \frac{a}{\alpha\ VH_E} = \frac{bV}{\alpha VH_E} = \frac{b}{\alpha H_E} \tag{11}$$

For the same reasons indicated previously, this quantity, A_{op}, will, in general, be much less sensitive to geographic location than any of the individual parameters on which it depends.

225. Using this approach, estimates have been made of optimal intervention levels for various foods contaminated with various nuclides [4]. The optimum activity levels will clearly vary with the nuclide (depending on its radiotoxicity) and foodstuff (depending on its cost) considered. Typically, the levels of committed dose corresponding to the annual consumption of foodstuffs at the optimum activity concentrations have been estimated to be in the range of about 1 to 10 mSv.

226. Derived intervention levels established in this way are applicable to given foodstuffs irrespective of the contamination of other foodstuffs and can, therefore, be applied directly. However, if a large number of foodstuffs are contaminated and the "optimal" levels are relatively high, the national competent authorities should keep the situation under review to prevent the possibility of unduly high individual risks resulting from the combined ingestion. This situation, however, is most unlikely to arise. Practical

considerations will, in general, dictate that foodstuffs are grouped into a few broad categories for the purposes of implementing intervention, rather than restricting foodstuffs on the basis of individual food items (e.g., [10]).

227. It should be noted that in this simplified example the only component included in the cost of the remedial measure was that corresponding to the value of the lost produce. In practice there will be additional costs, including the costs of disposal and of the institutional framework that will need to be implemented and operated to effect the control. If account were taken of these and other comparable factors, the optimal activity concentrations, and corresponding levels of dose, would be greater than those estimated in [4] and indicated above.

228. The example is also only strictly valid while the benefits of the radiation averted and the costs of the remedial action arise within the same community (e.g. within a given country). Where food is being imported into another country unaffected by an accident it could be argued that in carrying out the optimization the proper cost to be assumed is not the cost of the lost produce but the marginal increase in cost of having to secure an alternative supply of uncontaminated or less contaminated produce. This would, in itself, lead to somewhat lower optimum levels of dose and nuclide concentrations for intervention. The establishment of intervention levels solely on this basis, however, would be wrong conceptually as no account would have been taken of the costs that may arise in the disruption of international trade that could ensue from the adoption of unduly low levels of intervention; similarly, if very low levels are imposed, then the costs of the control measures required to effect the policy may become overriding. The quantification of some of these aspects is often difficult; however, this should not preclude them being given due attention as the alternative is that intervention may be introduced when it is neither justified nor optimized, with attendant losses to the broader community. Some of these aspects are addressed further in Section VI in the context of harmonization of international trade in foodstuffs.

Individual risk-related considerations

229. As in any application of the principles of optimization for assessing the appropriate level of radiological protection, the results obtained using the methods described above should be reviewed to ensure that they do not pose

an unduly high risk to individuals. This need arises from the fact that optimization is based on collective considerations; therefore, individual doses obtained as the result of optimization are, in reality, average values.

230. ICRP has suggested that measures to restrict the distribution of foodstuffs should be considered if the dose to the individuals who would be affected by the protective measure is projected to exceed 5 mSv effective dose equivalent as a result of intakes in the first year after an accident [1, Annex C]. Although this figure was primarily intended to apply in the near field, it is also appropriate in the far field.

231. If the criterion for intervention is set at an effective dose equivalent level of 5 mSv, this implies a thyroid dose of 167 mSv if this organ is irradiated alone. This dose is considered too high, given the incidence of non-fatal cancer following thyroid irradiation and the potential of I-131 for irradiation of the thyroid alone. An additional limitation of the thyroid dose to 50 mSv would make allowance for these factors.

232. In practice it was found that the average levels of radioactive material in individuals resulting from the Chernobyl accident were substantially lower than was predicted from the deposited activity where those individuals lived (Fry and Britcher [7], Meekings [8]). Due to the complexity of the food web and because most individuals obtain components of their diet from widely different areas, only a fraction of the food consumed is likely to be contaminated at a level corresponding to the deposition level where they live. It can therefore be concluded that applying the dose criteria in para. 231 above may well result in mean doses significantly lower than the intervention level.

233. It should be noted that an effective dose equivalent value of 5 mSv falls in the middle of the range of intervention levels obtained by the use of Equation (8), which is of the order of 1 to 10 mSv. Use of this value for planning purposes is therefore considered justified if no detailed optimization is carried out.

234. The individual radiation dose in the second and subsequent years following a nuclear accident is likely to be considerably less than that received in the first year. As the situation in individual countries will vary, it is not considered necessary to recommend any revised values of the

intervention levels of dose, or of the derived intervention levels, for these subsequent years. In the rare situation in which the annual dose does not fall significantly by the second or third year, the competent authorities would need to consider the specific circumstances when deciding whether there was a need for any additional action.

235. One further point concerning individual risk associated with the selection of an intervention level of dose should be considered. ICRP has indicated several years ago that serious mental retardation could result from exposure of the foetus during the period 8-15 weeks after fertilization, with a risk of 0.4 Sv^{-1}. Assuming uniform exposure over a year, 5 mSv would incur a risk of serious mental retardation in the order of 3×10^{-4} for a child who was exposed as a foetus. However, there is evidence that a signficant threshold may exist [9], in which case no extra precautions need to be introduced, because the threshold may be as high as several millisieverts. Until the presence or absence of a threshold is confirmed, national authorities may wish to consider this as a possible stochastic effect that confers critical group status on the foetus at this stage of development.

Additional qualification of the simplified illustrative optimizations

236. The justification of remedial measures and the role of optimization in establishing intervention levels have been discussed and illustrated in a very ideal and simplified framework. In that framework resources to implement the remedial measures were assumed to be always readily available, irrespective of the intervention level. Another underlying assumption was that society attaches values in a linear manner, judging, for example, that twice a cost is twice as undesirable, irrespective of the amounts involved.

237. As both assumptions are not necessarily realistic over the entire range of possibilities, the results of optimizations of the type illustrated above must be examined in the light of constraints and "utilities". The choice of very low intervention levels may result, in some cases, in the application of a protective measure over very large areas or involving large numbers of people, and therefore may imply a very large total cost exceeding the resources that society may be willing, or even able, to commit. On the other hand, if the total cost involved in the application of a given protective measure is small and becomes trivial on a per caput basis, there may be a tendency to select lower intervention levels than those resulting from a "linear" optimization.

238. The interplay of constraints and utilities will complicate the optimization assessment. There are, of course, formal techniques for optimization which take account of such considerations; in many cases, however, it may be sufficient to take account of these factors, where they are important, in a qualitative manner. Furthermore, when the net benefit from a remedial measure is relatively insensitive to the choice of intervention level, qualitative judgements as to the most appropriate choice of level are not only valid but almost inevitable.

239. Two final comments are necessary. First, it should be noted that the two illustrative examples are concerned with establishing the optimal levels for intervention, assuming intervention to be justified. In the practical process of determining intervention levels iteration will be necessary between the requirements of optimization and justification. However, the overriding requirement is the need to demonstrate that intervention is justified. Secondly, it will rarely be sufficient to adopt, automatically, the intervention level emerging from such a simple quantitative balance. A further important input would be an assessment of the sensitivity of the net benefit of the protective measure to the choice of intervention level; in this process account should be taken of the uncertainty in the various components in the balance and of the scope for different value judgements as to their respective importance. It should also be recognized that although a certain degree of pessimism can be tolerated when determining derived intervention levels for the short-lived radionuclides because of the relatively short period for which protective measures will need to be applied, this is not the case for longer-lived radionuclides, where the input factor, to optimization must be realistic if long-term unnecessary expenditure is to be avoided.

THE NEED FOR PRE-PLANNING

240. The basic principles underlying intervention imply that the level at which it is introduced may vary with the prevailing circumstances. Therefore, in establishing a practical scheme for intervention, flexibility must be maintained; it would be wrong to establish an intervention level that was to be used as a limit and applied irrespective of the circumstances. However, this need for flexibility should not be used as an argument against establishing intervention levels in advance, on grounds that the various balances (i.e., Equations 1 and 3) could be carried out on the day. Such an

approach would almost certainly be counter-productive, given the other pressures likely to be encountered in an accident situation. There is, therefore, an important role for pre-planning in the establishment of intervention levels or ranges of intervention levels for different protective measures. These can be established by prior analyses, of the type indicated in paras 206-235, for a wide range of plausible accident scenarios. These analyses would indicate the sensitivity of the intervention level to the significant variables and should enable generic levels, or at least generic ranges of levels, to be selected; values within these ranges could then be selected according to the circumstances of an accident should one occur. The importance of such pre-planning in ensuring the timely and effective introduction of protective measures in an accident cannot be overstated.

241. The use of a two-tier system as advocated in Safety Series No. 72, for formulating guidance on intervention has the conceptual and practical advantages of meeting the need for flexibility in emergency response while, at the same time, placing sensible constraints on it. The range between the upper and lower bounds of intervention is likely to vary in accordance with how specific the guidance is intended to be, increasing with the need for more generic application. Any revision of the quantitative guidance on intervention levels given in Safety Series No. 72 (see Section IV), when attempting to establish levels appropriate for international guidance, will need to take into consideration those levels which have been optimized and justified nationally. The upper and lower levels chosen for these purposes should provide a high degree of assurance that the intervention level would fall within the specified range if a detailed justification and optimization were performed for the circumstances of interest.

III. INTERVENTION LEVELS AND DOSE LIMITS

301. There has been much confusion over the role of dose limits in the establishment of intervention following an accident. Several factors have contributed to this confusion, not least the equality between some of the intervention levels of dose proposed [1,2] and the annual dose limits. Notwithstanding such equality, the two quantities are very different in principle, in their aims and how they are derived. These differences are discussed and it is important that they are recognized; failure to do so may lead to the use of dose limits in situations for which they are not appropriate and to the introduction of intervention that may not be in the best interests of those affected.

302. In an accident the sources of exposure are, by definition, not under control and therefore the system of dose limitation, recommended by ICRP [5] and incorporated into the IAEA Basic Safety Standards [6], does not apply. However, the principles underlying the system of dose limitation can form the basis for planning intervention in the event of an accident. In particular, two of the three components of the system, namely "justification" and "optimization" have important roles in aiding decisions on intervention; the third component, dose limits, is not, however, relevant. The aims of intervention levels are quite different from those of dose limits. The dose limits recommended by ICRP are meant to apply to the sum of the doses from a specified combination of sources, a combination which, among others, does not include exposures from nuclides present in the environment due to accidents. Intervention levels relate specifically to the course of action or protective measure being considered and, in the present context, concern solely the situation following an accident. The choice of intervention levels should, in principle, depend upon the circumstances of an accident although it may be possible to establish levels which are sufficiently robust for application in a wider range of circumstances.

303. One area where there has been much confusion over the role of dose limits in determining intervention has been the imposition of foodstuff restrictions in the longer term following an accident and at distances far from the release (e.g. the situation in Western Europe and elsewhere

post-Chernobyl). It has been argued that, because exposures from contaminated foodstuffs are controllable (i.e. by restricting their production or consumption), they should be subjected to the full system of dose limitation, including the application of the dose limits recommended by ICRP [5]. This, however, represents a misinterpretation of the intent of ICRP's recommendations [11].

304. The linear non-threshold assumption for the induction of stochastic health effects implies that a given increment of dose causes the same increment of risk, irrespective of previously accumulated doses or of future doses that might be incurred. It is, therefore, possible to stipulate limits for the dose from any defined combination of sources, corresponding to a risk from that combination of sources which one does not want to exceed. The dose limits recommended by the ICRP in Publication 26, and in additional statements, were meant to apply to the combination of sources stipulated in those documents, a combination which does not include radionuclides already present in the environment due to a previous accident, nor for that matter from any other source.

305. The situation with regard to the control of exposure from foodstuffs contaminated as a result of an accident is similar to some sources of natural radiation which are also excluded from the combination of sources to which the dose limits apply. Unlike controllable sources of radiation to which the dose limitation system applies, the detriment associated with these natural sources is not offset by any corresponding nett benefit. Intervention can only mitigate the problem and, at best, reduce the radiological component of the detriment to zero. ICRP [12] recognized that almost all exposures to natural sources of radiation are controllable to some extent but the degree of controllability varies very widely, as does the complexity, cost and inconvenience of the possible control measures. Controllability must, therefore, be a major consideration in determining the combination of sources to be included within any system of dose limitation. From this viewpoint, there is a clear difference between <u>existing</u> exposure situations (e.g. from radionuclides already present in the environment from whatever origin) where any control would involve intervention or remedial measures within that environment (i.e. either directly or on people) and <u>future</u> situations (e.g. effluents from nuclear installations) which can be subject to limitation and control during the design and planning stages. The full system of dose limitation can be more readily and effectively applied to sources in the

latter category with consequential implications for the combination of sources to which the dose limits are applied. This situation is exemplified in the different approaches recommended by ICRP to the control of radon exposures in dwellings. For existing dwellings dose reduction can only be achieved by remedial measures and guidance has been given on intervention levels. Exposure from future dwellings should be subject to the full system of dose limitation, albeit with a separate upper-bound of dose recommended for this particular source.

306. The same distinction applies to exposures from artifical radionuclides. For future situations, for example the limitation of exposures from effluents, control is exercised by pre-planning in the design and operation of the source of the effluent so that it is consistent with the system of dose limitation; on the contrary, for radionuclides already present in the environment, exposures can only be altered by taking remedial measures within that environment. As an aid to decisions on the introduction of such measures ICRP has recommended the use of intervention levels specific to the protective measure being considered. Such intervention levels, however, should not be determined, nor indeed overly influenced, by the existence of any limits intended for application to future situations, nor specifically, by the primary dose limits recommended by the ICRP for members of the public.

IV. QUANTITATIVE GUIDANCE IN SAFETY SERIES No. 72

401. The fundamental principle involved in deciding whether to introduce a remedial measure is that the cost and risk incurred by its introduction should be less than that of the radiation dose averted (see paras 203-207). It is clear that the risks, difficulties, disruption and distress that follow the implementation of various remedial measures will be widely different and thus the level of dose at which a given protective measure is introduced will be influenced by such factors. Indeed, even for a given remedial measure, considerable variation can be anticipated in these factors with attendant implications for the intervention level of dose. To be most effective the intervention level should be specific to the circumstances of interest. In some cases, however, it may be possible to establish intervention levels that are applicable to a wider range of circumstances, in particular where the level is relatively insensitive to plausible variations in the circumstances that may be encountered.

402. In both ICRP Publication 40 [1] and Safety Series No. 72 [2] emphasis is given to the importance of establishing intervention levels particular to the circumstances of interest and to the role of national authorities in this respect. Nevertheless, quantitative guidance on intervention levels was provided in both documents as an aid to national authorities in establishing their own particular levels. For a number of remedial measures, ranges of intervention levels were proposed; the lower level was intended to be indicative of a level of dose below which the introduction of the remedial measure was unlikely to be warranted and the upper level indicative of where implementation of the remedial measure should almost certainly have been attempted. A factor of ten separated the upper and lower levels of dose.

403. The availability of such quantitative guidance is helpful to those with responsibility for establishing intervention levels; it would be counterproductive, however, were it used directly to establish levels without having undertaken a proper analysis of the various factors particular to the circumstances of interest. The number of factors involved in the establishment of intervention levels, their inherent variability and the scope for differing judgements on the weight to be assigned to each are such that

intervention levels outside the ranges proposed [1,2] cannot be precluded; indeed, to a limited extent, they might be expected.

404. With a view to enhancing the usefulness of the quantitative guidance given in [1,2] there would be merit in investigating further its robustness, both in terms of the quantities specified and the numerical values that they were assigned. The bounds of the ranges of intervention levels judged likely to encompass most practical conditions are also susceptible, albeit to a lesser extent, to the factors previously identified and to judgements on the relative weights to be assigned to each. The increased attention given internationally to the selection and justification of intervention levels in the aftermath of Chernobyl makes this an opportune time to review and, if necessary, revise the quantitative guidance previously formulated. This would also enable the confidence attached to such guidance to be enhanced and, moreover, it would provide an opportunity to identify and explain more fully the different value judgements being made in the establishment of intervention levels in different countries. The identification of any differences in approach is the first step in attempting to reach a more harmonized approach in those areas where this is desirable and beneficial (e.g. international trade). Such a review is expected to form an important part of the revision of Safety Series No. 72.

405. Particular attention also needs to be given to the appropriateness of some of the quantities proposed for intervention levels in Safety Series No. 72. In particular, the quantities proposed for the intermediate phase appear to be too inflexible for general use. Because of the extremely wide temporal variation in dose that might be encountered depending on, among other matters, the nuclide composition of a release, quantities other than the dose in the first year (or committed from intakes in the first year) will be required. A closer link needs to be maintained between the temporal pattern of the dose and the duration of the protective measure. It is beyond the scope of this report to review the merits of alternative approaches or quantities; however, it is already apparent that a quantity such as dose rate may be more appropriate and generally applicable for judging when relocation is implemented and/or removed. Similarly, a primary intervention level expressed in terms of nuclide concentrations in foodstuffs may be a more practical and appropriate means of establishing optimal control. These matters require more detailed consideration, however, than is possible here with a view to enhancing the usefulness and applicability of any quantitative guidance.

V. DERIVED INTERVENTION LEVELS — CLARIFICATION AND AMPLIFICATION OF THE GUIDANCE GIVEN IN SAFETY SERIES No. 81

GENERAL

501. The principles and procedures for estimating Derived Intervention Levels (DILs) were set out in Safety Series No. 81 [3]. The importance of DILs being realistic surrogates for intervention levels was recognized in Safety Series No. 81, as were the constraints this placed on the estimation of universally applicable DILs (i.e. due to the potentially wide variation in the values of many of the parameters which influence DILs with the particular circumstances of the accidental release and the local environmental conditions). Notwithstanding these limitations, quantitative guidance was given in Safety Series No. 81 for DILs for potentially significant nuclides in a range of environmental materials. The DILs were established to correspond with the quantitative guidance given in Safety Series No. 72 on intervention levels (but see qualification of this guidance in Section IV of this report). Each DIL was qualified with respect to the extent to which it might find general application or need to be re-estimated on a case by case basis.

502. Following the publication of Safety Series No. 81, and in the light of international experience post-Chernobyl in the estimation and use of DILs, it has become apparent that a number of issues in Safety Series No. 81 warrant either re-emphasis or clarification and amplification. These aspects are addressed together with a number of topics which may warrant further attention in the future in order to enhance the usefulness of the guidance on DILs.

Realism and compromise in establishing DILs

503. The models and data used to establish DILs should be realistic and particular to the circumstances under consideration. They should avoid the incorporation of undue pessimism as this may compromise the underlying objective of intervention which is to introduce protective measures which have a net benefit to the individuals involved. At a local/national level such realism should not be difficult to achieve. Significant differences may, however, occur between DILs in different countries/regions because of differences in habits and environmental conditions.

504. Some sacrifice of realism may be justified in the interests of achieving some degree of regional or international harmonisation in the choice of DILs or in establishing a scheme for intervention that is presentationally simple and readily applicable. In the former case any DILs would, among other factors, need to accommodate different national practices with regard to diet. In the latter case it may be convenient to establish DILs applicable to broad categories of foodstuffs and nuclides, with the loss of precision that this introduces being compensated by the advantages of a more practicable scheme. An important input to reaching a more harmonized approach internationally is to review the technical factors incorporated into DILs established in various Member States and identify the sources of any differences. A review carried out by NEA following the Chernobyl accident indicates that both technical and socio-political considerations contributed to the differences in the DILs adopted by Member States. In seeking a more harmonized approach (at least on radiological protection grounds) due weight would need to be given to the respective realism/pessimism of the various DILs. It would be inappropriate to adopt undue pessimisms in the technical evaluation of DILs intended for broader application. It is recognized, however, that some compromise may be necessary, for other than technical reasons, in the interests of international accord. This aspect is addressed further in Section VI in the context of harmonisation of international trade.

BASIS OF QUANTITATIVE GUIDANCE IN SAFETY SERIES NO. 81 AND LIMITATIONS ON ITS APPLICABILITY

505. The DILs established in Safety Series No. 81 were derived mainly in the context of intervention at a local/national level. For application to the control of international trade in foodstuffs, other broader considerations would need to be taken into account (e.g. fraction of food imported, variation in the nature of the contamination of imported food, harmonisation of trade, etc.) and these may be sufficiently important to preclude the DILs in Safety Series No. 81 being used for this purpose (see Section VI).

Pessimisms in quantitative DILs given in Safety Series No. 81

506. The DILs in Safety Series No. 81 were all derived assuming the annual intake of a given foodstuff to have been initially contaminated at the same level. This assumption is potentially very pessimistic and takes no account of contributions to diet arising from a much wider area and at very different

levels of contamination. Further consideration should be given to the potential for adopting a more realistic approach. Data on dietary practices being collected by the Food and Agriculture Organization, the World Health Organization, and in a number of Member States, should be useful in this respect.

Quantities for expressing DILs

507. DILs for foodstuffs have often been expressed in terms of peak concentrations and have been derived using models to determine the relationship between the peak concentration to the integrated concentration over a given period. Further consideration needs to be given to

- the robustness of the models for application to the wide range of conditions in which DILs are often applied

- whether there is a more appropriate and practical basis for expressing derived intervention levels than peak concentrations (e.g. levels which apply irrespective of the time at which they occur - see paras 230-235).

INTERVENTION LEVELS FOR INGESTION

508. There is some ambiguity in the intervention levels recommended for the banning of foodstuffs given in Safety Series No. 72 and ICRP Publication 40; in particular, whether the levels are intended to refer to the summated dose from the intake of all foodstuffs or to one particular category of food for which a given protective measure is being considered. In principle, an intervention level of dose is required for each food category, because the choice of level must reflect the costs, difficulties, etc. of restrictions which may differ significantly with the foodstuff considered; the intervention levels proposed in [1,2] should, therefore, be interpreted in this context. When developing the recommendations it was recognised that the adoption of this approach may require national authorities to specify an upper bound to the summated dose from ingestion to prevent the possibility of unacceptably high levels of individual risk from ingestion; in practice, however, this is unlikely to be necessary as practical schemes for intervention are likely to group foodstuffs into only a few broad categories,

with a similar approach being followed for grouping nuclides [3]. In Safety Series No. 81, DILs are estimated for an assumed intervention level of 5mSv for each separate food category.

509. More generally, however, it should be recognized that the procedure to be adopted in establishing DILs for foodstuffs is inextricably linked to how the intervention level of dose was established. If the intervention level of dose was established for application to individual categories of food (e.g. milk, green vegetables, etc.) then DILs should be estimated for application to those individual categories.

Categorization of foods for the purposes of establishing DILs

510. The optimum categorisation of foods for the purposes of establishing DILs should be reviewed. A balance will need to be achieved between the conflicting requirements of a large number of subdivisions, in the interests of ensuring a realistic approach, and a much smaller number dictated by the availability of data on dietary habits and the desire for a simple practicable scheme of intervention.

INTERVENTION AND DILs FOR OTHER REMEDIAL MEASURES

511. Guidance could usefully be developed on intervention and derived intervention levels for a number of remedial measures not specifically addressed in Safety Series Nos. 72 and 81. The potentially more important which warrant further consideration in this context include:

- decontamination of clothing,
- decontamination of buildings,
- decontamination of roads,
- decontamination of land,
- control of contaminated livestock,
- decontamination of vehicles,
- discarding contaminated foodstuffs,
- prohibiting the use of contaminated biosphere products, e.g. for soil improvement, fertilisation, combustion, etc.,
- reclamation of agricultural and forestry land.

Metabolic and dosimetric models

512. The guidance given in Safety Series No. 81 on metabolic and dosimetric models (i.e. dose per unit intake) for members of the public will need to be re-assessed following the completion of the ICRP review of this topic.

VI. HARMONIZATION FOR INTERNATIONAL TRADE IN FOODSTUFFS

GENERAL

601. As a result of a major nuclear accident all countries may eventually be affected, to varying degrees, by the atmospheric transport of radioactive materials. The impact will of course vary over many orders of magnitude depending on the amount of material released, distance and the meteorological conditions at the time. In those countries where the greatest effects are experienced, local protective measures may need to be introduced in order to protect those individuals, or larger population groups, most at risk. In those countries where no such direct intervention is necessary, consideration still has to be given to assuring a proper level of protection in respect of goods and materials imported from countries more directly affected. Although all countries have recognized the need for appropriate constraints in this area, there has been no international agreement on the standards to be adopted. The absence of such a harmonized approach following the Chernobyl accident led to considerable confusion among the international community, loss of public confidence and the erection of artificial barriers to trade.

602. Guidance is, therefore, needed upon which to base an internationally harmonized approach to the trading problems which might arise in the event of a future accident. The basic principles underlying intervention are set out and amplified in paras 203-219 and these should form the basis for reaching a harmonized approach. The principles are equally applicable to determining intervention on a local, regional or international scale. The values and weights to be assigned to the respective components in judging whether intervention is both justified and optimal (see Equations 1 and 3, paras 207 and 217) will differ, however, in the various cases. Consequently, it should not be surprising if intervention levels for application on a local scale differ from those established in the context of international trade.

603. Several factors will contribute to these differences. Some have already been identified (see paras 230-239 and 501-503) and, together with others, are discussed further here. Before addressing differences that might arise between intervention levels established for local or international

application it is relevant, first, to summarize the potential origins of differences that might arise between levels established in various countries for application to locally produced foodstuffs.

REASONS FOR DIFFERENT FOOD DILs

604. Subject to the assumption that intervention levels in various countries have been established in accordance with the basic principles of justification and optimization, then any differences must reflect different values or weights assigned to the parameters in Equation 1. For intervention of foodstuffs only two of the components in Equation 1 are in general significant, the costs of the radiation detriment and those of the remedial measures. Subject to the assumption, among others, that the cost of the radiation detriment is linearly proportional to the collective dose, it has been shown (paras 230-234) that the intervention level, expressed in terms of a nuclide concentration in a given foodstuff, may be relatively insensitive to geographical location. The adoption of other assumptions and/or the inclusion of factors excluded from the deliberately simplified presentation in paras 230-234 may, however, lead to greater variation. Some of the potentially more significant factors that could contribute to different choices of intervention level include:

- the relationship assumed between detriment cost and dose; the assumption of a linear relationship between cost and collective dose may have a different outcome to weighting the cost according to the levels of individual dose which comprise the collective dose;

- the application of different weights to the detriment costs and the costs of the protective measure due to different groups in the population having to bear the respective risks and costs (see paras 235 and 237-239);

- the inclusion in the detriment cost of health impacts not directly attributable to the radiation exposure (e.g. anxiety); and

- the inclusion of other tangible costs of introducing foodstuff restrictions (the direct cost of the lost produce was the only component considered in the simplified example in paras 230-236), for example, the costs of disposal of contaminated produce, the costs of implementing the control system, etc.).

Perhaps the most important potential source of difference, however, is the inclusion and weight given to factors of a socio-political nature which are somewhat less tangible than those listed above. For example, there may be pressures to introduce intervention in response to a perceived risk by the public, even when the actual level of risk and the cost of avoiding it would, in itself, not justify intervention; similarly, there may be pressures to maintain doses beneath existing dose limits, or some other prescribed limits developed for totally different purposes, despite this being wrong in principle (see paras 301-306) and possibly counterproductive. Many factors of this type would need to be assigned negative costs in the quantity, X, the cost of the protective measures in Equation 1 (para 207) and their inclusion would often result in the adoption of lower levels of intervention than would otherwise occur; situations can be envisaged, however, where the effect would be in the opposite direction. Clearly, the inclusion of such factors, even qualitatively, can have an important and potentially overriding influence on whether a given intervention is judged to be justified and optimal.

REQUIREMENTS FOR INTERNATIONAL TRADE

605. The potential for divergence between intervention levels becomes even greater in the context of international trade. This is most easily illustrated by reference to two distinct situations, one in which foodstuffs in a given country have been contaminated as a direct result of an accident (not necessarily occurring in that country) and the other where a country has not been directly affected but may be, indirectly, by the import of contaminated produce. In the country directly affected it is legitimate to balance the costs of the lost produce, of disposal and of implementing the control measures, against those of the radiation detriment averted when establishing intervention levels. In the second case it could be argued that only the marginal costs of securing alternative uncontaminated (or less contaminated) food supplies would be the appropriate quantity to balance against the radiation detriment averted, provided the costs of implementing the necessary controls were small by comparison. In many cases these marginal costs would be small in comparison with the overall cost of the foodstuff; consequently, very much lower intervention levels than would be deemed appropriate in those countries directly contaminated may ensue. There may be exceptions to this generalization, for example, when the foodstuffs are supplied through a national or international aid programme or for famine relief (e.g. where the absence of an alternative food supply would result in

severe hardship or starvation). The potential for very wide variation in the choice of level is, nevertheless, apparent.

606. One essential consideration, however, is missing from the above discussion and it concerns the influence on international trade of various countries adopting different, or unduly low, levels for intervention. The adoption of widely different levels would greatly complicate and potentially severely disrupt international trade in foodstuffs to the probable detriment of all concerned. Equally, the adoption of unduly low levels in some countries may incur very large costs, merely to implement the control measures necessary to ensure compliance; moreover, they may provoke retaliatory measures in the trading of other goods or services. Costs, albeit some of which may be difficult to quantify, will be associated with each of these issues and they need to be included in the balancing process (see Equation 1, para 207) when determining whether intervention is justified and, if so, at what level. When these aspects are properly included in the balance the potentially large divergence in the choice of intervention levels for the purposes of international trade, as indicated by the somewhat constrained analyses described in para 605, should be greatly reduced.

BENEFITS OF HARMONIZATION

607. The benefits of an internationally harmonized approach in this area are obviously considerable. The difficulties consequent upon the absence of an agreed approach were amply demonstrated immediately following the accident at Chernobyl and, to a lesser extent, still exist more than two years later. The achievement of a harmonized approach, however, will not be easy, given the many inter-related, and sometimes conflicting factors involved, in particular those of a socio-political nature. Recognition of the complex interplay between the many factors involved, however, is the first step towards successfully resolving the problem. The formulation of the significant factors involved in reaching a harmonized approach and an analysis of their influence on the choice of intervention level (including sensitivity analyses) would provide a valuable input to making further progress in this area and is essential if the confusion and difficulties associated with international trade in potentially contaminated foodstuffs, such as followed the Chernobyl accident, are to be avoided in the event of any future large scale accidental release of radioactive materials.

VII. MISCELLANEOUS

SELECTION OF INDIVIDUAL HABITS WHEN ESTABLISHING INTERVENTION LEVELS

701. In practice, protective measures will often be applied to groups in the population whose characteristics such as age, sex, state of health, etc. will be similar to those in the more general population. In principle, because the aim of protective measures is to achieve a net benefit among the group affected, it would be most appropriate to assume habits that are broadly representative (e.g. average) of the whole group when establishing and applying intervention levels. The assumption of habits typical of more extreme members of the affected group would distort the overall balance being attempted between the radiation risk averted and the risk and cost consequent upon the protective measure; the inevitable outcome of such an approach would be that the overall risk and/or cost to which the affected group would be exposed would be higher than it need have been.

702. There may, however, be some exceptions to this generalization. First, where intervention is being introduced to avoid non-stochastic effects, it will be necessary to establish intervention levels based on the habits of the more extreme members of the population group. In general, however, this will rarely be of practical concern because intervention is likely to be introduced, or attempted at levels significantly below those for which non-stochastic effects become significant. Second, the choice of average habits will only remain reasonable provided the variation in risk (both that associated with the exposure and the protective measure) within the affected group is not too great. For example, there may be individuals within an affected group who may receive much higher doses than the average because of their particular characteristics or habits (e.g. ingestion or inhalation of iodine isotopes by infants, individuals with much higher than average dietary intake). In addition, some individuals may be more radiosensitive than others (e.g. foetus, thyroid cancer in children and in some ethnic groups). On the other hand, there may be sub-groups that are at greater risk from the implementation of a given protective measure (e.g. evacuation of the infirm or handicapped).

703. In establishing intervention levels for application to general groups in the population, it will be necessary, therefore, to ensure that the variation in the overall risk within the affected group is not too great. Where it is, consideration should be given to the establishment of intervention levels for particular sub-groups in a population and to the introduction of protective measures in a differential manner. Examples of where such an approach might be warranted are the exposure of pregnant women (in particular, because of the relatively high risk of mental retardation consequent upon foetal exposure during specific periods of its development), the consumption of milk by children especially when contaminated by radioiodines, the evacuation of the old or the infirm, and the relocation of employed people from premises in which work of very high commercial or strategic value is being undertaken. The potential difficulties of introducing protective measures selectively into a general population should not, however, be underestimated (e.g. selective evacuation of individual members of a family group) and in some cases they may be sufficient to preclude such a course of action.

CLARIFICATION OF QUANTITIES

704. The quantities proposed for intervention levels in Safety Series No. 72 require clarification in the following respects.

(a) Various conventions can be adopted for the specification of intervention levels of dose and the doses to be evaluated for comparison with them; what is imperative is that a consistent approach is adopted in the estimation of both quantities. The following is one of a number of possible satisfactory conventions:

> where an intervention level has been established principally to avoid non-stochastic health effects, the intervention level is the projected dose in the absence of the protective measure; both the intervention level and the dose being compared with it must be relevant to the health effect being considered, with due account being taken of the influence of the temporal pattern of dose on the risk of non-stochastic effects [13, 14].

- where the intervention level has been established on the basis of reducing the risk of stochastic health effects, the dose to be compared with the intervention level is that fraction of the projected dose averted by the introduction of the protective measure. The exposure from all pathways influenced by the protective measure should be included.

(b) No quantification is provided for the expression "short term" in para 1009 of Safety Series No. 72. In the absence of other overriding considerations, a time of about one week is suggested.

(c) In Safety Series No. 72, intervention levels of dose are expressed in terms of whole body, effective and single organ doses. Provided that exposures are within the stochastic range then, for practical purposes, it will generally be sufficient to establish intervention levels in terms of whole body/effective dose equivalents, and in addition, single organ doses for the skin and thyroid. The skin requires separate consideration because it is not normally included in the quantity, effective dose, yet its exposure is associated with a risk of skin cancer. The thyroid requires separate consideration because effective dose only takes account of the fatal cancer component of the risk of thyroid exposure which is small in comparison with the risk of cancer incidence.

(d) The quantities specified in Safety Series No. 72 for intervention levels of dose are probably too inflexible for general application and further consideration needs to be given to the identification of more appropriate and generally applicable quantities (see para 405).

GROUPS SUBJECTED TO ENHANCED EXPOSURES BY THE NATURE OF THEIR WORK

705. Following an accidental release of radioactive material into the environment there may be groups of individuals subjected to enhanced exposure due to the nature of their work. This may arise in different ways, for example handling contaminated materials or equipment or performing tasks which mobilize or concentrate the radionuclide contaminant. These situations may arise in various occupations, for example agricultural activities on

contaminated land, urban waste handling, sewage treatment, maintenance of air-conditioning systems and replacement of filters, grass harvesting and fodder storage, etc.

706. While these exposures occur during the course of work, they do not arise from controlled sources and should not be considered as "occupational exposures to be controlled within the system of dose limitation". In this respect they are similar to exposure to radon decay products during work in existing buildings. In both cases one is confronted with a situation where radionuclides are found to be present in the environment and any required restriction of doses can only be achieved by some remedial measures in that environment.

707. The number of occupational situations where such enhanced exposures may occur is potentially quite large and it is difficult to predetermine in any detailed way what remedial measures would be applicable in the wide variety of different conditions that may be encountered. Intervention levels can only be sensibly specified once the possible remedial measures and particular circumstances of the exposure are established.

708. For these reasons, competent authorities may find it convenient to eatablish investigation levels as a basis for screening the various activities with a view to identifying those where further consideration is warranted. Those falling above the screening level would be subjected to more detailed analysis to determine whether remedial measures were practicable and/or justified after which appropriate intervention levels could be established for generic application to like activities. A compilation of the types of activity that might warrant screening would also be helpful.

709. Further guidance would also be useful on limiting doses to non-radiation workers who may be involved in the response to an accident (e.g. policemen, firemen, drivers of vehicles used for evacuation, etc.).

ADDITIVITY OF DOSES FOR COMPARISON WITH INTERVENTION LEVELS IN THE EVENT OF MULTIPLE ACCIDENTS

710. There is a need for further guidance and clarification on the account to be taken of exposures from other sources when determining intervention. It is conceivable, but extremely unlikely, that more than one accident might

significantly contaminate the same environment within the same time frame. In the unlikely event that such a situation occurred, the summated exposures from all the accidents should be considered together and not separately when deciding upon whether intervention was both justified and optimal. In practice, when intervention is implemented on the basis of a comparison of the measured levels in the environment with Derived Intervention Levels, then account would automatically be taken of all significant contributors to exposure.

711. In principle, in determining intervention, account should be taken of the net reduction in exposure summated over all sources as a result of applying the remedial measure. In practice, only the exposure consequent upon the accident will, in general, be significant but there may be special cases where this may not be so (e.g. areas with high residual levels of weapons fall-out).

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LIST OF PARTICIPANTS

Advisory Group Meeting to Review Intervention Levels
for Application in the Event of a Major Accident
Vienna, 2-6 February 1987

Bengtsson, G.	National Institute of Radiation Protection Stockholm
Beninson, D. (Chairman)	Comision Nacional de Energia Atomica Argentina
Clarke, R.	National Radiological Protection Board United Kingdom
Collins, H.E.	International Atomic Energy Agency Vienna
Emmerson, B.W. (Scientific Secretary)	International Atomic Energy Agency Vienna
Ilari, O.	OECD Nuclear Energy Agency France
Kelly, N. (Consultant)	Central Electricity Generation Board United Kingdom
Lange, J.	Bundesministerium f. Umwelt-, Naturschutz und Reaktorsicherheit Federal Republic of Germany
Linsley, G.	International Atomic Energy Agency Vienna
Logsdon, J.	U.S. Environmental Protection Agency United States of America
Luykx, F.	Commission of the European Communities Luxembourg
Meekings, G.S.	Ministry of Agriculture, Fisheries and Food United Kingdom
Nenot, J.C.	Centre d'Etudes Nucleaires France
Pretre, S.	Swiss Federal Office of Energy Switzerland
Richardson, A.	U.S. Environmental Protection Agency United States of America

Riedler,	Institut f. Strahlenhygiene Federal Republic of Germany
Rubery, E.	Dept. of Health and Social Security United Kingdom
Salo, A.	International Atomic Energy Agency Vienna
Sigurbjoernsson, B.	International Atomic Energy Agency Vienna
Suga, S.	Japan Atomic Energy Research Institute Japan
Sztanyik, L.	National Research Institute for Radiobiology and Radiohygiene Hungary
Waight, P.J.	World Health Organisation Switzerland
Wei, L.	China National Centre for Preventive Medicine People's Republic of China
Xue, W.	Permanent Mission of the People's Republic of China to the International Atomic Energy Agency Vienna

Consultants Meeting to Prepare Draft of
Agency TECDOC Publication on Review of Safety Series No. 72
Vienna, 20-24 July 1987

Beninson, D.	Comision Nacional de Energia Atomica Argentina
Emmerson, B.W. (Scientific Secretary)	International Atomic Energy Agency Vienna
Kelly, N.	Central Electricity Generation Board United Kingdom

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