PROTECTION OF THE PUBLIC IN THE EVENT OF RADIATION ACCIDENTS

Proceedings of a Seminar jointly sponsored by the Food and Agriculture Organization of the United Nations, the International Atomic Energy Agency, and the World Health Organization.

Geneva, 18-22 November 1963

WORLD HEALTH ORGANIZATION
GENEVA
1965

PRINTED IN SWITZERLAND

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PREFACE

The considerable advances that have been made in recent years in the uses and applications of ionizing radiations, while bringing many benefits to mankind, have also given rise to a new range of problems. Contamination of the environment from accidental release of radioactive material is one of them. Few such accidents have occurred, because of careful design and the adoption of strict safety measures by the authorities responsible for developments in these fields. Nevertheless, the numbers of fixed and mobile reactors, of processing plants for nuclear fuels, and of laboratory and industrial activities involving radioisotopes are growing, thereby increasing the likelihood of accidents.

Advance planning for action in the event of such emergencies is essential. It is necessary, for instance, for measurements of radiation levels and information on meteorological and topological factors influencing the spread of radioactive contamination to be available as soon as possible after an accident has happened, in order that the extent of the emergency may be assessed and appropriate action determined. The collection and analysis of such data will require, in most countries, the collaboration of several departments and services. So will the carrying out of measures for the protection of the population and decontamination and reclamation procedures for crops and soil.

Because of the intricacy and interplay of the responsibilities of different national agencies, prerequisites to successful action are forethought and co-operation. For this reason FAO, IAEA, and WHO, the three UN agencies most closely concerned with the various aspects of these questions, jointly planned two international meetings on radioactive contamination of the environment. These meetings were designed to give guidance and afford an opportunity for joint discussion to advisory and administrative officers in public health, food, and agricultural, veterinary, and fisheries services, and in the field of atomic energy.

The first of these meetings, the " Seminar on agricultural and public health aspects of radioactive contamination in normal and emergency situations " was held at Scheveningen, Netherlands, in December 1961.[1] *It was attended by about 250 participants from 33 countries and representatives of nine international organizations. It presented in broad outline the problem of radioactive contamination in air, water, and food, and was concerned more with the mechanisms of transfer of radionuclides to man and with monitoring programmes than with the specific measures to be taken in the event of a radiation accident.*

[1] Food and Agriculture Organization of the United Nations (1962) *Proceedings of a Seminar organized by the Food and Agriculture Organization of the United Nations, the World Health Organization and the International Atomic Energy Agency on Agricultural and Public Health Aspects of Radioactive Contamination in Normal and Emergency Situations,* Rome (mimeographed).

It was on this specific aspect that the second of these meetings concentrated, the " Seminar on the protection of the public in the event of radiation accidents ", held in Geneva from 18 to 22 November 1963. The proceedings of this second meeting are presented in the present volume. The Seminar, which was attended by 200 participants from 37 countries and representatives of eight international organizations, outlined the steps that must be taken to determine the extent of the radiation risk and reviewed the various problems associated with contamination of persons, food, agricultural resources, etc. The practicability of various measures designed to avoid irradiation or prevent harmful effects was assessed and an attempt made to weigh their disadvantages against the hazards of accidental exposure to radiation.

First Meeting

INTRODUCTION

PUBLIC HEALTH ASPECTS OF RADIATION EMERGENCIES: THE NATURE OF THE PROBLEM

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It has been said on many occasions, but deserves to be said once more, that the scientific and technical advances which made possible the peaceful applications of nuclear energy have marked an epoch in the history of mankind. There is, however, nothing new in the fact that technical progress entails enormous consequences of a social, economic and political nature. Nor is it new that there are two aspects to all technical progress—one being the benefit and the other the risk, the loss. This was true when gunpowder was discovered, and can with equal truth be said of the technical conquests of our own time: the automobile, the aeroplane, the spacecraft, pesticides, antibiotics, etc.

Every time society has been confronted with the necessity of adapting itself to a new epoch-making discovery, it has been faced with the elementary problem of weighing the advantages against the disadvantages—the benefits against the risks. Consciously or unconsciously these deliberations have been carried out; the process has frequently lasted decades, often many evaluations and re-evaluations have taken place, but in the end technical progress has always been integrated into human society—first in the highly organized and most complicated, and later in the less developed communities. I know of no case where mankind has, in the long run, rejected any form of technical progress.

Ionizing radiation has now been in the service of man for nearly three quarters of a century. After the discoveries of Röntgen and Becquerel, the harmful biological effects of radiation were quickly recognized. The injuries were confined to the individual—the scientist, the doctor, or the patient—although at that time only the direct, somatic effects were known and nobody realized the genetic hazards. With the increasing use of X-rays and radium in medicine, more experience was gained regarding the harmful effects of radiation, and thus the foundations were laid of the comprehensive radiation protection system of our own time.

The applications of radiation were for several years predominantly in the field of medicine, and doctors, as so often before and since, had to learn

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to use a tool which is highly beneficial when properly applied but equally harmful if used without the necessary caution. This was not new to the doctor, trained as he was to weigh the advantages and disadvantages of using new diagnostic or therapeutic methods.

In the 1920's the International Commission on Radiological Protection (ICRP) was established as an international body, independent of the health authorities in individual countries. This commission, composed of physicists and doctors from many countries, systematically reviewed knowledge of radiation. With the introduction of exact measuring units for radiation, the foundation was laid for the recommendations which were to become of such importance for the protection of scientists, doctors, radiation workers, and patients.

Many years were to go by before it was acknowledged that these problems demand the interest of the health services to the same extent as do other harmful factors. But the use of X-rays and radium in medicine, and the recognition of the harmful biological effects of radiation, as well as the work of the ICRP, eventually compelled many countries to provide legislation, rules and regulations, which aimed at protection against unintentional biological injury.

The great leap forward in this development took place 20 years ago. On December 2, 1942, scientists succeeded for the first time in initiating and controlling a self-sustaining nuclear chain reaction. At present there are 39 power reactors in operation in 10 countries. Their total output now is approximately 3500 MW (electric) which by 1966 will have risen to over 10 000 MW. Another 33 power reactors are under construction in 14 countries; their output in 1966 is estimated at over 7000 MW—and other power reactors are being planned.

The discovery and exploitation of nuclear fission resulted in an enormous increase in the quantities and varieties of radioactive material in the environment. Radioisotopes are applied at present in industry, in medicine, in agriculture, in hydrology and in many other fields. As an illustration of the quantities of radioactive material in use it may suffice to mention that in the USA in the half-year October 1961 to March 1962, 23 346 shipments were made.

One of the consequences of the introduction of the fission process was that the health hazard of radiation, instead of being confined to a small group, now affected the public as a whole.

The attitude of the ordinary citizen to this new scientific and technical conquest was decisively affected by the fact that it first came to his attention in the form of an atomic weapon. It is understandable that the mistrust created by the detonation of nuclear weapons may have eclipsed the hopes that the harnessing of nuclear energy also offered—hopes of increased economic and social prosperity and progress, and of increased security against hunger and poverty.

According to a Study Group convened by WHO,[1] prominent among the factors that have contributed to the creation of mistrust have been the news bulletins of two world wars, the effects of psychological warfare, and political propaganda; and yet, more serious in respect of the public attitude to atomic power is the widespread publicizing of disagreements among scientists, not only in connexion with nuclear energy, but also in other matters. For many years, mistrust was the predominant attitude of the public—and even today, mistrust still lives on, fed by the fear of fallout from nuclear weapons tests and from accidents in connexion with the peaceful uses of atomic energy.

It took time for the health authorities to realize that the development of atomic energy opened up a new field of responsibility in public health work. It was not easy to acknowledge that here was a new factor in environmental hygiene that had come to stay. The problems raised had so many complicated technical and scientific aspects that it was only too tempting to leave them to be solved by physicists and technicians rather than by biologists and doctors. Today, however, it is generally realized that the problems arising from the applications of nuclear energy pertain to the many tasks that must be dealt with by the health authorities in every country.

The effects of ionizing radiation cover a very wide range, from the immediately recognizable beneficial effects, such as the healing influence on malignant disease, to the less obvious but extensive effects on economics and consequently on the welfare of man.

The same physical phenomena are also capable of producing harmful effects on all living tissue, including the human organism—effects that resemble in a great many ways the harmful influence of many other agents with which man has been familiar or to which, at least, he has been exposed, for thousands of years. Among these are micro-organisms, viruses, bacteria, and fungi, to which may be added man-made hazards, such as chemical substances in the environment, in the food-chain, and in the atmosphere—all that has been called the "microchemical challenge".

It is often emphasized as being characteristic of radiation, in contrast to other harmful phenomena in the environment, that it cannot immediately be apprehended by the senses. This is not a characteristic of radiation alone, for who can recognize the presence of micro-organisms or of certain chemical substances in food by his senses? Nor is the effect of ionizing radiation on the gonads, with its consequences for the progeny of those directly exposed to radiation, a specific one. Nevertheless, these properties are of great importance, particularly since there lies in them the reason for the interest, and partly for the exaggerated mistrust, shown by the public when radiation is discussed—a mistrust that, incidentally, is just as genuine a health problem as are all other harmful effects of radiation.

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[1] World Health Organization (1958) *Mental health aspects of the peaceful uses of atomic energy*, Geneva. (*Wld Hlth Org. techn. Rep. Ser.*, 1958, **151**).

These same properties of ionizing radiation that give rise to concern in the public must also be given the most serious attention by the authorities —health authorities and others—who, within the complicated structure of modern society, must ensure both that nuclear energy will be of benefit to society and that the risk involved in the application of nuclear energy is reduced to as low a level as possible, in fact to a level where it becomes acceptable.

When we take stock and attempt to summarize what has been achieved in the development of the peaceful applications of nuclear energy, the following can safely be stated: No technical conquest has ever been carried to a higher degree of safety and no other industry has caused so little damage to the life and health of those employed in it. Considering the predominantly injurious biological effects of radiation, it is surprising how safely radiation can be applied within different spheres of community life.

Apart from the early cases of permanent skin burns on the hands of those who experimented with and demonstrated X-ray machines and apart from a number of cases of leukaemia in radiologists, the most dramatic early demonstration of radiation hazards came in 1920, when women who painted luminous watch dials with radium acquired bone cancer from radium lodged in their bones. More recently, there have been a few reactor accidents, but very few other accidental exposures have been recorded.

The fact alone that these accidents have involved direct damage to the individual, and not to larger groups, let alone strata of society, places the problem in a class by itself from the public health point of view. That radiation hazards range so high in public and professional concern is due almost entirely to a deepening awareness of its potential capacity to kill or disable, coupled with the recognition that radiation seems destined to become an increasingly ubiquitous feature of contemporary and future society.

The reason why the introduction of nuclear energy, in spite of its widespread use in medicine, industry, agriculture and numerous other fields, did not cause major accidents is that the study of methods of radiation protection has been carried out so intensely from the very start—and that the perfection of these methods and of measuring techniques has proceeded simultaneously with the development of the applications of nuclear energy, and sometimes even in advance of them.

The concern of the present Seminar is first and foremost the fear of long-term somatic or genetic injury. In spite of an enormous amount of scientific information, knowledge about the possible somatic effects of small radiation doses is still very limited. It has all been derived from animal experiments, from radiation therapy, from a few nuclear accidents, and from the early experiences with X-rays and with radium paint. In all these cases, the exposure levels were high. More is known about the effects of small radiation doses in the field of genetics, but even here knowledge has to be based mainly upon experiments with animals.

This lack of exact knowledge about long-term somatic and genetic effects of small radiation doses compels us to keep exposure levels to a minimum, the general philosophy being that any unnecessary exposure is too much exposure.

A very large amount of literature on radiation hazards and radiation protection, dealing with almost every aspect—scientific, practical, legal and administrative—is available today. In addition, a great number of conferences, seminars and committee meetings are held, both on a national and on an international level.

The Seminar that starts today, although in a sense a continuation of earlier meetings, has its own well-defined objectives, which we must keep constantly in mind in the course of our discussions.

First, I should like to comment on the term "radiation accident". In the context of this Seminar, we may take this to mean an accident involving the public, not the individual,worker, scientist, or patient—an event that concerns part of the population, the whole nation, or that may even spread beyond the borders of a country. In this connexion, and for the purpose of this Seminar, it should again be emphasized that "radiation accidents" refer to emergencies arising from accidents to nuclear installations of any kind and from the peaceful uses and transport of radioactive materials. Situations resulting from nuclear weapons tests or from nuclear weapons attack, are not strictly within the terms of reference of this Seminar, although many of the results we hope to achieve may have some bearing on the solution of problems arising from such situations.

Much effort and large sums of money are invested in safety precautions in connexion with the use of ionizing radiation. The probability of serious radiation accidents is therefore very slight. On the other hand, it must be admitted that technical faults and the possibility of human error can give rise to severe accidents. It is therefore necessary to give considerable thought to emergency planning, which will form the basis for action should an accident occur.

An accident, an emergency, is something that happens unexpectedly and unintentionally, and one of its characteristics is that prompt action is usually required. In countries where natural catastrophes are fairly frequent occurrences, public and private agencies are prepared to meet emergencies with planned measures; however the degree of preparedness obviously differs from country to country. Depending on the structure of the country and the character of the disaster, one or other of the administrative bodies will carry the weight of planning and organization. Any accident, any disaster, constitutes a threat to the health and lives of the population, so any public health service must, to some degree, be involved in the preparations to meet emergencies.

There are three administrative organizations that must take the main responsibility in the event of a radiation accident: the public health services, the agricultural services, and the atomic energy authorities. It is therefore logical that the three United Nations organizations concerned with these fields should be the sponsors of this Seminar.

The next point I should like to stress is that the purpose of the present Seminar is predominantly a practical one. Its principal objectives are:

(*a*) to identify and examine the practical problems that are likely to face the public health, agricultural and atomic energy authorities in emergency situations involving radiation;

(*b*) to outline the practical steps that must be taken to determine whether a serious radiation risk exists;

(*c*) to evaluate the extent of the emergency; and

(*d*) to indicate the practical measures that should be taken by the above-mentioned authorities, in close co-operation with numerous central and local agencies.

It is not my task to discuss these objectives in detail—that will be done in the next few days by the participants in this Seminar. I hope that as many as possible will take an active part, since an enormous number of different problems are involved—physical, biological, medical, agricultural, nutritional, meteorological, sociological and administrative, to mention only a few.

In comparison with other aspects of public health, the information available on radiation hazards is considerable. I have mentioned that knowledge of the effects of small doses of radiation is limited. However, investigations into the physical nature of the sources of radiation and the biological effects of radiation have been carried much further than is the case in any other field concerning hazards to human health. Our main problem today is how to use in practice the tremendous amount of information available and how to formulate it and make it applicable to the decisions that must be taken in the event of radiation accidents.

The third point on which I wish to comment is the problem of setting maximum acceptable levels of radiation exposure to the population in emergency situations. This is the central problem of this Seminar and because of its importance it will be discussed in three sessions, in group discussions, and finally in a panel discussion. It is planned to consider the question from the radiobiological, genetic and statistical points of view, including a survey of the maximum permissible levels that have been proposed in various countries.

In all our discussions of this central question we must be very careful in one respect: to make quite clear to each other what we mean by the words, the terminology, we use. The radiation vocabulary contains many different phrases, some carefully defined, some not. For those without a thorough understanding of the problems connected with the mechanism of radiation injury there will be numerous pifalls, even in the terminology. It must be our principal task not so much to try to define exactly what is meant by such terms as "maximum permissible dose", "maximum acceptable level", "radiation protection guides" and "ranges", as to make clear to everybody the philosophy, the thinking, behind our words.

As mentioned earlier, all safety precautions taken in connexion with the use of ionizing radiation are based on the criteria formulated by the ICRP. The general principle behind these recommendations is that all exposure should be kept as low as practicable, and that all unnecessary exposure should be avoided.

For example, with regard to the maximum permissible doses for occupational exposure, the 1959 recommendations of the ICRP say *inter alia*: "A permissible dose ... carries a negligible probability of severe somatic or genetic injuries; ... any effects that ensue more frequently are limited to those of a minor nature and would not be considered unacceptable by the exposed individual and by competent medical authorities ... Any severe somatic injuries ... would be limited to an exceedingly small fraction of the exposed groups ... The permissible dose can therefore be expected to produce effects that could be detectable only by statistical methods applied to large groups."

In occupational exposure to ionizing radiation, the minimum risk mentioned is considered to be balanced by the advantage inherent in the use of radiation. It is possible to control carefully the radiation dose and to stop further exposure as soon as this becomes desirable. In the industrial application of radiation it is to a certain extent a question of economics how low the dose to which workers are exposed should be kept. If the hazard is too great, the project must be abandoned, or alternative methods must be found.

In the case of medical applications, it is necessary to evaluate both the radiation to which the patient is exposed and the radiation to which the doctor and staff are exposed. It is the duty of the doctor to weigh the hazards to the patient against the benefit to the patient. It may be permissible in this context to use an old Danish proverb that says: desperate ills need desperate remedies. The doctor himself must sometimes risk exposure to more than the maximum permissible dose for the sake of the possibly vitally important treatment the patient requires. Here I am thinking particularly of the gynaecologist, who, with the methods at his disposal today, can be exposed to radiation doses that are large as compared with the maximum permissible ones for occupationally exposed persons.

It is within these spheres that the ICRP recommendations are relevant, in other words where the sources of radiation can be controlled. They are not regarded as standards of safety or standards of danger—but they are standards of good practice—standards which there is generally no reason to exceed—at least not without strong motives, as for instance in the case of medical use of radioisotopes.

So far, I have discussed standards in relation to what could be called normal conditions. The problems are very different when abnormal conditions are considered. Although I have excluded from this discussion the problem of fallout from nuclear weapons tests, this type of exposure might be mentioned as an introduction to, and an illustration of, present thinking in regard to acceptable doses in a situation when the source of radiation cannot be controlled. In such a situation—and it is worth remembering that a similar situation might very well arise after a nuclear accident—measures might be taken, for example, against the use of contaminated food. It is by no means obvious that these measures should, or will, be taken at levels which would cause the authorities to take action against other sources of contamination. The occupational exposure standards mentioned previously were chosen with a great margin of safety. It is possible, for example, that measures prohibiting the use of contaminated food would involve a greater risk—because of economic, medical, social or other consequences—than the risk of using the contaminated food.

I should now like to set out certain guiding principles that I think should be borne in mind when we discuss the establishment of maximum acceptable levels of radiation exposure to the population under the abnormal conditions of a radiation accident.

First of all, exposure to radiation involves one set of hazards; countermeasures, whatever they be, involve another set of hazards. Every decision that is taken in an emergency situation must, as far as possible, be accompanied by an evaluation of the overall cost and need.

The following are some of the basic factors to be considered before any decision is made: The biological effects of a given radiation dose will depend on the composition of the group that is exposed. Moreover, the evaluation of the radiation dose received is in itself a difficult task, because the physical measurements, which can be carried out rapidly in an emergency situation, do not directly reveal anything about this dose. Finally, an evaluation of how the situation is likely to develop must be taken into account. Similarly, the possible undesirable effects of countermeasures will depend on the conditions to which the group concerned is subjected at the critical moment.

Even at this early stage of the Seminar, it can be stated that the establishment of generally valid figures for acceptable radiation doses is unwise. It is desirable to have certain established acceptable levels, on which planning can be based, but these must not be taken as limits upon which to base decisions in specific situations. In every case, the disadvantages must be carefully weighed and their total effects must be kept as small as possible. And here again it is important to realize what is possible and justifiable from the view point of the community. The task becomes still more complex because the factors to be weighed are, to a certain extent, functions of one another.

Not many of us have experienced a serious radiation accident or have had the experience of tackling the difficulties encountered in weighing risks and gains in a radiation emergency. But this does not mean that there is no experience to stimulate our imagination and give useful directives for our thinking and planning.

Let us look at a few emergencies of a different character, outside the radiation field, where the authorities are faced with the problem and the duty to meet the consequences of the accident or disaster, and to provide either full compensation or compensation up to a certain limit for the damage to the population. All peace-time disasters have features in common; all have health and medical aspects, and considerable attention has been paid to these.

First, I should like to deal with the problems raised by large natural catastrophes, such as floods and earthquakes. At least in part of the area hit by such a catastrophe, the situation will often be so hopeless for the survivors that the disaster appears to be almost total: there is everything to gain and nothing to lose. No cost seems too high if there is a chance to save lives. The problem facing the rescue teams is simplified and the approach primitive. For example evacuation may be compellingly necessary and have to be carried out regardless of the high cost to life or health. Billeting outside the disaster area in unhygienic circumstances, in cramped quarters, very much inferior to what are normally regarded as hygienically justifiable, may be the only possibility. The character and extent of the disaster determine the risk to which victims are exposed during rescue work; the aim is to do the most good for the greatest number of victims by using all available resources.

This is a description of the utmost emergency situation into which people can be brought by a disaster, a type of emergency where the risk to the exposed group is absolute. It must be the duty of all responsible authorities, through careful planning and instruction and the provision of efficient rescue material and personnel, to limit the area of worst distress as much as possible.

Let me now describe another type of emergency from the public health field, the situation in a country where the population has been vaccinated against smallpox to a reasonable extent and where smallpox cases are brought in. This is a situation that any public health authority must be prepared to cope with at any time, since at the present day people can fly anywhere in the world within a very short time. Everybody knows that the specific means for combating smallpox is vaccination or re-vaccination, but not everybody is aware that vaccination and re-vaccination, when carried out as a mass measure, have been shown by experience to cause a certain number of cases of illness—even serious ones—and a certain number of deaths.

This means that the public health authority must make a calculation, an evaluation of the risk due to the spreading of smallpox with subsequent disease, invalidity, and death, against the risk due to mass vaccination.

This is not the occasion to explain how this process of evaluation proceeds, I only wish to direct your attention to the fact that it is a natural duty for public health workers—just as natural as the doctor's duty to weigh up the risk of an operation against the risk of disease for the patient.

With the smallpox example just described I have drawn your attention to a type of emergency where the risk for the exposed population group is relative. A third example will demonstrate the weighing of two health hazards against one other—hazards that have no connexion with an accident or a disaster.

It is generally known that the use of pesticides in agriculture involves a certain risk, namely that the final product, the foodstuff prepared from the treated grain, vegetables or fruit, will contain some of the poison and thus present a certain hazard to the consumer. Pesticides may sometimes be used exclusively to improve the quality of the crop or to augment the yield, i.e., the motives for using pesticides are mainly economic ones. In this case, no health hazard should be tolerated—the "acceptable level" of the poison in the food is zero or very close to zero.

Pesticides may also be used to eradicate a vector transferring an illness to the population, for example, malaria or encephalitis. The motives for using pesticides are here first of all public health motives. In this case, the authorities have to weigh one health hazard against the other. Often the situation will be clear: the illness represents a very grave risk to the population, to the life of the nation. Weighing this hazard against the risks from pesticides in the food, the country's authorities will feel forced to accept the smaller risk rather than the greater, and allow a certain concentration of pesticides in the food.

I have mentioned three different examples of emergency situations, each with its definite features:

(*a*) the natural catastrophe, with its absolute character;

(*b*) the epidemic situation which has much in common with the accident, but is relative in character; and

(*c*) the situation which demands weighing of health hazards, but which lacks the character of an accident.

I think you will agree with me that the smallpox example is the one that comes closest to the subject of this Seminar, Protection of the Public in the Event of a Radiation Accident, but in all three examples there are elements that can throw light upon the problems we are going to deal with in the next few days.

Many other examples could be given from the field of public health alone. A complete scale of emergencies and of the risks involved could be enumerated and matched with known measures and their characteristic risks, but I shall limit myself to the examples already given. I think they show clearly that we must often deal with situations where a great many factors have to be taken into consideration. Careful clarification of all relevant data and considerable knowledge and experience on the part of those taking the decision are required. I think they show, too, that weighing of risks is not a question of mathematics or of numerical calculation which can be turned over to an electronic computer—established figures or levels do not present any solution. The problems we are dealing with are far too complex.

Let us keep in mind that the more we know beforehand about the risks and hazards connected with ionizing radiation, the better our planning; and the more carefully we evaluate the acute situation, the better we shall be able to make the decisions on which so much will depend for innumerable human beings. And let us keep in mind also that in this kind of work many different people, with different background and training are involved. Co-operation is therefore indispensable. And may I add that the final decision demands not merely knowledge but intuition—not to mention courage—on the part of those who have to take the responsibility.