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**PUBLIC
HEALTH RESPONSIBILITIES IN
RADIATION PROTECTION**

**Fourth Report
of the Expert Committee on
Radiation**

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PUBLIC HEALTH RESPONSIBILITIES IN RADIATION PROTECTION

Fourth Report of the Expert Committee on Radiation

The Expert Committee on Radiation met in Geneva from 11 to 17 September 1962. Dr M. G. Candau, Director-General, opened the meeting and welcomed the participants and representatives of other international organizations. He referred to the increasingly widespread use and numerous applications of ionizing radiation and radioactive materials in medicine, industry and research, and to contemporary developments in atomic energy. Dr Candau said it was clearly necessary that public health authorities be not only fully aware of the hazards to health associated with ionizing radiation and of their responsibilities in this respect, but also fully prepared to meet these responsibilities. He stated that this meeting of the Expert Committee on Radiation had been convened to provide guidance to health authorities on the scope of public health responsibilities in radiation protection, and on the means of discharging them, including recommendations on desirable legislative and administrative frameworks, and on the staff and facilities required.

Dr E. J. Henningsen was elected Chairman and Dr F. G. Krotkov Vice-Chairman; Dr D. R. Chadwick was elected rapporteur.

INTRODUCTION

The public health service of every country has a basic responsibility for promoting and creating favourable conditions for improving the standard of health of its population. This is recognized in the WHO Constitution. A significant part of this general responsibility, which has grown in importance in recent years, is radiation protection. Sources of ionizing radiation have been in use for a considerable time, but their applications are now increasing markedly and have become very diverse. While substantial medical, scientific, and industrial benefits are derived from these numerous and varied uses, health authorities must insist on adequate controls to protect the public from excessive exposure to radiation.

Ionizing radiation can cause serious damage to living cells. Its penetration in tissues is associated with a variety of effects. Those of greatest concern from the health point of view are cancer and genetic changes. There is no need here to recall the lamentable history of the pioneers who

developed the practical use of X-rays, so many of whom died of malignant disease. Through its action on man's genetic make-up and the cumulative nature of these effects, radiation exposure may influence the health of individuals—indeed populations—of generations yet unborn. The significance of radiation-induced genetic effects, involving as it does the genetic heritage of the human species, has added a new dimension to public health thinking.

It is essential, therefore, that national health authorities give immediate attention to their responsibilities for radiation protection and ensure the development of an adequate system of control. They should be aware, however, that while radiation protection has new and challenging facets, the problems of radiation control fit naturally into the pattern of public health responsibilities. Even the carcinogenic and mutagenic risks are not unique to radiation. There are other agents, such as certain chemical air pollutants, insecticides and food additives, that have similar characteristics.¹ Moreover, radioactive contamination presents only a new aspect of the already existing problem of pollution control.

It should also be kept in mind that, while ionizing radiation presents very serious problems, it has been the subject of extensive research and a good deal more is known about its effects than about those of most other environmental contaminants. Similarly, more effort has been devoted to devising effective means of protection against radiation injury than against injury from other noxious agents. However, much still remains to be done by way of putting such controls into practice. An outstanding example is the elimination of unnecessary radiation exposure in the course of diagnostic and therapeutic X-ray procedures in medicine: in most countries, diagnostic uses of X-rays make the largest contribution to the dose received from all man-made sources of radiation.

1. NATURE AND SCOPE OF PUBLIC HEALTH RESPONSIBILITIES IN RADIATION PROTECTION

Public health responsibilities in regard to radiation protection comprise essentially four elements:

- (1) Identification and measurement of all sources of radiation exposure of the population.
- (2) Evaluation and assessment of these exposures in terms of the biological hazard to the exposed population groups, including the stimulation and conduct of research.

¹ *Wld Hlth Org. techn. Rep. Ser.*, 1962, 248.

(3) Development and application of methods of control.

(4) Conduct of programmes of professional and public information and education on the health impact of radiation sources.

It is important to emphasize that public health agencies should concern themselves with all sources of radiation exposure of the population. The effects of radiation are to a large extent cumulative and the total impact of radiation exposure on a population will be the result of the exposures from all sources. It is thus an important responsibility of the health agency to evaluate all exposures and consider the total.

The establishment of appropriate radiation protection standards requires the collection and evaluation of scientific data on radiation effects and the preparation of guides after due consideration of the social and economic factors involved. The International Commission on Radiological Protection has developed recommended standards which are widely accepted and provide useful guides to national health authorities. There will of course be a continuing need for re-evaluation of these standards in the light of developing information. Continuing research will be necessary, particularly with regard to the quantitative relationship between radiation dose and effects on man. Health authorities should themselves conduct such research as is practicable and should encourage research by others.

The development and application of methods of control are likely to require the efforts of various agencies and groups involved in the radiation field. The long life of some radioactive materials and the large amounts produced in atomic energy activities underline the importance of adequate control of pollution of the environment. While atomic energy groups may be directing their attention to the development of methods of treatment and disposal of radioactive waste, it is the responsibility of health agencies to satisfy themselves as to the adequacy of these methods. Again, much work has been done and is going on at the present time in the field of medical X-rays to devise simple, inexpensive methods of obtaining satisfactory or even improved diagnostic results with less radiation exposure to the patient. Not only should such efforts be encouraged but also health agencies should develop programmes to ensure the widest possible application of such exposure-reducing techniques.

Attitudes towards the health effects of radiation vary between two extremes: indifference and lack of appreciation of the dangers of radiation exposure, and undue anxiety leading to inappropriate and often dangerous action. Indifference may often be found among people who have used radiation for many years; this constitutes a problem of professional education in connexion with the establishment of adequate control programmes. Another challenging aspect of the educational problem is over-anxiety about radiation hazards. Some people, for example, through

fear of radiation refuse necessary X-ray examinations from competent physicians. X-ray examinations may well be life-saving and harm can come of the refusal of the patient to be X-rayed. On the other hand, unnecessary X-ray examinations should be avoided, especially in the case of children and pregnant women. It is therefore an important responsibility of health agencies to present balanced information on radiation to the general public and to educate radiation users.

The Committee recognized that there are great variations among countries in the organization of the various government services. Not only are there differences in the allocation of responsibility to different agencies of the central government, but also differences in the relative degree of central versus local control. For example, measures designed to prevent radiation injury may be the concern of departments such as those responsible for transport, labour, agriculture and atomic energy. Close and careful co-ordination among these various agencies is essential to successful management of the radiation problem. **It cannot be too strongly emphasized that it is the responsibility of the health agency to provide a single focal point for evaluation of the total health impact of all sources of radiation and to ensure that adequate measures for health protection are taken.**

This evaluation must include many potential sources of radiation exposure, ranging from abnormally high natural radiation levels in certain regions to a nuclear accident of major proportions.

The importance of the different categories of radiation hazard to be dealt with may be classified in two general ways. One is in terms of the severity of exposure to an individual or segment of the population, the other is in terms of the total integrated population dose. Even though doses to individuals may be relatively small, the total integrated population dose may be an important consideration, primarily for genetic reasons. Certain radiation sources and activities that require surveillance and control are listed below in approximate order of importance, considering the total integrated population dose, frequency of occurrence, and possible magnitude of exposure. No attempt has been made to deal with the question of division of responsibility for the control of these sources.

1.1 X-ray equipment (medical, dental and industrial)

This provides the commonest and greatest source of man-made radiation exposure and the one that can most readily be controlled. Industrial X-ray equipment has been included in this category because its control requires the same general equipment and skills as the control of medical and dental X-ray apparatus.

1.2 Radioactive materials (natural and man-made)

Because of the similarity of the control measures required, this category includes both the medical uses of radioactive materials and the non-medical uses. It also includes the mining, production and disposal of radioactive materials. In this connexion, it should be noted that it may be necessary to establish national waste, storage or disposal sites. The handling of loose radioactive materials will require a somewhat different approach from that adopted in the handling of sealed sources (see section 3.3.2), with greater emphasis on the control of environmental contamination.

1.3 Nuclear facilities

There are public health considerations involved at the planning stage, nuclear siting and design assessment, as well as during the operation of fixed and mobile reactors, of fuel production and reprocessing plants, and of critical and sub-critical assemblies; this does not preclude recognition of the safety responsibilities of atomic energy agencies.

1.4 Environmental contamination control

This would include the monitoring and evaluation of possible radioactive contamination of the environment from such sources as nuclear or industrial activities, or the disposal of wastes from medical and research facilities, or fall-out from nuclear tests.

1.5 Transport of radioactive materials

It is of particular importance to make certain that adequate control is exercised over the transport of radioactive materials, particularly when shipments are transferred, and that plans are made for the evaluation and control of any possible accidents. This is an area in which it is important that uniform international standards be maintained.

1.6 Miscellaneous radiation sources

This includes radioactive materials in foods and drugs, machine-produced ionizing radiations other than X-rays, and consumer products such as self-luminous timepieces and static eliminators and also the employment of fluoroscopy for shoe fitting.

1.7 New and future developments

It is important that health authorities be alerted to the problems associated with the increasing use and application of currently available radia-

tion sources and with the development of new sources or applications of radiation in the future. The development of nuclear-powered ships is an example, and the presence of such ships in seaports raises questions of direct public health significance.

The Committee emphasized the importance of programmes of radiation protection. Conditions will undoubtedly vary from one country to another, not only in terms of the number of different types of radiation sources but also in the resources that are available to devote to this problem. It may not be practicable or necessary to develop at the outset a comprehensive programme covering all sources of exposure. However, as a first step towards evolving such a programme much can be gained by developing control measures even for a single source, such as, for instance, the much-needed control of X-ray machines. The experience thus gained will be valuable in the development of a broader programme.

2. BASIC ELEMENTS OF A LEGAL SYSTEM FOR EXERCISING RADIATION CONTROL

2.1 Need for legislation

In many nations, additional legislation is necessary if the health agency is to have adequate authority to formulate and carry out an effective radiation control programme. If it does not have sufficient authority, the health agency may not be able to impose the necessary requirements of registration or licensing nor to enforce its rules on radiation protection. It may even lack adequate authority to inspect facilities and may only be able to conduct an educational programme. What is most important, it may have serious difficulty in obtaining adequate funds to establish a radiation control unit and hire the necessary inspection personnel. The mere enactment of a statute specifically vesting responsibility for radiation protection in the national health agency might alert those with control over the national budget to the need for sufficient funds to operate a national programme of radiation health and safety.

It is a basic principle that the enabling authority should be formulated in terms as broad and flexible as the national legal system permits. Flexibility is essential because of the rapidity with which developments are occurring in the application of radiation sources and in the radiation protection problems associated with them. Therefore, the health agency must have considerable discretionary powers to select the necessary forms of control and to develop codes and regulations. Some sources of radiation may lend themselves to adequate control simply by registration and occasional inspection; other sources may require a system of pre-evaluation through licensing.

2.2 Possible scope of authorizing legislation

The list which follows is not intended as a description of the necessary contents of national legislation but as a check list for the health agency to ensure that it has adequate authority to undertake its responsibilities for radiation protection.

2.2.1 *Authority to establish the necessary elements of a control system*

The health agency should be given not only broad authority to ensure an adequate scheme of control but, most important, considerable discretionary powers to select the kinds of controls which can be imposed. The essential elements of a control scheme are set forth below :

2.2.1.1 *Promulgation of rules, codes of practice and regulations.* The health agency should be granted broad authority to promulgate such rules, codes and regulations as it deems necessary to ensure adequate protection of the public from the hazards of ionizing radiation. Such directives may be of two types : permissible levels of exposure, and technical and administrative specifications aimed at providing reasonable assurance that these levels will not be exceeded. The latter includes shielding and monitoring systems, as well as such matters as qualifications of the user and the training and supervision of employees. For example, the agency may wish to limit the diagnostic and therapeutic uses of radiation to authorized physicians and dentists.

Permissible levels of exposure are the subject of extensive recommendations by the International Commission on Radiological Protection, whose competence and authority on the subject of radiation effects are accepted internationally. In elaborating the basic technical and administrative standards, useful guidance can be obtained from the publications of the International Commission on Radiological Protection, the World Health Organization, the International Atomic Energy Agency, and the International Labour Organisation. The guidance provided by these international organizations will be helpful in harmonizing national codes and rules, particularly in matters of transport and waste disposal. After formulating a basic set of rules applicable to all activities, the health agency might then proceed to develop detailed guides or regulations directed at specific issues, such as medical X-rays, industrial radiography, transport, and disposal of radioactive wastes.

2.2.1.2 *Authority to license or require registration.* Once specifications have been developed, several means exist for assuring compliance with them. One is to require registration so that users can be identified and their facilities inspected. Another is to require licensing of particular uses,

subject to pre-evaluation, before persons are permitted to engage in them. The choice between the two methods depends upon the potential hazard of the use. Obviously, licensing may prevent an unsafe operation from getting started, whereas registration, coupled with a system of inspection, can only be remedial in nature.

2.2.1.3 *Inspection and right of access.* Perhaps the most important element of the regulatory scheme is inspection; this is the only effective means of assuring compliance with regulatory requirements. The regulatory agency should have a clear right of access to and inspection of all facilities in the chain of activities from the manufacture to the disposal of radioactive materials, and devices using or producing ionizing radiation.

The frequency and nature of inspections should be left to the discretion of the regulating agency, since experience is the only effective guide in this matter. The frequency and extensiveness of the inspection will vary with the hazard and the nature of the use involved. Moreover, conditions will differ, depending on such factors as the sophistication of the user.

2.2.1.4 *Authority to require reports and the keeping of records.* Broad discretion should be vested in the agency to ensure that it can obtain information essential to the fulfilment of its regulatory responsibility. It should be permitted to require such reports and the maintenance of such records as are necessary to discharging its responsibilities. Reports might include such matters as immediate notification of any serious accident to permit prompt corrective action, notice of the termination of the use of the source or sources to prevent needless inspections, and reports by manufacturers and suppliers to permit identification of users. Records might include periodic information relating to the use of the source, individual exposure records and environmental monitoring information.

2.2.1.5 *Enforcement.* While a system of radiation protection should emphasize education and voluntary compliance, the seriousness of the hazard justifies administrative sanctions, such as suspension or revocation of the right to continue to use the source of ionizing radiation, and severe penalties for those who do not voluntarily abide by the rules.

2.2.2 *Committees*

The health agency may find it desirable to have one or more committees—for example, to enable the agency to seek the opinions and advice of highly qualified experts or to promote co-ordination among the agencies with responsibilities in the field of radiation protection (see also page 13). Therefore, the health agency should be given adequate authority to establish

such committees as it may need, but there should not be a mandate for the establishment of any particular committee, nor should the composition and responsibilities of committees be set forth through legislation. Any such provisions might impede the agency in the conduct of its programme.

2.2.3 *Training of staff*

The health agency should have adequate authority for the expenditure of funds for training personnel. It should make full use of all existing national and international facilities as well as providing where necessary its own training courses.

2.2.4 *Research*

The need for authority to conduct research on radiation protection will vary with the scope of the protection programme, and with the research organization of the country. Full use should be made of facilities already available for research relevant to the health agency's responsibilities.

The health agency should, as a minimum, have the authority to conduct research, or contract for the conduct of research, relating directly to the evaluation and prevention of risks associated with the possession and use of sources of ionizing radiation. This would include research on means of measuring or detecting radiation, means of controlling exposure to radiation, and the effects of irradiation.

2.2.5 *Prohibition of uses*

Provision will need to be made in the legislation for the prohibition of uses of radiation that are deemed to be unacceptable, taking account of both the hazards and the benefits likely to be derived. Shoe-fitting fluoroscope machines, for instance, have been outlawed specifically by some national and local authorities to prevent the unnecessary and harmful exposure resulting from their use, especially in view of their questionable value. Other applications, such as luminous toys, might fall in the same category. In this context, it will be the particular responsibility of the health agency to assess the health risks involved.

2.2.6 *Fees for licensing and regulation*

One possible approach that has been used by some national authorities to obtain funds is to impose a registration or licensing fee upon the user.

3. ORGANIZATION OF SERVICES REQUIRED TO MEET PUBLIC HEALTH RESPONSIBILITIES FOR RADIATION PROTECTION

3.1 Administrative structure

A basic problem in determining the administrative structure is whether a separate unit should be established within the health agency or whether the radiation protection services should be distributed throughout the appropriate existing units within the health agency.

The advantages of creating a new and separate unit are threefold. First, it is possible to plan and carry out in a single unit a more effective programme including all the public health responsibilities for radiation protection. Secondly, it provides a single focal point for the important task of co-ordinating the activities relating to radiation protection within the health agency between the national and local health units, and between the various interested national agencies. Thirdly, the creation of a new unit emphasizes the significance of this responsibility of the health agency. This may make obtaining adequate funds somewhat easier, as well as attracting competent personnel.

Undoubtedly, the choice made between these two approaches will depend on the extent of activities involving radiation sources and on the traditional administrative structure of the country. It is the opinion of the Committee that in general the advantages of the separate unit are sufficiently great to justify recommending this approach. In the conduct of particular activities, such as measuring pollution, research and inspection, maximum use should be made of existing personnel and units in the health agency and in other agencies.

The health agency will need to adopt a scheme to ensure co-ordination of its radiation protection programme with the activities of other governmental agencies in this field. For instance, in a number of countries, the labour agency is responsible for the protection of workers against radiation. In addition there may be an organization for the promotion or development of atomic energy, such as an atomic energy commission or a department of commerce agency, which will have an interest in any health regulations adopted because of their potential impact on the utilization of radiation sources. Moreover, transport agencies are likely to have authority to control radiation sources from a safety standpoint during transportation.

One means of effecting co-ordination would be through continuing contacts between the head of the radiation protection unit of the health agency and representatives of these other bodies. An alternative method would be the establishment of a co-ordinating committee. Such a com-

mittee might not only create a flow of information between government departments but also review any codes, rules or regulations before their issuance to assure harmonization of rules promulgated by the various agencies.

The health agency should undoubtedly consider the formation of one or more advisory committees. This would enable the agency to augment the experience of its staff and obtain the advice and assistance of persons with experience and a high degree of competence from universities, industries and elsewhere. An advisory committee could assist the agency in a number of areas such as :

- (1) advice on assessment of national problems of radiation protection ;
- (2) review of proposed regulations ;
- (3) advice on training programmes ;
- (4) recommendations on particularly difficult problems connected with specific uses of ionizing radiation.

The advisory committee might include not only persons with experience in radiation safety, such as health physicists, radiologists, geneticists and pathologists, but also representatives of the main categories of users, e.g., physicians, manufacturers of X-ray machines or other radiological equipment, and operators of research facilities using sources of ionizing radiation.

The agency should bear in mind that the functions of an advisory committee will tend to change as the programme develops and might be of a temporary nature. Initially, a committee to assist in the formulation of the programme would be highly desirable ; later it might be useful to have a committee to advise on major policy matters or on particularly difficult problems of evaluation, such as the assessment of the safety of a major nuclear facility.

3.2 Organization of services

For any particular programme of radiation protection the choice of staff and equipment will depend not only upon the scope of the programme but also upon the availability of personnel with appropriate training and experience at the various technical levels. The degree of financial support available is also an important consideration.

The functions of the staff will generally fall into three distinct categories :

- (a) programme planning and direction ;
- (b) technical support ;
- (c) inspection and enforcement.

The most important requirement is to secure the service of a well-qualified person to be the head of the programme. He should have technical training in radiation protection and also have a public health background. It may be necessary to engage an experienced public health worker and provide him with supplementary academic training in the field of radiation. One possibility may be the appointment of someone who can serve as a university faculty member and at the same time provide the necessary programme direction.

The composition of the technical staff as well as the equipment to be provided may vary widely, depending upon the needs of the programme and on the available resources. The technical support required may range from the part-time attention of the programme director, assisted by a technician (responsible for calibrating, maintaining and servicing a few simple instruments, and possibly for operating a film-badge programme) to a completely staffed laboratory capable of evaluating environmental contamination and undertaking radiochemical analyses.

The field staff of inspectors will also vary considerably depending upon the needs and resources as well as the existing structure of the agency. The technical training and experience required of inspectors will depend upon the scope of the programme.

During the initial stages of a radiation control programme it may be advisable to limit its scope to those types of inspection that can be done by technicians. In planning for radiation inspection, the decision must be made whether to employ radiation specialists who deal solely with radiation or to add the radiation inspection function to other duties of field employees of the agency. This choice will depend greatly upon the scope of the programme, the structure of the health organization, the distances to be travelled, and the existence of other related programmes. Both methods of staffing the inspection service have been employed effectively under different circumstances.

Field workers generally require both formal academic training and in-service training. Such training can be provided effectively by assigning a new field worker to another agency with an existing radiation programme to serve as an apprentice. After a programme has been established, the practice of assigning a new inspector to serve an apprenticeship with an experienced field worker has proved useful. Such training should be supplemented by formal programmes of instruction.

3.3 Example of programme components

In section 1 it was emphasized that a radiation protection programme directed initially at one type of radiation source might well lead to the development of a comprehensive programme including all sources of exposure. The examples that follow are intended to give some idea of

what might be accomplished in three types of programme and the resources that would be required. No attempt has been made to present a comprehensive programme or to treat any one of the elements completely.

3.3.1 *Medical and dental X-ray installations*

In the use of medical and dental X-ray equipment there are three groups of persons to be protected : the patients, the operators, and the neighbours. Excessive exposures result from deficiencies in the equipment itself, its accessories, its installation, or its use. The equipment, its installation and accessories, and some aspects of its use can be readily inspected, but there are many aspects of the use of X-rays that are not subject to regulation but for which an educational programme should be instituted. For example, whether or not a child or a pregnant woman should be exposed to X-rays is a decision requiring professional judgment, and caution should be encouraged. The choice must often be made between radiography and fluoroscopy, giving due weight to the fact that fluoroscopy involves very much higher exposure for the same examination. Evaluation of the need for radiation therapy requires training, experience and judgment. Much will depend on ensuring that radiological procedures are only carried out by well-qualified persons.

Certain serious deficiencies in X-ray procedures are common and account for most of the unnecessary or excessive exposure of patients, operators and neighbours. Checking that the following precautions have been observed can form the basis of a simple but effective control programme :

- (a) limitation of the useful X-ray beam to the area of clinical interest, with particular care to protect the gonads ;
- (b) use of the recommended filter ;
- (c) proper protection of the operator ;
- (d) use of shielding material beneath an X-ray table or behind a wall-mounted film holder where the spaces below or beyond are occupied ;
- (e) employment of accessories, such as intensifying and fluorescent screens of films, that are in good condition and up to standard ;
- (f) provision of adequate room-darkening facilities in fluoroscopy and use of goggles for dark adaptation ;
- (g) use of protective aprons and gloves for fluoroscopy.

Neglect of any of these precautions can result in unnecessary doses to patients, operators or even to neighbours. In addition, certain other aspects of the design and installation of the equipment, as well as its structural shielding, can result in a varying degree of over-exposure. Some of

these factors can be reviewed in the planning stage, particularly in the case of the shielding of high-voltage therapy equipment.

As in all radiation control programmes, there should be a well-trained and experienced person in charge of the inspection service. The field staff should have some university training, preferably in engineering or perhaps in science, or should have equivalent technical experience, supplemented by specialized training.

For a relatively limited programme covering diagnostic equipment only, the field staff can make a worthwhile evaluation of X-ray installations by visual inspection and interview, supplemented by a few measurements or tests with simple instruments. It is possible, if resources are limited, to make such tests using only photographic film packets and fluorescent screens. It is preferable, however, if resources are available, to supply each field man with the following principal items of equipment :

- one portable ionization-type survey instrument ;
- one Geiger-Müller type survey instrument ;
- one X-ray dose-rate meter or thimble-type ionization instrument for measuring X-ray tube radiation output ;
- one self-reading pocket dosimeter.

The mechanical condition of the X-ray apparatus should always be carefully examined and tested. For certain special problems and for surveying high-voltage therapy installations, radiation instruments are indispensable.

In a limited programme, the maintenance, servicing and calibration of instruments can often be done by the field staff. In larger programmes, the equipping and staffing of an instrument shop and laboratory may be desirable.

A film-badge monitoring programme is very important in a programme of X-ray equipment control. The field staff should be supplied with personnel-monitoring film badges ; badges are also useful to test the adequacy of structural shielding. X-ray equipment users should employ personnel monitoring if there is a likelihood of significant exposure, for example, when using portable or bedside units or in fluoroscopy.

At the headquarters of the inspection service it is important to have facilities for the processing and evaluation of personnel-monitoring type films. This would include ordinary dark-room facilities with temperature controls and a photo-electric film densimeter.

A relatively simple standard radiographic or fluoroscopic installation can be inspected in about an hour. It is suggested that each installation be inspected at least every two years and perhaps more frequently. Hospitals or other installations with heavy work-loads should be visited at least once a year. One method is to assign approximately 200 to 300 X-ray

machines (radiographic or fluoroscopic) to each field man in large cities and from 50 to 100 to each man in rural areas.

A programme for the control of medical and dental X-ray equipment can include not only industrial X-ray machines but also gamma-ray installations.

3.3.2 *Radioactive materials (sealed and unsealed sources)*

Radioactive material is used either as a sealed source (i.e., in a sealed container) or as an unsealed source. Experience has shown that with use containers, such as radium capsules and needles, often develop leaks or ruptures. This may result in the escape of some of the material in quantities that, although not normally visible, may be sufficient to cause serious contamination. Loose radioactive materials (unsealed sources) are used in a variety of ways in laboratory and medical procedures. In the process of converting such materials from one chemical or physical form to another, or in measuring quantities, there is apt to be a loss of material by spillage or by release to the atmosphere. Material lost from sealed or unsealed sources may be inhaled or ingested, or may cause contamination of sensitive radiation instruments detrimental to their operation.

One problem commonly encountered in the handling of radioactive materials is the rupturing of radium applicators which can result in the escape not only of the radium source but also of radon gas. Another problem is loss or mislaying of radioactive materials, including sealed sources, owing to failure to keep accurate records of the materials in stock and in use. Yet another risk is exposure of persons nearby through failure to provide adequate shielding when sealed or unsealed sources are in storage or in use.

The first procedure necessary for the detection and evaluation of hazards is to make radiation measurements in the areas to be occupied by personnel in order to determine whether the radiation levels are within reasonable limits considering the time of occupancy. Measurements should be made not only of the radiation level in the atmosphere but also to show whether any radioactive material has been deposited on the exposed surfaces; this may necessitate the use of sampling techniques.

In addition to a well-trained programme director, staff requirements for this type of work include field workers for performing inspections as well as some technical staff for laboratory examinations. The field workers should have some university training in engineering or science, or equivalent experience, supplemented by additional specialized training as discussed elsewhere in this report (see section 3.2, page 14). For a small programme, both the analysis of samples collected in the field and the servicing, maintenance and calibration of field instruments are usually performed by the field inspectors themselves. In larger programmes, these

tasks may be performed by a technician. For very large programmes, a more complete analytical and instrument laboratory may be desirable.

Each field worker should be provided with at least the following items of equipment, including a generous supply of spare instruments to avoid loss of time during repairs, maintenance or calibration :

- one beta-gamma survey instrument ;
- one alpha survey instrument ;
- one kit for taking smear samples ;
- one high-volume air sampler and a supply of filters.

At headquarters, a simple but sensitive laboratory instrument (with an additional standby instrument) for measuring alpha, beta and gamma radiation from collected samples is needed. A film-badge service should be available both for monitoring field workers and also for users of radioactive materials if commercial film-badge services are not available.

Except in the case of large laboratories or large-scale users of radioactive materials, a field worker should be able to inspect an installation in a period ranging from two hours to half a day. Each installation employing sealed sources exclusively need be inspected only once every year or two unless there has been an incident or a significant change. The frequency of inspections of installations employing loose materials will vary considerably depending upon the manner of use and the quantity of materials involved. The frequency should probably not be greater than once a year. One method is to assign to each inspector about 100 installations in large cities, or from 25 to 50 installations where considerable travelling is involved.

The effectiveness of a control programme for radioactive materials depends to a large extent upon the acceptance by the user of his responsibilities, including :

- (a) Provision of a regular programme of personnel-monitoring and contamination sampling (air, exposed surfaces, etc.) whenever indicated.
- (b) Appointment of a single person, the source custodian, to be accountable for all sources and to maintain accurate records of receipts and withdrawals of all radioactive material stocks from the storage facilities.
- (c) Provision of properly located, shielded and secured storage facilities.
- (d) Provision of proper shielding, equipment and, where necessary, ventilation for work areas in which radioactive materials are used ; the equipment should include special handling devices such as tongs, forceps and safety pipettes, which will provide the users with adequate protection.
- (e) Provision of temporary storage and transport containers.
- (f) Regular sampling of sealed sources and work surfaces to detect leakage (large or active installations).

(g) Provision for the storage and disposal of radioactive wastes, including discarded but still active sources.

3.3.3 *Airborne radioactive contamination*

The possibility of local or generalized airborne contamination of the environment with radioactive substances arises in connexion with a wide range of atomic energy activities, including the operation of various types of nuclear reactors, the processing of irradiated fuel and the production, transport and use of radioactive nuclides. Some increased environmental radioactivity already exists from nuclear weapons tests. The assessment of fall-out is not dissimilar from that of the environmental contamination that may be associated with other atomic energy activities. In the former case and generally in the latter it is from the products of nuclear fission that contamination arises, and in both cases the nuclides of principal interest are the radioactive isotopes of iodine and strontium. Therefore, the experience to be gained from fall-out monitoring would have immediate application in the event of substantial atomic energy developments.

When contamination of the atmosphere has occurred as a result of nuclear testing, fission products are deposited on the surface of the earth and may appear in human foodstuffs and possibly in drinking-water; these are the main public health considerations. Although routine air sampling is sometimes carried out, the results can seldom be applied directly to the assessment of public health hazards, although they may give some comparative day-to-day indication of the total radioactivity of the atmosphere, and some guidance as to the deposition that might be expected.

In countries where milk is consumed in large quantities, this item of diet is the principal vehicle of radioactive contamination, but in countries where little milk is consumed, the principal vehicle may be some other item of diet, such as cereals or leaf vegetables.

It follows that the measurement of the levels of iodine and strontium isotopes, particularly iodine-131 and strontium-90, in the principal items of diet is the essential basis of any programme for the evaluation of the public health issues associated with fall-out contamination.

Short-term evaluation will depend very largely upon the systematic measurement of iodine-131 in samples of milk or other appropriate foodstuffs; the long-term effects will be judged largely from corresponding measurements of the strontium-90 content. The frequency and distribution of sampling for iodine-131 will be related very much to the incidence of weapon testing. When measurements of iodine are deemed to be necessary, a typical sampling programme might aim at covering a reasonable fraction of a country's milk supply on a weekly basis. The geographic coverage obtained may be considerably increased and the work-load

diminished by the pooling of samples. Measurements of strontium-90 are of continuing importance and the health issues are of a long-term nature. Whilst weekly sampling might seem indicated in certain instances, adequate information can generally be provided by less frequent assay of bulked samples at intervals of, say, one to two months.

The objective of a programme of fall-out monitoring is to provide reasonably representative information about the total intake of radioactive nuclides in human diet. It follows that in a milk-consuming country, although the main effort should be devoted to the monitoring of milk, some attempt should also be made to assess the intake of radioactive materials in other items of diet such as cereals, potatoes and leaf vegetables. On the other hand, the major effort may properly be directed at the latter items in countries in which the consumption of milk is low.

The analytical procedures required are in part those normally employed in biochemical laboratories, for example drying, ashing and homogenizing, although the large number of samples involved creates special storage problems. In principle, the chemical techniques are based on standard analytical methods, although the final assay of the radioactive content of prepared samples calls for special equipment and expertise. Detailed information on selected chemical methods and counting techniques, and on the required instrumentation, is contained in the report of the Joint WHO/FAO Expert Committee on Methods of Radiochemical Analysis.¹

The type of staff structure required to operate such a monitoring programme can be illustrated in the following way. The head of the department should preferably be a biologist with some special training in radiation problems. In addition to planning and directing the programme, he would be responsible for interpreting the data obtained in terms of the accepted standards, and for advising departments on their significance. He would require two technical sections to assist him. One would be concerned with sampling procedures, including the collection, recording and preparation of samples; this section should include an experienced agricultural scientist with competence in statistics. The other section would be concerned with the analysis and assay of samples and should be headed by an analytical chemist with some skill in radiochemical methods. The number of supporting staff required throughout the department would be determined by the size of the programme.

Depending upon the degree of sensitivity required, a single analyst could measure about 10 strontium-90 samples per week, whereas he could handle hundreds of iodine-131 samples per week, especially if some of the available semi-automatic equipment were employed.

¹ *Wld Hlth Org. techn. Rep. Ser.*, 1959, 173.

3.3.4 *Emergencies resulting from radiation accidents*

Consideration must be given to possible emergencies arising from accidents involving the potential exposure to dangerous levels of radiation of individuals or groups in the general population. Of course, provision will also need to be made for the management of accidents involving only industrial workers, but this problem will not be considered here.

It is necessary at the outset to make a distinction between minor and major accidents since the considerations involved are quite different. An example of a minor accident might be the loss or damage of a radiation source such as a radium needle. This would affect only a small number of people in a limited geographic area and the potential exposures would be slight. Minor accidents can usually be handled either by the person responsible for the use of radiation—provided that he sends proper reports to the health agency—or by the health agency itself, if necessary with the assistance of other groups. Although any one minor accident may have a relatively small adverse effect, such accidents are likely to be quite frequent; there is thus an urgent necessity for the health department to have well-developed plans, facilities and resources for dealing with minor accidents.

Such plans should include provision for rapid communication with the responsible authority so that appropriate counter-measures may be taken. Prompt notification may also lead to the recovery of a sealed source, the nature of which is otherwise likely to go unrecognized since radiation cannot be detected by the unaided senses.

The importance of public information in connexion with an accident cannot be over-emphasized. It too might help in the recovery of a sealed source, and it would allay undue anxiety, which might lead to imprudent action entailing consequences more severe than those of potential radiation exposure.

Major accidents present an entirely different kind of problem. Such accidents may involve relatively large geographic areas, relatively large numbers of people or relatively high exposures. Drastic measures may have to be considered, such as the evacuation of population groups from contaminated areas or the condemnation of contaminated food or water-supplies. It is quite clear, therefore, that major accidents will involve many agencies, both central and local, and co-ordination becomes imperative.

Pre-planning for major radiation accidents is of the first importance, particularly as some of the necessary actions will have to be taken very promptly in order to be effective—for example, evacuation of population groups downwind of a nuclear accident involving the release of radioactive material into the atmosphere. It is generally considered that inhalation of short-lived radioactive materials may constitute the greatest

potential hazard. It is clear, therefore, that unless the population groups are evacuated or adequately sheltered before the radioactive cloud reaches the area the measure will be ineffective.

Although many agencies will be involved, those responsible for health should take the initiative in the development of an emergency plan for major radiation accidents. Needless to say, where general emergency plans for various kinds of catastrophe exist in a country, the radiation emergency plan should be effectively integrated into the total plan. However, radiation accidents present certain unique features, such as the inability of the human senses to detect the radiation; it cannot be assumed, therefore, that an ordinary emergency plan will be applicable without adaptation.

It has been previously emphasized that major radiation accidents are likely to involve many agencies and that co-ordination is a key feature of the plan. Another consideration is the preparation of other agencies for the tasks that they would need to perform in a radiation emergency. This will include training and education of appropriate persons and provision of necessary equipment and facilities. Firemen, for instance, should be trained in the management of fires involving contamination with radioactive materials. Arrangements for the management of radiation casualties should be made at suitably located clinics and hospitals.

In major emergencies, prompt and reliable public information is even more important than in minor accidents. The health agency should provide a central point from which health information is made available. The possibilities of conflicting information are always present when many different agencies and individuals are releasing information to the public. The avoidance of confusion and purposeless and inappropriate activity is one of the most important considerations in emergency situations. Prompt, reliable and authoritative information will do much to allay unwarranted fears and to secure the necessary co-operation from the public.

The criteria to be used to determine what actions have to be taken form an important part of any plan. Drastic measures such as evacuation of population groups or condemnation of contaminated food and water-supplies inevitably involve adverse health effects as well as other consequences. The total impact of any preventive measure must be carefully weighed against the risk of the radiation exposure which the measure is intended to reduce or avoid. Many groups are directing attention to the development of radiation protection guidance for emergencies. Although it seems quite unlikely that absolute standards will ever be evolved, it is essential to have some "guidelines" on which to assess the need for urgent action in the event of a major reactor accident. The specific and local factors associated with any accident will have to be carefully weighed by the appropriate authority at the time. Here again the importance of effective communication is obvious.

In establishing a plan, the health agency should ensure that adequate authority exists to take necessary emergency actions, such as condemnation of property and ordering evacuation.

Finally, the chances of successful operation of any plan will be greatly enhanced by carrying out exercises to test its effectiveness. It is virtually impossible to anticipate all the problems that will arise in connexion with an emergency. Carefully conducted exercises, however, will serve to pinpoint many of the unanticipated problems and permit modification and improvement of the plan.

4. RECOMMENDATIONS

The Committee strongly emphasizes the importance of the responsibility of the health agency to provide a single focal point for evaluation of the total health impact of all sources of radiation and to ensure that adequate measures for health protection are taken.

The Committee recommends :

- (1) that health agencies recognize their fundamental responsibility for protection of the public health against the hazards arising from all sources of ionizing radiation ;
- (2) that health agencies initiate programmes to meet this responsibility ;
- (3) that the authority of the health agency include broad discretion and flexibility in the establishment of a programme of control of radiation sources.

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