The World Health Organization is a specialized agency of the United Nations with primary responsibility for international health matters and public health. Through this organization, which was created in 1948, the health professions of some 165 countries exchange their knowledge and experience with the aim of making possible the attainment by all citizens of the world by the year 2000 of a level of health that will permit them to lead a socially and economically productive life.

By means of direct technical cooperation with its Member States, and by stimulating such cooperation among them, WHO promotes the development of comprehensive health services, the prevention and control of diseases, the improvement of environmental conditions, the development of health manpower, the coordination and development of biomedical and health services research, and the planning and implementation of health programmes

These broad fields of endeavour encompass a wide variety of activities, such as developing systems of primary health care that reach the whole population of Member countries, promoting the health of mothers and children; combating malnutrition, controlling malaria and other communicable diseases, including tuberculosis and leprosy; having achieved the eradication of smallpox, promoting mass immunization against a number of other preventable diseases; improving mental health, providing safe water supplies; and training health personnel of all categories.

Progress towards better health throughout the world also demands international cooperation in such matters as establishing international standards for biological substances, pesticides, and pharmaceuticals, formulating environmental health criteria, recommending international nonproprietary names for drugs; administering the International Health Regulations; revising the International Classification of Diseases, Injuries, and Causes of Death; and collecting and disseminating health statistical information.

Further information on many aspects of WHO's work is presented in the Organization's publications.

The views expressed in this book are those of the experts who participated in two meetings on the subject of derived intervention levels, and do not necessarily represent the decisions or the stated policy of the World Health Organization.

DERIVED INTERVENTION LEVELS FOR RADIONUCLIDES IN FOOD

Guidelines for application after widespread radioactive contamination resulting from a major radiation accident

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CONTENTS

PREFACE

After the Chernobyl accident in April 1986 it was recognized that the available guidelines on the management of the consequences of a nuclear accident did not adequately cover the actions to be taken to protect the population in areas far removed from the accident site. Several meetings of international organizations were held to determine how this deficiency could be remedied. One outcome of the discussions was that WHO undertook to produce guideline values for derived intervention levels for radionuclides in environmental media, especially food, below which actions to reduce or avoid the potential health detriment would not be justified. Such guideline values could provide the basis upon which national authorities could implement their own derived intervention levels and so promote harmonization.

This book has been prepared from the reports of two 1987 WHO meetings on the subject of derived intervention levels. The report of the Working Group on Guideline Values for Derived Intervention Levels was widely circulated to national governments and comments were received from 24. A subsequent report was produced after the meeting of the Task Group on Guideline Values for Derived Intervention Levels. The participants at both meetings are listed in Annex 5, and their contribution to a particularly difficult topic is gratefully acknowledged. Special acknowledgement should be made of the contributions of Dr R. H. Clarke (National Radiological Protection Board, Didcot, Oxon, England) and of Dr D. Beninson (National Commission of Atomic Energy, Buenos Aires, Argentina). Dr Clarke performed considerable editorial and drafting duties, and Dr Beninson, as Chairman of both meetings, was largely responsible for encouraging the consensus that was eventually achieved in spite of the initially divergent views of participants.

WHO would also like to thank the Commission of the European Communities, the Food and Agriculture Organization of the United Nations, the International Atomic Energy Agency, and the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development, which provided not only their expertise but also much of the data used in the calculation of derived intervention levels.

ABBREVIATIONS

CEC	Commission of the European Communities
FAO	Food and Agriculture Organization of the United Nations
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
NEA	Nuclear Energy Agency of OECD
OECD	Organisation for Economic Co-operation and Development
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
USNRC	United States Nuclear Regulatory Commission
WHO	World Health Organization

Chapter 1

INTRODUCTION

Guidance on the management of the consequences of a nuclear accident is already available from a number of international organizations (e.g., IAEA 1985b, ICRP 1984b, WHO 1984). This guidance, however, concentrates on the actions required within a limited geographical area close to the accident site. After the major nuclear accident that occurred in Chernobyl, USSR, in April 1986, it became clear that additional guidance was needed for action over long time scales and for dealing with the widespread radioactive contamination that affected many countries at considerable distances from the accident site.

The actions undertaken by national authorities after the accident at Chernobyl *did* protect the public, but varied widely, even within similarly affected areas, and caused unnecessary confusion and unwarranted concern among members of the public (OECD/NEA 1987). Even within one country many organizations were necessarily involved, centrally, regionally, and locally, and the lack of coherent guidelines meant that approaches were sometimes inconsistent.

One of the major difficulties in areas away from the site of a nuclear accident concerns decisions on the safety of contaminated food and drinking-water. WHO, in close consultation with several other international organizations (see Preface), has therefore considered it appropriate to develop guidelines to assist national authorities in making decisions on the control of food in the event of widespread contamination by radionuclides resulting from a major nuclear accident. The guidelines are based on health protection principles and aim to minimize the risk to the population as a whole while taking due account of sensitive groups. They are intended to contribute to the national decision-making processes, and to provide a basis for a harmonized post-accident response by national authorities, while not imposing unnecessary constraints. It should be stressed that the guidelines relate only to the post-accident situation and are not applicable when a nuclear plant is operating normally. They concern only the "far field" (the area far removed from the accident site) and do not include guidance on the actions needed close to the accident site.

These guidelines deal solely with appropriate intervention levels for controlling exposure to radiation from contaminated food and drinking-water. However, it is important to remember that, after a nuclear accident, members of the public may be exposed to radiation externally and by inhalation of radionuclides as well as via ingestion of food and water. All routes of exposure should be taken into account by national authorities in the decision-making process.

PRINCIPLES FOR THE CONTROL OF FOOD CONTAMINANTS

For the routine control of environmental pollution, limits are normally placed on the *release* of potentially harmful contaminants that may affect water, air, or soil and cause damage to the ecosystem or to human health. In addition, international guidelines have been developed defining acceptable *levels of intake* of contaminants — see for example the *Guidelines for drinking-water quality* (WHO 1984/5), and the reports of the FAO/WHO joint expert committees on food additives and pesticide residues.

In the case of foodstuffs, levels of contaminants in the product are usually regulated, but primary control is nevertheless aimed at the prevention of contamination.

Non-radioactive contaminants

Food control legislation and the principles that have evolved for its implementation over the past 80 to 100 years are designed both to reassure consumers of the quality, safety, and value of foods available on the market, and to provide food producers and the food-processing and marketing industries with basic criteria that, when met, facilitate trade in foods while safeguarding public health.

Certain contaminants such as mycotoxins, pathogenic microorganisms, heavy metals, and undesirable organic compounds occur in foods despite every effort to limit or prevent their occurrence. Some of the chemical contaminants are carcinogenic, and in such cases it is generally assumed that there will be a "no-effect level" on which to base an "acceptable level" for the contaminant in food. Toxicological information is usually available from the results of animal feeding studies, but it is rare to have data relating to health effects in human beings that can be used in the risk assessment of such contaminants. In these circumstances decisions on acceptable levels may include making a number of conservative assumptions, for example that all of a particular affected food item will be uniformly contaminated. A number of safety factors are also usually introduced so that the inherent uncertainties in the risk assessment procedure are allowed for.

In normal situations, food contamination can be controlled by, for example, limiting discharges from chemical industrial sites, controlling the manner in which chemicals such as pesticides or veterinary drugs are used, or minimizing levels of chemical toxins produced by fungal contamination of crops. A different situation exists after an accident. Although contamination of food from a chemical accident is usually fairly localized and affected foods can be readily controlled, it has always been recognized that, if the effects of condemning a source of contamination would be unduly severe, it might be necessary to accept less restrictive controls. It is rare for a chemical accident to have transboundary consequences, but this can occur (as after contamination of the Rhine in 1986). Generally the situation can be dealt with by bilateral agreements between national governments, so that contaminated food and water can be taken out of circulation or otherwise controlled fairly readily.

Radioactive contaminants

The principles for controlling radioactive contaminants in a normal situation, where efforts are mainly concerned with the prevention of contamination of the environment or foodstuffs, cannot be applied when an accident occurs. In the case of a nuclear accident causing widespread dispersion of radionuclides, controls have to be imposed after the event, with the objective of avoiding or minimizing the adverse effects. Nuclear accidents have special characteristics, in terms of the large areas and populations that may be affected. WHO has therefore considered it important to develop *public health guidelines* for the management of accidental radioactive contamination of food. These are based on risk assessment considerations that inevitably differ from those used to control human exposures in normal situations.

During the routine operation of a nuclear facility where the source of radiation is under control, radiation doses to members of the public are limited by applying restrictions to that source, for example by controlling the rate of release of radionuclides from the facility. These controls are generally based upon the ICRP system of dose limitation (ICRP 1977). During an accident, the source of exposure to radiation is by definition not under control and, as with chemical exposures, it is reasonable to accept that the normal system of dose limitation does not apply and that different criteria are necessary in decision-making.

Several studies have been made in human beings of the effects of acute and chronic high-dose exposure to radiation. Although the levels of exposure are not strictly comparable to those likely after a nuclear accident, these studies provide more accurate risk estimates than extrapolation from the animal feeding studies used as the basis of risk assessment for most chemicals. For planning radiation protection, the radiation risk estimates are generally applied without additional safety factors. However, as with chemicals, several pessimistic assumptions are built into the risk assessment; these introduce a margin of safety into the setting of intervention levels for radionuclides in food.

After a nuclear accident, as after a chemical accident, control measures may need to be less restrictive than in a normal situation if the total detriment arising from the accident and from the countermeasures is to be minimized. Since a major nuclear accident could result in contamination of areas of land thousands of kilometres from the source, international harmonization on control methods is needed to prevent discordant actions, which may cause unnecessary confusion.

The setting of acceptable levels of radionuclides in food will not itself ensure that exposures of individuals to radiation from food are kept below any agreed level. National authorities can determine this only by monitoring levels of contamination in the food and using actual food consumption data to assist in determining total intakes of the relevant contaminants.

Radiation accidents

The contamination resulting from a severe radiation accident creates problems for public health and other authorities that are very different in the vicinity of the accident and at a distance. The levels of exposure, the pathways of exposure, and the time frame over which the protective measures have to be implemented will depend on the specific circumstances of the accident, the season of the year, meteorological conditions, and agricultural practices.

Near field

In the immediate vicinity of the accident, radiation exposure rates can be very high, and in the worst case, can lead to acute health effects if protective measures are not implemented quickly. For convenience, the immediate area of the accident (with a radius of up to a few tens of kilometres) is referred to here as the "near field". If the accident is severe and involves the release of fission products as well as noble gases, then the pathways of exposure that predominate in the near field are whole-body external exposure from the airborne plume and from material deposited on the ground, and inhalation of radioactive material in the plume, which leads to radiation doses to internal organs. The external dose rate from radioactive material deposited on the ground may be dominant, especially if rainfall has enhanced the deposition; this deposited material, the transfer of its activity through food chains, and the inhalation of resuspended material then become important exposure pathways to be considered in decision-making. In the near field, urgent action such as sheltering, evacuation, and decontamination of individuals may be necessary. Administration of stable iodine tablets may also have to be part of the emergency response where radioiodines are released in significant quantities.

The risks, difficulties, and disruption that follow the implementation of various countermeasures after a nuclear accident differ widely, and thus the level of radiation dose at which a given countermeasure is introduced should be influenced by such considerations. Intervention levels must also be sufficiently flexible in application to be adapted to the particular conditions prevailing at the time of the accident.

In the guidance given to date by international organizations for the near field, an approach has been adopted with two tiers of reference dose levels for each protective measure. On radiation protection grounds, a lower level of dose has been recommended (IAEA 1985b, ICRP 1984b, WHO 1984) below which introduction of a particular countermeasure is not likely to be warranted, and an upper level of dose has been recommended above which implementation of the countermeasure should almost certainly be attempted. The upper level for the most difficult protective measure, evacuation, has been set at a whole body dose of 500 mSv if likely to be incurred in a short period of time. This corresponds to the level below which nonstochastic effects would not occur in a normal population. The lower intervention level of dose has been set at one-tenth of the upper level. For protective measures that are considered the easiest to be implemented (sheltering, control of foodstuffs), the upper and lower reference levels of dose to the whole body have been suggested at 50 and 5 mSv respectively. When preparing emergency plans, national authorities should set operational intervention levels between these upper and lower reference levels of dose.

Far field

The international guidance given so far does not specifically address the response to major nuclear accidents with substantial releases of radionuclides that spread to regions far from the accident site. Nevertheless, depending on the release characteristics and meteorological conditions, radionuclides can spread over very large areas — referred to here as the "far field". The problems thus created for the public health, agricultural, and other authorities differ from those in the near field.

The activity concentration of the plume lessens with time by radioactive decay of the radionuclides, by dilution, and by deposition on the ground, so that at large distances from the accident site (hundreds of kilometres) this source of potential contamination diminishes. There is relatively little deposition unless the passage of the plume coincides with rainfall. Local ground contamination is then very variable, but may be quite severe in some localities and contribute significantly to the external dose in the long term. However, outside these areas the plume contributes very little to the individual radiation dose either externally or internally through inhalation. In these circumstances, most of the exposure in the first years after the accident will occur from the incorporation of the deposited radionuclides into the human food chain. Thus, the doses in the far field tend to be less than in the near field and the principal mode of exposure changes from direct to indirect. Because the individual doses are lower at a distance than close to the accident, public health authorities will not need to introduce measures designed to reduce or avoid high-dose effects. Instead, food control and other appropriate authorities will need to consider effects on food availability and trade, while public health personnel will be more concerned with the potential future effects on the health of the exposed population.

Introduction of countermeasures

After a major nuclear accident, public health authorities may need to introduce measures to restrict the radiation doses received by members of the public so that the risks of adverse effects are small. Advice to limit exposure from ground deposition is not likely to be practicable except in very exceptional cases. On the other hand, measures may be needed to minimize the incorporation of radionuclides into foodstuffs produced in areas where local ground contamination is severe. Control over foodstuffs may have to be exercised for a very long time (months or even years) since radionuclides deposited on the ground may only slowly find their way into the food chain via animal feed or by being taken up by plants. Countermeasures can be taken either to minimize radioactive contamination in the food chain by, for example, feeding animals with the previous season's produce (at certain times of the year), or to prevent the consumption of contaminated food, for example by curtailing the sale of milk containing high concentrations of iodine-131 and converting it to cheese for later consumption. Such countermeasures may be taken as a precaution in the immediate aftermath of an accident, until a comprehensive assessment of the situation can be made.

Intervention levels in terms of *radiation dose* may be used as a basis for timely decision-making after an accident. In practice, however, the results of measurements made in the environment and on foods will be expressed in terms of *activity concentrations*, for example Bq/kg or Bq/l. "Derived intervention levels" (in terms of Bq/kg or Bq/l rather than radiation dose) would therefore be more appropriate for authorities considering the introduction of particular protective measures. Such derived intervention levels can be determined (once intervention levels of dose have been set) from knowledge of physiological and metabolic processes in human beings, of the distribution of radionuclides in the body after different intakes, and of the resulting radiation doses to various body organs. Necessarily, the levels are based on "reference persons" of different age groups and on average intakes of air, food, and water. Because derived intervention levels relate to concentrations of radionuclides in the different environmental media, such as air, water, land, and food, and because such concentrations can be readily measured, swift action can be taken to minimize the exposure of individuals to radiation should the derived intervention levels be exceeded. In the far field without ground deposition of radionuclides, the largest contribution to the radiation doses received by individuals is through the food chain. Accordingly, the derived intervention levels considered here relate only to foods consumed by the population.