COMMISSION OF THE EUROPEAN COMMUNITIES

radiological protection – 2

ORGANIZATION AND OPERATION OF RADIOACTIVITY SURVEILLANCE AND CONTROL IN THE VICINITY OF NUCLEAR PLANTS

A Practical Guide

1975

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ORGANISATION AND OPERATION OF RADIOACTIVITY SURVEILLANCE AND CONTROL IN THE VICINITY OF NUCLEAR PLANTS

- A Practical Guide -

Directorate General of Social Affairs
Health Protection Directorate

1975

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C O N T E N T S

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PREFACE

The protection of public health against ionizing radiation is one of the responsibilities of the Commission of the European Communities provided for in Chapter III of the Treaty establishing the European Atomic Energy Community.

The assessment of risks in connection with nuclear installations should be based on the most accurate knowledge possible of the radioactive contamination level of the environment in the vicinity of the nuclear installations. A large number of control and monitoring programmes are currently under way in the Member States of the European Community. However, the great increase in the numbers and power of nuclear installations has obliged the authorities responsible for radiation protection to attempt to rationalise the conception and application of their control and monitoring programme. Furthermore, at the Community level, the harmonisation of these programmes is desirable, principally with a view to facilitating the exchange of information and providing better comparability of results obtained in the various member states in compliance with a concern expressed in Articles 35 and 36 of the Treaty.

Work to this end undertaken by the group of experts and directed by the Health Protection Directorate of the Directorate General for Social Affairs has led to the drafting of a document that will be particularly useful to all those who have or will have to take decisions concerning radiation protection. Like the "Practical guide to the establishment of controls of the radioactive contamination of foodstuffs, and beverages" published in December 1967 by the Commission, the present document is a concrete and realistic guide which gives a brief general survey of the problems posed by the control and monitoring of radioactivity and draws from them lessons applicable to particular situations.

Dr P. RECHT
Director

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1. INTRODUCTION

In principle any nuclear installation is capable of releasing radioactive material into the environment but the potentialities vary very widely. In practice, installations in which small quantities of radionuclides or sealed sources are employed can only release small quantities of radioactive contamination into the surroundings. As regards other types of installations (research reactors or laboratories, nuclear power stations, fuel reprocessing plants) discharges of radioactivity may be potentially more significant.

All Common Market countries have their own regulations on the design, installation and operation of nuclear installations. Though these national regulations differ in points of detail, they all control the discharge of radioactive effluents to the environment so as to guarantee that the dose limits set by the Commission of the European Communities for individual members of the public are not exceeded. Suitable control measurements carried out by the competent authority and by the operator then make it possible to ensure that the authorised discharge limits are actually respected.

Off the site of the nuclear installation there is the question of monitoring contamination of the environment. Dependent on the national regulations in force this may be the function of the operator, and/or the competent national authority.

The present document is a guide on the monitoring and control of environmental radioactivity with reference to nuclear installations in normal operating conditions. It therefore takes into account both routine discharges of radioactivity and unforeseen discharges which pass through the normal channels of discharge. It excludes discharges due to accidents which are outside the scope of the present study and document. It should be added that the probability of any large release of activity not being noted at the point of discharge is practically zero.

Since this document is specifically concerned with monitoring the environment it does not give any particular consideration to the measurement of actual discharges.

The document also confirms and updates in the light of present knowledge the content of earlier publications. It should, however, be stated that looking back, no big mistakes have been made in the field of environmental protection. This document presents a rationalisation of the earlier programmes and involves no major changes. In particular it may be noted that in several cases it has been possible to reduce the scope of detection programmes without loss of safety or of information on the state of the environment. This is due to the improved knowledge of environmental problems achieved in the past few years. A certain uniformity of criteria in the organisation of monitoring networks around nuclear installations may prove to be very useful from the Communities' point of view since it will facilitate exchanges of national experience and permit a better comparison of the results obtained.

These criteria are set out in detail in the following sections.

2. SCOPE AND PURPOSE OF MONITORING IN THE VICINITY OF NUCLEAR INSTALLATIONS

Publication 7 of the International Commission on Radiological Protection underlines the importance of evaluating the actual or potential exposure of man to radioactive substances or to radiation present in his environment and of estimating the probable upper limits of such exposure.

The aims of such monitoring are

- to ensure that legal provisions on environmental contamination are respected;
- to verify indirectly the performance of the waste containment and disposal system in order to ensure rapid detection of possible leaks and to facilitate the taking of suitable measures;
- the establishment of good public relations by keeping the public objectively informed;

- to cover the operator's responsibility for any damages which might be claimed against him;

- to carry out scientific studies with a view to improving our knowledge of the transport of radionuclides in the environment.

These studies essentially concern the behaviour of radionuclides in the environment, i.e. their eco-cycles, and aim at defining the <u>limiting capacity of the environment</u>.

The limiting capacity of the environment for a radionuclide can be defined as the maximum annual quantity of that radionuclide which can be discharged in certain defined conditions into a particular sector of the environment in such a way that the resulting dose commitment received via the critical pathways does not exceed the annual dose limit for individual members of the public as laid down in the basic standards of the Commission of the European Communities.

By "in certain defined conditions" is understood the complete set of conditions (chemical characteristics of the effluents, the mode of discharge, etc.) which characterise the release of the radioactive residues into the environment. Similarly by "a particular sector of the environment" is implied a limitation of the concept of environmental capacity to a reduced area of the surroundings which is directly affected by the discharge and where the critical pathways are situated.

The "dose commitment" resulting from a particular discharge is defined as an integral for an infinite period of the intensity of the average dose received by individuals of the critical group of the exposed population; a definition analogous to that of UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiations - General Assembly, Official Records, 19th session, Suppl. no 14 A/6314 p. 68, 1966) for the world population.

When the discharges contain several radionuclides some distribution has to be made so that the sum of the contributions of each radionuclide does not exceed the annual dose limit already laid down.

Furthermore, it should be emphasised that the actual discharges do not correspond to the limiting capacity of the environment already defined but only to a fraction of this which can be called the <u>stipulated capacity of the environment</u>. The value of the latter is established in each particular case by the competent authorities responsible for radiation protection on the basis of the characteristics of the surroundings affected, the technical aspects of the discharge and the requirements of radiation protection.

It is appropriate to keep in mind that as regards radioactive contamination man is the most sensitive organism and, given the structure of the environments considered, is always regarded, in practice, as the limiting factor.

3. CRITICAL PARAMETERS AND BASIC DATA FOR PREPARATION OF THE ENVIRONMENTAL MONITORING PROGRAMME

3.1. Critical Parameters

The orientation and scope of an environmental control programme are based on certain critical parameters. The term "critical" does not imply any idea of danger. It describes a "factor which enables decisions to be taken on the level of public health protection".

3.1.1. Critical Group

Group of members of the population whose exposure is homogeneous and typical of that of the most highly exposed members of the exposed population.

3.1.2. Critical pathways

Pathways of exposure requiring special consideration as being the mechanisms of predominant exposure of individuals. A general diagram of these pathways is indicated in Figures1 and 2. Each of these pathways will be considered when we come to consider each particular medium.

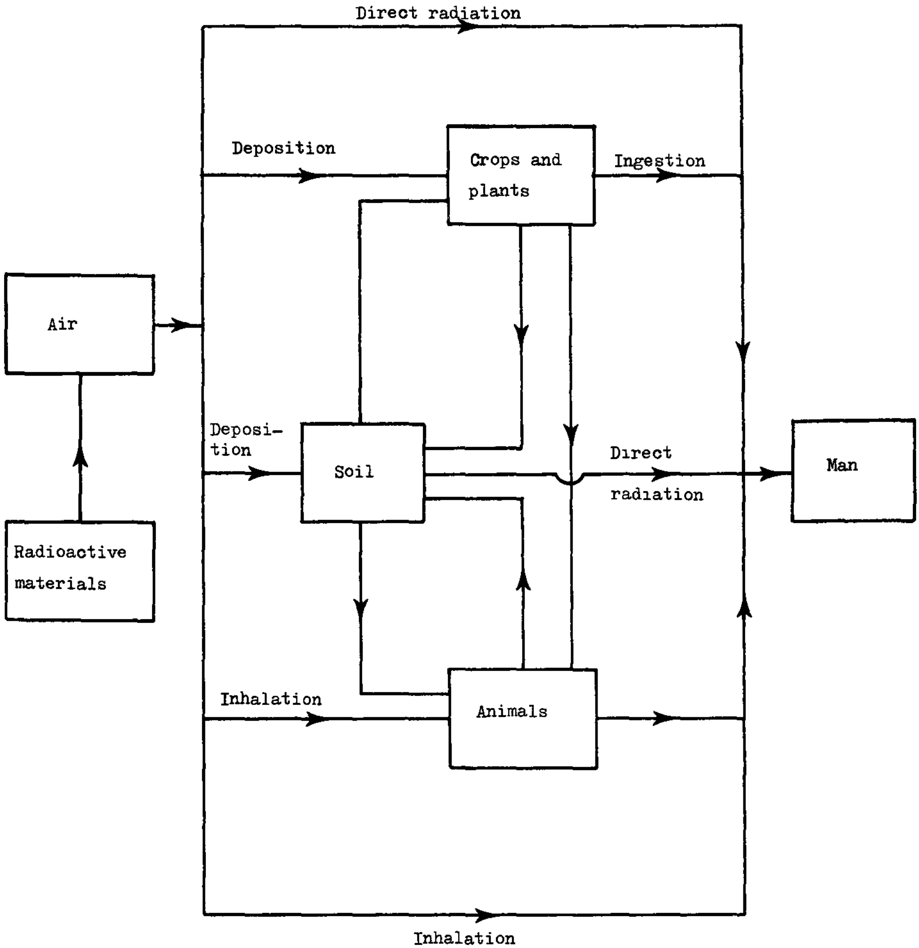

Fig. 1 - Simplified pathways between radioactive materials released to atmosphere and man

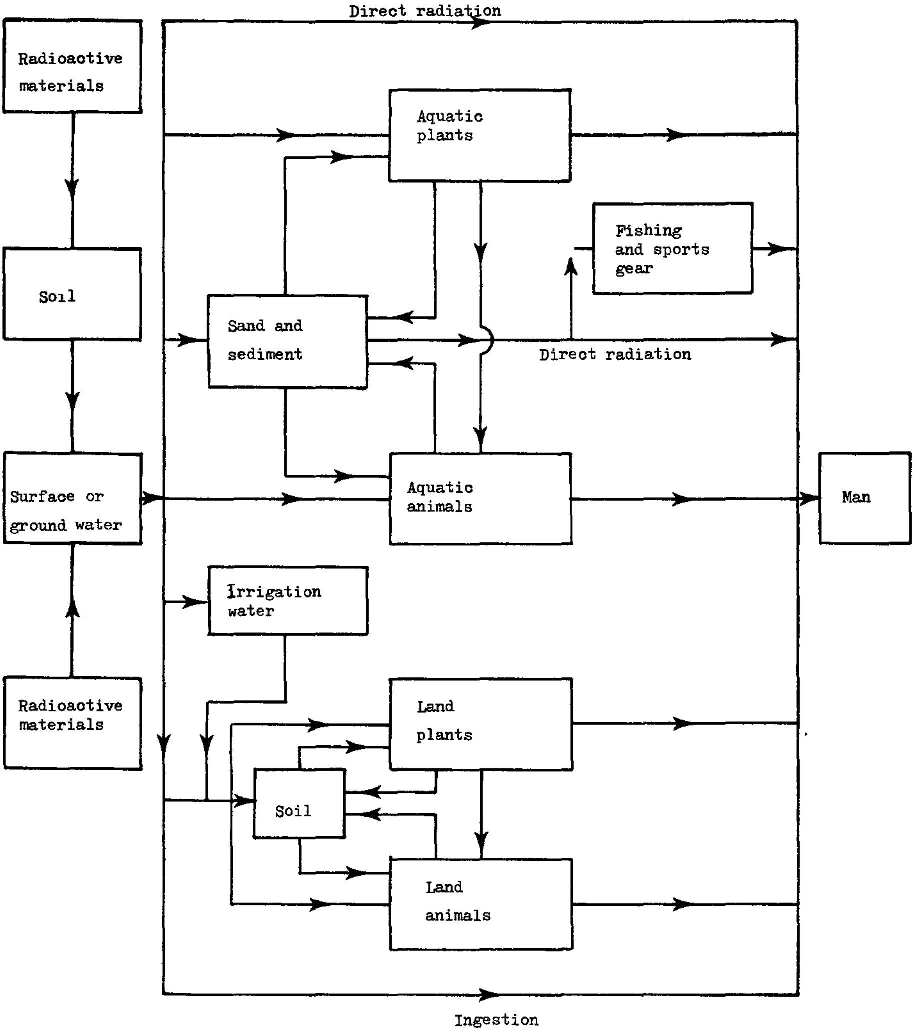

Fig. 2 - Simplified pathways between radioactive materials released to ground or surface waters (including oceans) and man

3.1.3. Critical radionuclides

Radionuclides which among those considered, account for most of the exposure of individuals.

3.2. Fundamental data

The following factors characterise the organisation of the monitoring programme and identify the critical parameters.

3.2.1. Characteristics of discharges

Radioactive discharges into the environment vary considerably in composition and quantity according to the installation producing them. The principal sources of radioactive wastes are primary nuclear installations (see Table 1).

TABLE 1

CHARACTERISTICS OF DISCHARGES FROM NUCLEAR INSTALLATIONS

TYPE OF INSTALLATION	Atmospheric discharges (1)		Liquid discharges (1)		Remarks
	Isotopic composition	Physical and chemical state	Isotopic composition	Physical and chemical state	
Mineral dressing Preparation of fuel	^{222}Rn ^{226}Ra ^{230}Th ^{234}Th U	Gas aerosols (after filtration)	^{226}Ra ^{230}Th ^{234}Th U	Solutions and suspensions	
Nuclear power stations (2) Reprocessing plants	Inert gases – I ^{3}H plus traces of fission and activation products	Gases – vapour aerosols (after filtration)	Fission and activation products, U & transuranics	Solutions, ionized and complexed forms	
Provisional storage areas			Miscellaneous	Miscellaneous	Theoretically no discharge
Research centres	Miscellaneous	Gases – vapour aerosols after filtration	Miscellaneous	Solutions, ionized and complexed forms	

(1) Before dilution in the receiving medium

(2) See "Radioactive Effluents from Nuclear Power Stations in the Community, Discharge Data, Radiological Aspects" – Commission of the European Communities, Directorate General of Social Affairs. Directorate of Health Protection, November 1972.

We have also to bear in mind that the method of discharge (continuous or intermittent) by influencing the instantaneous concentration of radiocontamination at the moment of release into the environment varies its availability for different biological processes. The figures in Table 2 (*) give an indication of the average dose to individuals living close to nuclear installations.

TABLE 2

	rad (MW_e year)$^{-1}$	
	External radiation	Internal radiation
Power reactors	10^{-6}	10^{-5} - 10^{-6}
Reprocessing plants	10^{-5}	10^{-7} - 10^{-9}

It should be remembered that nuclear installations expose the general public to at most only a small fraction of the dose limit or the dose due to natural radiation. Bearing in mind the elaborate safety systems provided in these installations, the risk of damage due to discharges from nuclear installations is so low as to be practically negligible compared with other risks arising in the normal life of the population.

3.2.2. Environmental characteristics

When radioactive effluents are introduced into the environment the radionuclides disperse into a zone which we shall call the "receiving environment", the boundaries of which are usually difficult to define precisely. However, the problem of precisely defining the limits of the zone is less important than it appears at first sight:

(*) Ionizing Radiations Levels and Effects, United Nations Official Publications, 1972, p. 108.

what must be defined as precisely as possible is the sector of the environment containing the critical pathways.

For emissions into the atmosphere it is useful to know the diffusion characteristics in order to determine stability categories. A knowledge of these quantities obtained from a period of observations extending if possible over several years enables us to form an idea of the frequencies of occurrence of the different stability categories. We then have all the information necessary for calculating concentrations at ground level on the basis of the most suitable diffusion formula for the case in question.

For liquid emissions it is necessary to know the hydrological characteristics of the waters affected for the different uses to which the water may be put: drinking water, irrigation water, fish farming, etc.

Finally it is desirable to list all forms of cultivation which could be affected by radioactive contamination, either through the air or by irrigation. In order that the competent authorities can arrive at a rational division of the environmental capacity it is also necessary to know the contribution of any emissions from other nuclear installations.

3.2.3. Characteristics of the General Public

The radioecological study indicated above needs to be accompanied by a socio-economic study giving not only a picture of population distribution around the installation in question but also information on the habits of this population.

In particular it is necessary to know their sources of drinking water and food, particularly sources originating from local production.

As regards dietary habits it is found that in practice with certain unusual exceptions (such as the consumption of "laverbread", a delicacy based on seaweed in South Wales) only certain foodstuffs such as fish and to a lesser extent dairy products can have any significant effect on the transport of radionuclides to man.

It is also desirable to take into account those population groups which though not living in the immediate neighbourhood of the installation consume foodstuffs largely originating from regions affected by the emissions.

3.2.4. General remarks

Examination of the above factors makes it possible to obtain a preliminary quantitative estimate of the dose which the general public might receive. It may often turn out that the figures are so far below the dose limit that the monitoring programme which one would specify on first principles can be considerably reduced.

One has always to bear in mind, however, not only the genuine requirements of radiological protection but also the effect on public opinion which may be greatly reassured by knowledge that there is an efficient programme for monitoring the environment.

Finally one has to bear in mind the inter-disciplinary character of this type of study which requires a combination of skills from the different branches of science. Specialist technical recommendations will of course have to be expressed in practical terms by the competent authorities who have to implement them.

4. PRE-OPERATIONAL STUDIES

4.1. Objectives of the studies

The objectives of pre-operational studies are closely bound up with the subsequent programme of environmental monitoring. These objectives are

- The acquisition of data on the critical parameters, radionuclides, exposure pathways and population groups which provide a basis for organising the routine monitoring programme;

- The collection of data on radioactivity levels in the environment before the nuclear installation starts operating in order to obtain a quantitative interpretation of the results of monitoring during the normal operation of the installation;

- The setting up of measuring methods and the education and training of personnel in order to guarantee the efficiency and continuity of normal monitoring.

The first two objectives aim at improving knowledge of the environment so as to permit a realistic evaluation of the dose to the general public due to the discharge of radioactive materials. The third objective in contrast is particularly important for the staff concerned with radiological protection. They need to familiarise themselves with the techniques of sampling and analysis which will be used in the eventual monitoring programmes.

4.2. Sources of radioactivity close to the installation

In addition to the nuclear installation in question there may be other sources of radioactivity in the same area. Since the operator is responsible exclusively for radioactivity arising from the operation of his installations it is important to distinguish each source of radioactivity.

The sources other than those due to the installation in question may be natural or artificial.

4.2.1. Natural Sources

These are of two kinds:

- extraterrestrial in origin (cosmic rays)
- terrestrial in origin (radionuclides naturally present in the earth's crust and in the atmosphere).

Natural radioactivity is generally characterised by relatively constant concentrations of the different radionuclides. Variations are either seasonal (there is a characteristic increase in spring in the content of various natural radionuclides in rain) or due to meteorological conditions (pressure, wind etc.) which influence the emergence of gaseous radionuclides such as radon or thoron from the soil and their diffusion into the atmosphere.

There are also discharges of radionuclides into the environment from non-nuclear installations (phosphate plants, conventional power stations etc.).

4.2.2. Artificial Sources

Nowadays it is normal to find a number of radionuclides of artificial origin in the environment. These can be divided into those produced and propagated by nuclear explosions (fission and activation products) and those released as the result of peaceful utilisation of atomic energy.

The concentrations of all these radionuclides show considerable variation both seasonally (here again one finds the typical increased concentration in rain during the spring) and also on account of meteorological conditions.

It therefore needs more than a few measurements to determine with sufficient accuracy those radioactive contaminants not originating from the nuclear installation in question. One has to be able to follow them over a sufficiently long time (at least a year) in order to know both the extent to which they fluctuate about their mean value and the tendency of this to vary. The results of local measurements of activity due to experimental nuclear explosions can usefully be supplemented by comparison with the results of measurements made by the national monitoring networks. These networks have a mass of data which usually covers a wide range both in time and in space. In this way it is possible to bring out any variations due to natural causes. This makes it easier to distinguish the emissions from the nuclear installation.

The other source of artificial radionuclides is that due to other nuclear installations or to users such as research laboratories and hospitals. The monitoring programme will therefore have to be organised to take account of these other sources and if possible to collaborate with the managements concerned.

4.3. Definition of the Monitoring Programme

On the basis of what has been said about it, it is not hard to arrive at certain principles.

Preliminary research must cover a period of at least a year, as certain environmental and biological parameters are directly related to seasonal variations. The programme must also make it possible to determine the parameters listed in section 3. It will therefore be based on a radioecological study which will serve to define the parameters most closely related to the environment and on a socio-economic study which will serve to characterise the extent to which the radioactive emissions from the installation in question reach man in the region affected.

It should also be borne in mind that the pre-operational study programme will serve to define the normal monitoring programme to be applied when the installation is working. In practice this could be on a smaller scale than the pre-operational programme in view of the improved knowledge of the environment obtained at the pre-operational stage and during the functioning of the installation which will make it possible to confine monitoring to those points which are of greatest importance and of known interest.

5. ORGANISATION OF ENVIRONMENTAL MONITORING

5.1. General remarks

The essential aim of an environmental monitoring programme is to ensure that the exposure of the general public does not exceed certain set limits. Consequently the characteristics of the programme (the type and scale of sampling and measurements) must make it possible to estimate the average exposure of the critical population groups taking a period of one year as a basis.

Once a programme of this type has been developed it needs to be reviewed periodically. On the one hand there may have been changes in the amount or nature of emissions from the nuclear installation, in the specific characteristics of the environment or in the habits of the exposed population and on the other hand there may have been improvements in control and analysis methods. Such revisions may lead to the scale of operations being reduced without loss of scientific information. The area monitored will in general be around the nuclear installation. However, there may already be a national monitoring programme intended to measure the levels of irradiation and contamination of natural origin or due to nuclear explosions. In that event this should be used to supplement the local programme as far as possible.

It is therefore desirable to arrive at some form of collaboration between the operator of the installation and those concerned on a national scale with measuring environmental radioactivity. This could achieve a considerable reduction in the routine monitoring which the operator would have to carry out. In particular where the pre-operational studies have given detailed information on the potential critical parameters, studies carried out while the installation is operating will be able to confirm or correct these results. The normal programme should relate particularly to exposure via the critical pathways and the critical radionuclides. It should then be able to supply information which will serve to calculate the actual and potential exposures of the critical population groups.

However, it can happen that the pre-operational studies do not give enough information to characterise all the critical parameters. The normal programme will then have been designed to permit not only an estimate of the exposure of the general public but also to give supplementary information on the possible critical parameters.

Internal and external exposure of the general public will remain considerably below the dose limits. Consequently it will be sufficient for the measurements made to give the upper limits of exposure, the results therefore being expressed as inequalities.

Although the effective dose is always very low it is important to be able to estimate the genetic dose for the population as a whole. The methods of measurement should be so selected that their sensitivity is compatible with the requirements of each particular case.

Finally it must be remembered that the monitoring programme must not merely give a picture of the situation at a given moment but must also give information on the trends of radionuclide concentrations and therefore of exposure doses.

5.2. Determination of Exposure Dose

The potential exposure of the general public affected by discharges can be evaluated on the basis of two general principles.

5.2.1. Estimation of dose as a function of quantities discharged

It is possible to calculate the exposure of the general public on the basis of the known quantities of radionuclides discharged into the environment and an estimate of the fraction of these which will reach the population. Those in charge of the monitoring programme must always have access to data on discharges from the installation to the environment; this data will be obtained by monitoring during release at the point of discharge. This method of evaluation may be sufficient where the quantities of radionuclides discharged from the installation are so low that the potential exposure of the general public is only an absolutely negligible fraction of the dose limit.

5.2.2. Estimation of dose as a function of concentrations measured along the Critical paths

It is also possible to arrive at the exposure of the general public by measurements of activity in the different critical pathways. In many cases it is difficult to arrive at the population dose due to the installations in question by this method alone since the dose due to the installation can be several orders of magnitude less than the dose due to natural radiation. In that situation the method of section 5.2.1. will be applied since those measurements will act as a control on measurements obtained under 5.2.2. Often, however, it will be possible only to confirm that the fraction of the dose to the general public due to the installation is less than some given value corresponding to the higher sensitivity of analysis or measurement.

5.3. Sampling and measurement

The frequency of sampling will be determined by suitable parameters such as the half life of the radionuclides in question and the probable rate at which their concentration in the environment varies as a result of the characteristics of the environment and of the discharge. In general at least one sample a year of the material to be analysed should be collected. For radionuclides with short half lives the sampling frequency will be suitably increased so that the maximum sampling interval is of the order of two or three half lives. If a particular radionuclide requires very frequent or even continuous sampling it will be possible to take composite samples and make less frequent measurements on these.

The frequency of measurements will allow for radioactive decay and for the sensitivity of the instruments so as to give results with a margin of error compatible with the accuracy required. The possibility of using composite samples both in space and in time makes it possible to achieve considerable economies in the work of monitoring without any adverse effect on the accuracy of measurement required but on the contrary with the advantage of the samples being more representative. It must be remembered that average concentration values are more important than individual figures. The criteria adopted will therefore be those which are more suitable for taking the different samples which will make up the composite sample.

As regards the type of measurement made it will be necessary to discriminate between the different radionuclides. At present there are methods (alpha and gamma spectrometry with semi-conductors, liquid scintillation spectrometry both with organic scintillators and Cerenkov effect etc.) which make in possible to measure all gamma emitters (and in certain cases beta emitters) without chemical separation. This makes it possible to carry out "ad hoc" analyses in a reasonably short time without excessive use of staff.

Measurements of total beta activity can be limited to the rare cases such as continuous control measurements in which it is sufficient to define the variation of activity relative to a generally constant value. When such variations are found the programme will then proceed to specific measurements by one of the preceding methods.

5.4. <u>Programme of calibration and comparison of results</u>

The measurements made by radiological protection laboratories need to be supported by suitable programmes of calibration and of comparison of results. The credibility of any given data depends largely on a knowledge of the associated errors.

Measurement errors are determined by calibrating the instruments against standard samples or by participation in programmes of calibration and comparison of results between several laboratories. Standard samples will generally be pure solutions of the radionuclide in question. On the other hand the matrices of the samples to be examined may consist of the most varied materials (soil, vegetation, milk etc.) and it is sometimes necessary to carry out chemical separations to isolate each radionuclide before measurement. Simple comparison of the results obtained from analysis of the sample with those obtained when the standard solution was analysed may not serve to reveal errors arising during the chemical separation.

This problem can be overcome by using standard reference samples or by participating in programmes of calibration and comparison of results. Such programmes are usually organised on a national scale by reference laboratories or on an international scale by such bodies as the International Atomic Energy Agency or the Commission of the European Communities which are obviously in the best position to provide this service. Such programmes extend to the comparison of methods employed and to general discussion during the examination of all the results (*). The programmes must of course be as realistic as possible so that the reference samples do simulate actual samples.

6. MONITORING RADIOACTIVE CONTAMINATION OF THE ATMOSPHERE

6.1. Introduction

In this case direct exposure of the general public can be due either to direct irradiation from a cloud of gas or radioactive dust released by the installation or to respiration of contaminated air. Direct irradiation is dealt with in section 10; here we shall confine ourselves to the problem of the atmosphere as a means of transferring contamination to man. Determining the radionuclide concentration in the air at the point of discharge (stack) is one of the quickest methods of detecting any abnormal situation. This fact influences the methods and criteria for collecting and measuring samples.

6.2. Sampling points

As suggested above, one sampling point will be chosen at the point of discharge (stack) from the installation in order to achieve rapid detection of any variation in the concentration of radionuclides in gaseous effluents. Further sampling points will be near the point of discharge and will include points in the region where the highest annual average concentration is expected on the basis of meteorological studies. Since the radioacti-

(*) EUR 4965 e
Rapid Determination of Radionuclides in Milk. Results of an intercomparison organised jointly by the I.A.E.A. and C.E.C. in 1972; by O. SUSCHNY, J. HEINONEN and D. MERTEN (I.A.E.A.), J. SMEETS, R. AMAVIS and A. BONINI (C.E.C.) - Report prepared by Division of Research and Laboratories of the International Atomic Energy Agency, Vienna and Health Protection Directorate of the Commission of the European Communities, Luxembourg; published by the Commission of the European Communities, 1973

vity of the environment (normal background) may vary either for natural causes or because of emissions from nuclear installations other than the one in question, it will also be useful to have a sampling point which can be regarded as a reference point and which is at some distance from the installation in the direction of the least frequent winds.

Finally, to complete the network, there can be a variable number of other sampling points distributed around the installation to detect any possible uncontrolled discharges.

The number and location of these points will be determined both by the amount discharged into the atmosphere and by the physical, meteorological and demographic characteristics of the area.

6.3. Types of measurement

Usually this will be a total alpha and/or total beta measurement on dust collected on filters or on gas retained in a trap (e.g. an activated carbon trap) or present in a buffer reservoir.

Since the natural background will give a value comparable to that of the discharges to atmosphere it will be necessary to adopt suitable means of distinguishing the different contributions. Fallout from nuclear explosions will obviously have to be allowed for if it is not negligible in relation to the figures for the discharges studied. Here it has to be remembered that seasonal fluctuations in fallout can be several times greater than the mean value. Comparison of values from the station near the installation with values from national monitoring networks may therefore help to make the distinction. National values are usually accompanied by good statistical information which helps to evaluate the cause of any variations in the radioactive contamination due to discharge.

These measurements should in any case be integrated with more specific measurements intended to determine the concentrations of different radionuclides. These concentrations could in particular be determined by gamma spectrometry of composite samples as indicated below at section 6.4. Similarly if total alpha measurements show any increases which cannot be attributed to variation in background, alpha spectrometry can be carried out on a thin sample after suitable chemical separation.

6.4. Frequency of sampling and measurements

Usually there will be continuous sampling at the point of discharge (stack) and the samples will be appropriately monitored to give information on the amount discharged and to give an immediate alarm in the event of unscheduled discharges.

As regards measurements in the environment, unless there are special technical factors determined by the characteristics of the installation and/or of the site which require other continuous sampling points it will be sufficient to take samples every 24 hours and then carry out the total beta measurements or possibly total alpha measurements on the samples taken.

On composite samples taken monthly or where there have been significant increases in activity it will be possible to make gamma spectrometry measurements to obtain more detailed and more complete information on the composition of gaseous effluents.

The volume of air to be filtered will be determined in such a way as to guarantee representative samples and adequate sensitivity for the measurement.

7. MONITORING OF RADIOACTIVE CONTAMINATION OF WATER

7.1. Introduction

Waters can be an important factor in the transport of radionuclides from wastes to man in view of the contribution made by fishery products and irrigated plants to ingestion of radiocontamination via the diet.

The existence of concentration phenomena in foodstuffs receiving contamination from water means that concentration limits have to be adopted which are lower than those set for drinking water. Where the water is not used for irrigation or fisheries the transfer of radionuclides to man may occur via drinking water, which will then be the critical pathway.

Where there are aqueducts supplying large groups of the population and capable of being contaminated by discharges from nuclear installations, drinking water can become an important route of transfer since it may be the cause of an appreciable collective dose. This will then have to be taken into consideration together with the determination of the dose delivered to the critical group as a result of the discharges made.

7.2. <u>Sampling Points</u>

As in the case of 6.2., the primary sampling point will normally be at the point of discharge of the radionuclides.

Where discharge is into a watercourse it will also be advisable to draw a sample up-stream of the discharge point in order to obtain information on any contamination not due to the installation itself. Since there may be cases where the direction of flow is reversed (e.g. because of tides) the up-stream point needs to be chosen in such a way that it is known not to be influenced by discharges from the installation.

Finally it may be necessary to choose further sampling points in zones where the most frequently caught fish in the region live and where water is drawn off for irrigation. It will also be desirable to know the average concentration in the receiving water: where this is a river the sampling should be done at a distance from the discharge point corresponding to the "mixing length". This length (beyond which there is a uniform distribution of effluent) varies for watercourse in question and for a given watercourse varies with the flow. It therefore needs to be determined by suitable experiments.

For a lake or basin the sampling point should be chosen in such a way as to give a representative mean value for the entire volume of water. Finally where effluent is discharged into or near the sea, samples should be taken at points where the concentration is higher on average than in any zones devoted to fishing or the collection of algae, shellfish etc. intended for consumption.

Where any discharges, deliberate or unintentional, can influence underground waters these will also need to be sampled at the point where the assumed concentration of radionuclides is highest.

7.3. <u>Types of measurement</u>

Samples taken in the discharge channel should be subjected to a total beta count (and possibly a total alpha count). The evidence is that this type of measurement serves purely as a guide and its only purpose is to detect unacceptable increases in radioactivity. Where pre-set levels are exceeded specific measurements of different radionuclides will be necessary, possibly preceded by suitable chemical separations.

For all other samples taken in the surrounding environment specific measurements of different radionuclides are normally required since the variations in concentration of naturally occurring radionuclides are often higher than any possible increase due to the radionuclides discharged from the installation in question.

Maximum concentrations are then established on the basis of the use to which the water will be put.

7.4. Frequency of sampling and measurements

The frequency of sampling and of measurement at the point of discharge will depend on the methods of discharge. Where discharges are continuous both sampling and measurement (in general a total beta count) will also have to be continuous as stated in the previous paragraphs, with the possible addition of specific analytical determinations where it is found that activity levels have increased beyond the statistical variations. However, for intermittent discharges (e.g. discharges made whenever a certain storage volume has been filled) the measurement will in general be preceded by a determination, on a representative sample, of the concentrations of the different radionuclides involved. In the case of effluents of very low activity it is sometimes possible to replace these determinations by a total beta count.

For samples taken at other points the sampling can be either continuous or weekly, monthly or quarterly according to the likely variations of activity, the scale on which discharges are made and the radionuclides discharged.

Measurements can also be made on composite samples (monthly or quarterly); these should preferably aim to supply specific information on the concentration of individual radionuclides.

The volume of the samples measured must be such as to permit the determination with sufficient accuracy of concentrations below the reference levels established for the water in question in view of the concentration effects found in the food chains associated with the water.

8. MONITORING OF RADIOACTIVE CONTAMINATION OF SOIL

8.1. Introduction

Soil can be contaminated either by discharges into the atmosphere of radioactive substances which are deposited after a certain time or by irrigation waters which have received radioactive discharges from a nuclear installation. Soil contamination can also be caused by leakage from pipes or from deposits of radioactive waste accumulated at appropriate storage points.

A large part of the radionuclides discharged into surface waters is absorbed to a great extent by suspended matter in the water or is deposited on the bed of the watercourse or on its banks. Elimination or accumulation of contamination will thus depend largely on the movement of the fine sediments on which the radionuclides preferentially attach.

8.2. Sampling points

Agricultural land, in view of what has been said above and for obvious reasons arising from concentration effects in cultivated plants, represents an intermediate link of pathways by which radionuclides can be transferred to man; this pathway is of importance only for long lived isotopes.

It should be possible therefore to establish a sampling point in regions of maximum build up according to the meteorological and hydrological characteristics of the site.

As regards sediments deposited on the beds of watercourses, however, there is generally more interest. In fact, these sediments act as integrators of the activity in the water and are also more easy to measure because of concentration effects occurring in the passage of radiocontamination from water to sediment.

Sediment samples can be collected at the following points:

a) up-stream of the point of discharge of liquid effluent from the installation at a distance such as to eliminate all influence of the installation, so as to indicate any contamination due to other sources

b) in zones favourable to sedimentation down-stream of the discharge point to indicate the overall behaviour of radio contamination in the water course and

c) on beaches or at points where sediments are collected for various purposes (dredging, formation of farming soil, etc.).

The object of these sampling operations is to monitor the possible modes of direct irradiation of persons who spend part of their time at those sites. As will be pointed out in section 10 the dose delivered can also be measured directly with suitable dosimeters.

This part of the monitoring programme will also serve to detect any undue concentrations in materials intended for use at places which may be remote from the installation and for which it would not be feasible to run a separate monitoring programme.

8.3. Types of measurement

Measurements on sediment and soil will have to be of a type specific for the different radionuclides in view of the presence of natural radionuclides in measurable concentrations.

In most cases gamma spectrometry measurements will be adequate to give a general picture of the situation sufficient for the purposes of radiological protection. As regards beta emitters (in particular strontium 90 which is of some interest because of its half life and chemical characteristics) it will always be necessary to precede the measurement by a specific chemical separation.

8.4. Frequency of sampling and measurements

In view of the integrating function of radiocontamination performed by the soil (both sediment and farm land) the collection and measurement of samples can be carried out at a fairly low frequency. This may be quarterly, sixmonthly or annually according to the extent of discharges at the particular site under examination.

The volume of sample to be collected will in general be several cubic decimetres and for agricultural land it must be restricted to the top 25 centimetre surface layer. However, the samples should consist of a number of sub-samples (5-10) taken from points several metres apart in order to guarantee good representation of the particular area.

9. MONITORING OF RADIOACTIVE CONTAMINATION OF FOODSTUFFS

9.1. Introduction

The food chain often plays an important part in the transmission of radionuclides to man. Knowledge of the concentrations of the different radionuclides is therefore fundamental to determining population doses.

Foodstuffs may be contaminated directly (e.g. lettuce by fallout near the installation or by irrigation water) or indirectly (e.g. in milk to which radiocontamination is transmitted via the food-cow-milk chain).

In certain type of foodstuffs and for some radionuclides (e.g. phosphorus 32 in fish) very high concentration factors of the order of 10^4 relative to water are observed.

9.2. Vegetation

9.2.1. Sampling points

Vegetation can be divided into edible and inedible species. The latter are of some importance since they can serve as biological indicators revealing radioactive contamination as a result of large concentration effects. Within this category we can consider for example: periphyton, algae, various aquatic plants, grass etc.

Edible species are important as direct carriers of radiocontamination into the food chain. Among the most important species we can distinguish cereals, vegetables and fruits. Areas down-wind of discharges into the atmosphere and points where irrigation uses water which might have been contaminated are important sampling points for vegetation.

In order to determine the background level, samples are taken from zones sufficiently far from the installation for its discharges to have no influence.

9.2.2. Types of Measurement

In general these will be measurements of particular radionuclides since total beta or alpha measurements are frequently of little significance in view of the presence of radionuclides of natural origin (for example: potassium 40, radium, etc.). The typical radionuclides to be determined in particular are those specifically concentrated by the biological indicators.

9.2.3. Frequency of sampling and measurements

The frequency of vegetation sampling depends on the characteristics of the plant in question. For annual plants (e.g. the various cereal species) the sampling and measuring frequency will also be annual. For plants which are harvested for food over several months (e.g. vegetables) we can in general take monthly samples during the growth period; the frequency of measurement will also be monthly. For short lived radioisotopes an appropriate frequency will be adopted for sampling and measurement.

Similarly for inedible plants we can arrange to take monthly samples over the whole growth period.

The weight of the samples will in general be in the order of a few kilogrammes of fresh weight.

9.3. Milk

9.3.1. Sampling points

Radioactive contamination is transferred to milk via the forage consumed by cows. The sampling zone will therefore coincide with areas irrigated by potentially contaminated waters or exposed to fallout from discharges to the atmosphere.

9.3.2. Types of measurement

The radionuclides to be found in milk are very closely determined by the metabolism of the cow. Gamma emitters can be measured by spectrometry on liquid samples or if necessary on dry residue. Beta emitters will require however suitable chemical separation before measurement.

9.3.3. Frequency of sampling and measurements

Representative samples can be taken every week and measured shortly afterwards by gamma spectrometry to determine the short lived isotopes. The samples can then be used to make up composite samples which can then be measured monthly for isotopes with longer half lives.

9.4. Aquatic fauna and flora

9.4.1. Sampling points

Fish, molluscs and crustacea are of particular importance in the propagation of radioactive contamination to man as a result of the high concentration factors which they generally present.

Sampling can be carried out either directly at the production points affected by the discharges or at points of collection and sale (markets) providing these are supplied from the production points. The most important radionuclides in this type of material are, in general, activation products and ruthenium 106.

9.4.2. Types of measurement

Specific measurements of the different radionuclides are essential. Since most of these are gamma emitters, usually no analytical problems occur since it is possible to carry out gamma spectrometry of the samples. In this way it is easy to determine concentrations of the order of some tens of pico-curies per kilogramme which are suitable at the reference levels.

9.4.3. Frequency of sampling and measurements

The scale and manner of discharges can obviously influence the sampling frequency. In general, however, quarterly sampling is sufficient. The frequency of measurements on the samples (preferably composite and statistically significant) can also be quarterly.

9.5. Meat

9.5.1. Sampling points

The scale of sampling for beef is important in areas where there is a significant amount of consumption by a certain group of the population. However, animals bred for the market may also be liable to radioactive contamination by inhalation or ingestion. In such cases sampling will be carried out at these breeding farms.

It is advisable to sample part of the diaphragm pillar partly because this is a muscle representative of the whole carcass so far as caesium 134 and 137 contamination is concerned and partly because it is a part having little value.

The thyroids of cattle, goats and sheep can serve as indicators of any contamination by iodine 131. This also makes it possible to characterise levels which are not directly measurable in milk.

As regards poultry the sample should be taken in the zone affected by transfer of radionuclides.

9.5.2. Types of measurement

The measurements required are determinations of particular radionuclides and present no special difficulty provided they can be carried out by direct gamma spectrometry.

9.5.3. Frequency of sampling and measurements

Quarterly sampling followed by appropriate measurement is generally sufficient. The sampling and measuring frequencies should be increased as appropriate where short lived radionuclides are involved.

It is desirable to use composite samples made up of pieces taken from at least ten heads.

10. MONITORING OF EXTERNAL IRRADIATION

10.1. Introduction

Close to nuclear installations there is the possibility of direct irradiation from the gas phase or other emissions transported by the atmosphere or from deposited sediments e.g. on the land or on the banks of watercourses.

The handling of contaminated material or equipment such as fishing nets can also be a cause of direct irradiation of the persons concerned.

Solid wastes arising from the installation can be a further source of direct irradiation. However, these are stored in appropriate depositories and shielded in such a way that they involve practically no risk of irradiation for the nearby population.

10.2. Measuring points

The external doses received by the exposed population can be evaluated by direct measurement of irradiation using dosimeters. These dosimeters can be located

- at a suitable number of points located around the point of discharge where maximum doses due to discharges from the nuclear installation are expected. For discharges into the atmosphere allowance must be made for the most frequent weather conditions, the topography and the characteristics of discharge points e.g. the height of the chimney;

- at other positions where the population is subject to external exposure (e.g. by deposition of sediments);

- at a sufficient distance and in the direction of the least frequent winds in order to obtain a relative indication of background radiation.

10.3. Types and frequency of measurement

The simplest and cheapest continuous method is to use integrating dosimeters which directly give the dose integrated over a period of time. These should be installed at fixed points with continuous exposure, some above ground level, and readings should be taken periodically.

Suitable instruments include thermoluminescent dosimeters and fluorescent glass plate dosimeters whose measuring range makes it possible to take periodic readings (e.g. monthly).

Photographic dosimeters are less suitable since their sensitivity varies with time and they are influenced by external factors such as temperature and humidity.

On the other hand, to obtain immediate information on doses one can use instantaneous dosimeters such as ionisation chambers or equivalent instruments with continuous recording of the measurements if necessary.

One can also carry out supplementary measurements to trace the general evolution of irradiation and detect any unauthorised discharges using detectors mounted on a vehicle. In this case, fixed reference points would be desirable to permit comparison of results obtained on different runs.

11. PRESENTATION OF RESULTS

In view of the plurality of installations and the utility of comparing the data collected it is desirable to follow certain rules in order to achieve a degree of uniformity in the presentation of results. The most commonly employed unit of measurement is the pico-curie and so far as monitoring networks around installations are concerned this will be per kilogram or per cubic decimetre of sample (per cubic metre for atmosphere). Strontium 90 concentrations are also given in pico-curies per gram of calcium.

Since the original material is often dried either for conservation or to increase the sensitivity of measurement it is necessary to specify whether the activity is based on fresh weight or dry weight. In the latter case it is also advisable to give the corresponding ratio (dry weight / fresh weight). In the Common Market countries bulletins at national and international level are published which show the results obtained by local and national monitoring networks for environmental radioactivity. These publications can usefully be taken as models for the presentation of data.

Finally, the results for monitoring networks close to a nuclear installation should be accompanied by complementary information such as an evaluation of the receiving capacity of the environment affected, an evaluation of the effective dose to the population etc. This makes it easier to evaluate the impact of the installation in question on the environment.

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