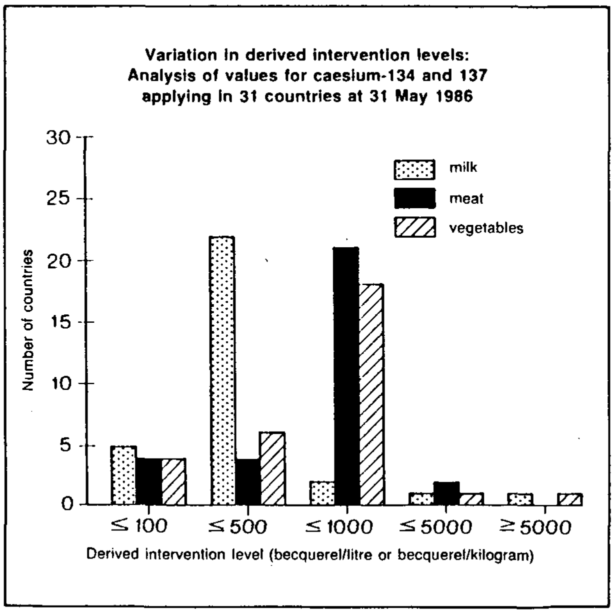
Intervening for the protection of the public following a nuclear accident

Controlling the distribution and consumption of contaminated food

by B.W. Emmerson

Before the explosion that destroyed Unit 4 of the Chernobyl nuclear power plant on 26 April 1986, the type of accident that could readily disperse 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 published international emergency response guidance or national emergency planning arrangements. They had concentrated, primarily, on responding to relatively short accidental releases of radioactive materials from nuclear facilities at specific locations within a country's borders, rather than to the transboundary consequences of contaminants originating from outside the country. Emphasis was on the provision of urgent measures in the early stages of an accident for protecting the public within the immediately affected area and out to relatively short distances from the point of release, the particular concern being the avoidance of non-stochastic effects and limiting the risk from stochastic effects for those individuals who may be exposed.* Additional measures that might need to be implemented when faced with a prolonged release of radioactive materials, dispersing over long distances and having a potential effect over large areas, had not been addressed in any detail.

The response of national authorities to the Chernobyl release varied widely, ranging from a simple reinforcement of existing environmental monitoring programmes to the banning of specified foodstuffs. *(See accompanying table.)* Undoubtedly, much additional anxiety and unnecessary confusion were caused by the differences between the protective measures that were introduced within and between countries, and a lack of consistent and understandable advice to the public (especially on the potential contamination of food and the environment, and any resultant radiation doses and effects).



Two major contributors to that confusion can be identified. They stem from an inconsistent approach in interpreting and applying the basic criteria that have been developed for the radiation protection of the public. The first was a failure to distinguish between the criteria that apply for normal situations, in which the source of exposure is fully under control, and the different criteria that apply in accident situations. The second was a failure to distinguish between the contamination control levels developed for protecting identified food consumer groups, and the more generic and conservative levels considered necessary for exercising overall control on foodstuffs moving in international trade, where the emphasis is on avoiding any unnecessary trade disruption. These two contributory factors are reviewed here with the objective of providing a better understanding of the radiation protection philosophy involved.

Mr Emmerson is a senior staff member in the IAEA Divison of Nuclear Safety.

* Non-stochastic effects are those which may occur above a particular threshold level, after which the severity of the effect increases as the dose increases. Stochastic effects are those for which the likelihood of their occurrence increases as the dose increases, without threshold; their severity does not depend upon the level of the dose.

To avoid future repetition of this confusion, the relevant international organizations having responsibilities for emergency response guidance have worked in close co-operation to review the adequacy of their recommendations, develop further guidance where necessary, and seek an agreed international approach to the establishment of criteria for controlling the consumption, or movement in international trade, of potentially contaminated foodstuffs. Considerable progress has been achieved in the past 2 years and an account of the actions taken by these organizations and their current recommendations was presented at the April 1988 IAEA International Conference on Radiation Protection in Nuclear Energy in Sydney, Australia.*

The basis for control

Radiation protection guidance provided by relevant international organizations, including the IAEA, is based on the recommendations of the International Commission on Radiological Protection (ICRP). Its general recommendations are set out in ICRP Publication 26.** They recognize two quite distinct conditions relating to the control of radiation exposure. The first concerns those exposures that can be foreseen and limited by imposing some form of control on the source of the radiation from which the exposure results. For these *planned* situations the three key elements of the Commission's system of dose limitation must be satisfied, namely:

- no practice that would involve exposure to a source of radiation should be adopted unless it can be shown that after weighing the benefits to be gained by its introduction against the associated disadvantages that would be incurred (including any detriment to health), the practice would result in a positive net benefit (the exposure must be justified);
- all exposures incurred as the result of the practice must be kept as low as reasonably achievable (ALARA), taking into account any relevant economic and social factors (the exposures must be optimized); and
- the Commission's recommended dose limits must not be exceeded.

To satisfy the requirements of the dose limitation system, appropriate nuclear safety and radiation protection features are incorporated into the plant design. These operate on the concept of defense in depth and are capable of anticipating and compensating for human errors, equipment malfunctions, and extreme natural phenomena. They are supported by formal rules and procedures that govern normal plant operation and provide for appropriate response to abnormal or accident situations.

The second condition relates to those situations in which the source of the exposure is not subject to control; for example, sources associated with natural background radiation, radon in buildings, and accident situations. For these *unplanned* situations, the potential for exposure can only be limited, if at all, by imposing some form of external intervention action. The concept of the ICRP dose limitation system is not applicable, although two of its three components, *justification* and *optimization,* can be used as an aid in post-accident intervention decisions. The third component, *dose limits*, is not relevant as the ICRP limits are intended to apply to the sum of the doses from a prescribed combination of planned/controlled exposure situations and cannot, therefore, include exposure from radioactive sources present in the environment over which there is no control. Furthermore, the dose limits recommended by ICRP for members of the public for controlled situations are set at a low degree of risk and would need to be exceeded by a considerable amount before becoming of radiological concern.

In large accidents involving the release of significant quantities of radioactive material to the environment, direct intervention measures to limit the risk to individuals, such as sheltering, provision of stable iodine, evacuation, and relocation, are unlikely to be justified beyond relatively short distances from the release point, probably not more than a few tens of kilometres. Conversely, because the released radioactive material will be diluted in the atmosphere and may ~~be subsequently dispersed over wide areas, the major~~ part of the collective dose to populations (i.e. the sum of the individual doses in a population) resulting from an accident will, in general, be accumulated out to much greater distances, as in the case of the Chernobyl accident. Although at these distances any dose incurred by individuals will be substantially below that of concern for non-stochastic effects or for significant individual stochastic risk, those countries that lie along the route of the dispersed radioactive material may still consider it prudent to reduce the collective dose to their populations through the introduction of less direct protective measures such as controlling the distribution or consumption of contaminated foodstuffs or drinking water.

The fundamental difference between the two conditions for exposure is that in the planned situation, the source of radiation is not permitted unless its presence will result in an overall benefit for society, whereas in the unplanned or accident situation, society derives no net benefit from the source of exposure and any intervention to mitigate the problem can, at best, only reduce the associated dose to zero. Thus, in the planned situation, optimization is used to achieve the maximum net benefit to society, whereas in the unplanned situation, optimization is applied to ensure the lowest net societal detriment.

* See "The development of intervention levels for the protection of the public in the event of a major nuclear accident — past, present and future", by B.W. Emmerson, *Proceedings of the international conference on radiation protection in nuclear energy,* Sydney, April 1988, IAEA (to be published).

** *Recommendations of the International Commission on Radiological Protection,* ICRP Publication 26, Pergamon Press, Oxford and New York (1977).

Principles of post-accident intervention

The basic principles developed by the ICRP for planning intervention action following an accident are:

- appropriate protective measures should be introduced to keep individual doses below the threshold for serious non-stochastic effects;
- protective measures should also be introduced to reduce the individual risk from stochastic effects, provided that after taking into account the alternative risks and costs associated with their introduction, the measures will result in an overall benefit to those to whom they apply; and
- the collective dose to the exposed populations should be reduced as far as is reasonably practicable, in order to limit the total number of stochastic effects.

The first two principles are concerned with the introduction of direct measures for the protection of individuals or groups of individuals. Their application tends to be limited to the earlier stages of an accident and out to relatively short distances from the point of release. The third principle is not concerned with individuals, but with the introduction of measures for reducing the collective dose, thereby limiting the overall incidence of stochastic effects in the population as a whole.

The nature of the measures taken to protect the public and the timing of their introduction will depend upon the potential (projected) risk to those individuals who would be exposed if the protective measures were not introduced, and on the prevailing circumstances (time of day, weather conditions, etc.) in the area to which the measures would apply. The specific levels of risk at which particular protective measures may need to be introduced are usually specified in terms of their equivalent radiation dose, normally expressed in terms of millisieverts (mSv). These values are commonly referred to as the *intervention levels of dose.** Because the introduction of any protective measure will, in itself, involve some degree of risk, difficulty, and societal cost that will vary with circumstance, it is not possible to set a fixed level of dose at which a specific measure should be introduced. On radiological grounds, however, it is possible to define, for each protective measure, a lower level of dose below which the introduction of the measure would not be warranted, and an upper level at which its implementation should almost certainly have been attempted.

In practice, decision-making in an emergency will be more rapid and effective if the intervention levels of dose are expressed in terms of the measured levels, or concentrations, of the radionuclides present in the materials of concern; for example, becquerels per cubic metre (of air) or per litre (of milk) or per kilogram of a particular food category (milk powder, meat, etc.). These are termed *derived intervention levels* and the annual consumption of foodstuffs contaminated at these levels should not result in radiation doses for the consumer group of concern exceeding the primary intervention level of dose.*

The relationship between the derived intervention level for a particular foodstuff and the intervention level of dose (sometimes referred to as the dose conversion factor) will depend on many parameters. Among the more important are the dietary habits of the potentially exposed individuals, the physical and chemical form of the released radioactive material, its metabolism when taken into the body, and the resultant radiation dose to the various body organs per unit intake of the particular radionuclides concerned. Agricultural practices and methods adopted in food preparation and processing can also have a significant influence. Provided the parameters that make up the dose conversion factor can be quantified, derived intervention levels can, in principle, be determined for the range of radionuclides that could be of radiological importance following a nuclear accident. To be of greatest value, the derived levels should be specific to the circumstances of the particular accidental release, the local environmental conditions, and the population to which they will apply.

Because of the potentially wide variation in many of these parameters, it is not possible to determine universally applicable derived intervention levels for every type of foodstuff. However, by conservatively grouping these variations, there may be sufficient common ground to enable generic levels to be developed for a broader application.

A major contribution to the collective dose following the widespread dispersion of radioactive material and its entry into the various food pathways will be from the consumption of contaminated foodstuffs. Even though the level of contamination in a particular food category may be well below that of concern for the individual consumer, the extent of the collective dose resulting from the consumption of the food by the population as a whole might, in itself, be considered as unacceptable. The distribution and consumption of contaminated foodstuffs therefore must be controlled to satisfy two key radiation protection criteria: reducing the risk to the individual, and minimizing the total societal detriment.

Controlling contaminated foods

Guidance provided by the ICRP indicates that measures to restrict the distribution of foodstuffs should be considered if the dose to individual consumers could otherwise exceed 5 mSv as a result of consumption during the first year following an accident.**

* Sometimes referred to as emergency reference levels (ERLs) or protective action guides (PAGs).

* The Agency has given guidance on the principles for establishing these intervention and derived intervention levels in its *Safety Series* publications Nos. 72 and 81. Additional interim guidance, considering the experience gained as a result of the Chernobyl accident, has been published in IAEA TECDOC 473.

** *Protection of the public in the event of major radiation accidents: principles for planning,* ICRP Publication 40, Pergamon Press, Oxford and New York (1984).

This represents a notional lifetime risk for the average individual of 1 in 10 000. It may be compared with the level of risk from another imposed, and widespread source of environmental exposure — radon in houses. The ICRP has recommended that simple and non-intrusive remedial measures should be introduced where the annual dose incurred from radon exposure exceeds 20 mSv; it should be also noted that the annual exposure to natural background radiation can result in doses between 1 and 10 mSv. An intervention level of 5 mSv is, therefore, comparable with the range in annual dose due to natural sources of radiation.

Sole reliance on a fixed value (e.g., 5 mSv in a year) as the intervention criterion could be open to criticism on grounds that, although ensuring an adequate control of the individual risk, it makes no allowance for the overall detriment to society. This societal detriment, which depends upon the total number of persons exposed and, hence, the collective dose, will become increasingly dominant as the distance from the release point increases and the influence of the individual dose criterion decreases. Restriction of the societal detriment to a level at which no further reduction would be warranted can be achieved by applying the concept of cost-benefit optimization analysis. At the optimum level, the cost of the intervention is balanced by the cost of the *health* detriment avoided. The purpose is to show that the exposed population is put in a "better" position by adopting the intervention measure than by not intervening, in that a lower overall detriment to society is achieved at a "reasonable" cost in economic and social terms. In practice, the optimum intervention level of dose is usually found to lie between 1 and 10 mSv. The maximum value obtained through this optimization procedure should, nevertheless, be constrained by the *individual* intervention level of dose (5 mSv) since this level would be exceeded only if there were overriding societal or humanitarian reasons.

The World Health Organization (WHO) and the United Nations Food and Agricultural Organization (FAO) have been principally concerned in the development of specific guidance on the distribution and consumption of contaminated foodstuffs. When implementing this guidance, it is essential to distinguish between those levels that have been established as a basis for controlling the food consumption for particular groups of individuals or populations to minimize their health detriment, and the more conservative levels developed for generic application to minimize disruptions in international trade. These are referred to here as *consumer-related* and *trade-related* levels.

● ***Consumer-related levels.*** As a result of the Chernobyl accident, and recognition that the available guidelines on post-accident management did not cover adequately the measures needed to protect populations in areas far removed from the accident site, WHO (as the lead international organization on health) undertook to develop and publish appropriate guidance. Through a series of international expert meetings, it reviewed various approaches for setting consumer-related derived intervention levels for foodstuffs and drinking water, and prepared draft guidelines for their application. These were circulated to national governments for comment and subsequently published in May 1988.* The WHO guidelines and associated derived intervention levels are aimed at assisting public health decision makers who are not specialists in radiation protection to exercise responsible judgement. They are considered to be of particular use to countries that do not have a nuclear power programme and have not developed expertise in the intervention area. The WHO derived

* *Derived intervention levels for radionuclides in food; guidelines for application after widespread radioactive contamination resulting from a major radiation accident,* WHO, Geneva (1988).

WHO guideline values for derived intervention levels in foodstuffs (becquerels per kilogram)

Class of radionuclide	Food categories							
	Cereals	Roots & tubers	Vegetables	Fruit	Meat	Milk	Fish	Drinking water
* High dose per unit intake factor (10^{-6} sievert/becquerel)	35	50	80	70	100	45	350	7
**Low dose per unit intake factor 10^{-8} sievert/becquerel)	3500	5000	8000	7000	10 000	4500	35 000	700

* Applies to plutonium-239 and other actinides.

**Applies to all other radionuclides of interest, including caesium-134 and 137, strontium-90 and iodine-131.

intervention levels have been determined on the basis of not exceeding the ICRP recommended lower intervention level of dose of 5 mSv, or 50 mSv to the thyroid. The supporting guidance recommends that before deciding to implement a protective measure, an optimization procedure should be applied to determine whether a lower level of individual dose at which to intervene is warranted.

Following a global survey of food consumption patterns, data from some 130 countries were used to establish eight different regional patterns. On the basis of the maximum regional consumption for the major food categories, a hypothetical diet was constructed for foods consumed in quantities greater than 20 kilograms per person per year. *(See table, page 15.)* The intervention level of dose (5 mSv) was then translated into corresponding radionuclide concentrations (derived intervention levels) for each of these major food categories, using assumed consumption rates of 550 kilograms of food and 700 litres of drinking water per person per year.

While it is not possible to predict which radionuclides will be discharged into the environment when developing generic accident response arrangements, those most likely to be of concern are strontium-90, iodine-131, caesium-134, caesium-137, and plutonium-239. Although each of these radionuclides will result in a somewhat different dose when ingested in equal quantities (dose-per-unit intake), they can be classified into two broad groups. The first includes all of the actinides, such as plutonium-239, for which a dose of 10^{-6} Sv per becquerel ingested has been ascribed. The second embraces the remainder of the above-mentioned radionuclides, such as the radio-caesiums, for which a value of 10^{-8} Sv per becquerel has been set. The variation in the dose-per-unit intake between the radionuclides within each group is sufficiently small as to allow the establishment of a single generic set of derived intervention levels for each of the food categories. However, for the minor food items (e.g. spices, herbs, and tea) with an annual consumption rate of less than 20 kilograms per person, vast quantities would need to be consumed before they made a significant dose contribution. For such food items, it may be necessary to consider the use of less restrictive levels.

Although these guideline values adequately will protect the general population, additional values have been provided for infants. This is necessary because the infant diet is largely restricted to only a few foods, and because certain radionuclides that may be present in these foods have a higher dose-per-unit intake for infants than for adults. *(See accompanying table.)*

Because one cannot make a general prediction as to which foods will be contaminated by which radionuclides in the event of an accident, the WHO guideline values are based on the premise that only one radionuclide is involved and only a single food category is affected. In any particular accident, however, it is likely that several radionuclides and food categories will be involved. To provide for this multiple food category contamination, the WHO guidance includes a procedure for apportioning derived intervention levels, thereby ensuring that the intervention level (5 mSv) is not exceeded.

It is important to recognize that the guideline values developed by WHO are intended for application to foodstuffs at the point of their consumption by identified population groups and in the form in which they will be consumed. Moreover, due to the complexity of the food web and because most people obtain the 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 that caused by the deposition of radioactive material in the area in which they live. Thus, by applying the WHO guideline values, the resulting mean doses to persons in the affected population are likely to be significantly lower than the intervention level of dose.

● ***Trade-related levels.*** One of the most important post-accident intervention requirements is the need for agreed guidance on the criteria that should govern trade in contaminated foodstuffs. Their absence at the time of the Chernobyl accident led to considerable confusion within the international community, loss of public confidence, and the erection of artificial trade barriers. To avoid a repetition of this situation in the event of a future accident, an internationally harmonized approach to the development of derived intervention levels has been pursued with some urgency. Although the basic principles of intervention should be common to the establishment of the consumer-related and trade-related control levels, it is essential that any criteria established for controlling foodstuffs moving in international trade be readily understood and easily implemented by those responsible for the clearance of shipments at the point of import or export, and who are not specialists in radiation protection. For such purposes, a range of levels for different radionuclide and food categories, such as the consumer-related controls developed by WHO, is not practicable. The ideal would be a single action level

WHO guideline values for derived intervention levels in milk and water for infants* (becquerels per litre)

Radionuclide	Value in Bq/litre
Strontium-90	160 (milk & water)
Iodine-131**	1600 (milk)
Caesium-137	1800 (milk)
Plutonium-239	7 (milk & water)

* Based on a consumption of 250 litres per year.

**Assuming a total mean lifetime in the body of 11.5 days and an organ dose of 50 mSv to the thyroid.

applicable to all foodstuffs, below which a consignment would be deemed acceptable without any further constraints. In practice, the solution will lie somewhere between these two approaches.

Promoting and advising on food quality and consumer protection at the international level is the concern of the FAO. In December 1986, in response to requests from several FAO Member States for advice on actions that would need to be taken with regard to the contaminated foods moving in international trade, an FAO expert consultation group developed interim international radionuclide action levels for foods (IRALFs).* The term "interim" was used to provide for periodic review and possible revision in the light of experience and of further FAO, WHO, and IAEA recommendations. In developing these levels, a relatively conservative approach was adopted. The objective was to provide a wide margin of safety so that the levels would be applicable as broadly as possible to minimize unnecessary constraints on international trade. FAO recommended that the IRALFs be applied to international food shipments. They also considered that their application would, *inter alia*, help protect the welfare of agricultural and fishing communities that might otherwise be affected by trade disruptions. The consultant's report and recommendations were submitted to the 17th Session of the Codex Alimentarius Commission (CAC) in June 1987 "for information", pending the development of joint FAO/WHO recommendations on trade-related levels.**

At an inter-secretariat meeting in March 1988 between FAO, WHO, and IAEA, a joint approach to the establishment of trade-related levels was developed using a procedure similar to that adopted for determining the WHO consumer-related levels. However, to enable the trade-related levels to be readily applicable within a simple regulatory framework, the procedure was modified to provide the minimum number of control levels. With the exception of milk and infant food, the WHO concept of separate food categories has been replaced by a single generic food group, with the control levels conservatively based on a 550 kilograms per person annual food consumption, all of which is assumed to be contaminated. The recommended levels were submitted to the 35th Session of the executive committee of the CAC in July 1988. *(See accompanying table.)* The executive committee noted that the proposed joint FAO/WHO trade-related approach, and the consumer-related approach recommended by WHO, were fully complementary. If implemented, they would enable countries to exercise adequate control of radionuclide contamination of foods moving in trade. In addition, they would be of assistance to national food control/health authorities in monitoring and controlling actual levels of radionuclide contamination in foods being consumed by specific population groups.

Joint FAO/WHO proposed derived intervention levels for the control of contaminated foodstuffs moving in international trade (becquerels per kilogram)

Radionuclide	Food groups	
	All foods (except for strontium-90 in milk and infant foods)	Milk and infant foods (strontium-90)
Strontium-90	1000	100
Plutonium-239	10	—
Total gamma activity for other radionuclides	1000	—

Note: Dried or concentrated food products should be controlled on the basis of the levels in the food after its preparation for consumption; i.e., after the relevant dilution or infusion. The levels given, therefore, should be multiplied by this same dilution or reconstitution factor.

At the request of the CAC executive committee, the FAO/WHO joint paper will be revised to include further explanatory material on the basis of the recommended trade-related levels. It then will be widely distributed to countries for comment through their Codex contact points. The revised paper and comments will be referred to the March 1989 meeting of the Codex Alimentarius Food Additives and Contaminants Committee for any necessary review by an *ad hoc* working group of governmental representatives. The committee then will refer the revised paper, comments, and report of the *ad hoc* working group to the 18th Session of the CAC in July 1989 for final review and acceptance prior to its official publication.

Outlook

In reviewing progress over the past 18 months to redress the lack of guidance on the distribution and consumption of contaminated foodstuffs, it is evident that much has been achieved, with considerable common ground to support the intervention criteria now recommended by the relevant international organizations, particularly those of WHO and FAO. These criteria should be viewed against the levels of naturally occurring radionuclides that are present in all foods and environmental materials. These unavoidable levels clearly illustrate the fallacy of adopting unrealistically

* *Recommended limits for radionuclide contamination of foods; report on an expert consultation*, FAO, Rome (1986).

** The Codex Alimentarius Commission is the competent international body for developing harmonized food standards, including limits on food additives or contaminants, aimed at the health protection of consumers and facilitating international trade.

Examples of naturally occurring radionuclide levels present in foodstuffs, man and the environment*

Milk (from potassium-40)	50 Bq/litre
Whiskey	50 Bq/litre
Fish (from potassium-40)	100 Bq/kg
Potatoes	100–150 Bq/kg
Cooking oil	180 Bq/kg
Sea water (from potassium-40)	12 000 Bq/cubic metre
Human ingestion of carbon-14 in food	100 Bq/day
Human ingestion of potassium-40 in food	100 Bq/day
Amount of natural radioactivity incorporated in the adult body	5 000 Bq
Estimated amount of radioactivity (from caesium-137) required to be ingested by an individual to reach the intervention level of 5 mSv	400 000 Bq

Note: Caesium-137 and the naturally occurring potassium-40 are of comparable radiotoxicity. Potassium-40 is present in all food products and living organisms.

* The figures quoted are average values.

low levels upon which to base food import or export controls. *(See accompanying table.)*

The need to regulate for the presence of contaminated foodstuffs in international trade has proved to be an area in which a harmonized approach is essential. The basis for such an approach should be through a simple control system involving a minimum number of radionuclides and food categories; the joint FAO/WHO recommended trade-related levels seem well suited for this purpose. The penalty of a simplified generic approach is that it is necessary to assign more conservative values to some of the input parameters than otherwise would be warranted on strict radiological protection grounds. Although this will increase the cost of the protection, it may be considered an acceptable "sacrifice" when viewed against the benefits offered by harmonized international trade control criteria.

In contrast, international harmonization of consumer-related levels may be more difficult to achieve. Although the guidance and recommended levels recently published by WHO were developed in conjunction with other international and inter-governmental organizations, some countries and inter-governmental organizations may hesitate to adopt these levels if they differ significantly from those already in use, particularly where they have been incorporated into national legislation. Even if a broad degree of harmonization were to be achieved, sufficient flexibility would always need to be incorporated to consider specific circumstances, including the particular habits of those to whom the protective measures would apply. Nevertheless, the generic approach adopted in developing the WHO levels and the supporting guidance on their application provides a uniform foundation upon which countries can structure their consumer-related derived intervention levels specific to actual circumstances. Its application in the event of any future nuclear accident should do much to avoid a repetition of the confusion and concern of the past 2 years.