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RADIOACTIVITY IN AGRICULTURAL PRODUCTS AND ITS ASSESSMENT BY ENVIRONMENTAL SURVEY

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1. INTRODUCTION

There is general agreement that the primary purpose of surveys of radioactivity in agricultural products near nuclear establishments is to ascertain whether radioactive substances have been discharged to an extent which has, or may in the future, deliver an unacceptable radiation dose to neighbouring members of the population. This requirement can, however, be interpreted in many ways; there could be little better evidence of this than the contrasting procedures which have been used in different areas. Sometimes, extensive measurements of the total alpha, beta and gamma activities on the ground, in foodstuffs and in water have been undertaken; sometimes, almost every local product on the shelves of the supermarket has been examined for many nuclides and the report on the year's activities may cover some 200 pages or more; sometimes, attention has been confined almost entirely to only a few nuclides in a very few foods. If it is concluded that relatively modest surveys provide adequate information it must follow that much effort has on occasions been squandered. No criticism of past activities is implied by this conclusion; indeed, if, as will be here suggested, adequate information can be obtained by relatively simple methods, this is largely a result of experience gained laboriously at an earlier time.

The basic principles of surveys are determined in part by the criteria for radiation protection and in part by the manner in which radioactive materials behave in food chains. These questions will, therefore, be considered before suggestions are made on the practical aspects of survey procedures.

2. BASIS OF RADIATION PROTECTION CRITERIA

The derivation of numerical values for assessing environmental contamination is outside this discussion.[1] It is important, however, to clarify some basic concepts. The Recommendations of the International Commission on Radiological Protection[2] at once come to mind in this context, but difficulties can arise in applying them to environmental situations. This is not surprising, as the 1959 Recommendations of ICRP were directed primarily to occupational situations, and statements on the exposure of the population were usually made in less definite terms. None the less, the general intentions of the Commission are apparent, especially from the addendum to its Recommendations agreed in 1959.* Referring to the exposure of the population, the Commission then stated:

> "The basis for the limits of permissible exposure of the population to man-made sources of ionising radiation is the dose received by the various organs of the body and not the MPC values or other criteria by which the dose is controlled."

This statement may reasonably be regarded as applying also to persons living in the neighbourhood of controlled areas (i.e. Group B (c)), and it is with them that we are here particularly concerned. This principle has a number of important implications:

(a) Since the dose received from any one nuclide is determined by the total radioactivity in the daily intake, the levels in individual components of diet, or water, are of interest only in so far as they contribute to this total.

(b) Since the dose delivered by unit intake of different nuclides differs very widely, measurements of the total alpha, beta or gamma activity have little value; individual nuclides must be considered.

(c) Since the basic criterion is the tissue dose, and *not* the radioactivity per unit weight of individual foods, the significance of dietary contamination is appropriately assessed in terms of those nuclides and foodstuffs which are responsible for the highest tissue dose.

Accordingly, if it can be shown that but a few nuclides will always be responsible for the major exposure in any area and that they will enter the body mainly in a few foods, attention can be confined to these *"critical" nuclides and foods*. The adjective "critical" can conveniently be applied to them with essentially the same meaning as the phrase "critical organ". As will be shown later, the main contribution of food chain studies to the design of environmental surveys has been the unequivocal identification of critical nuclides and foods in many circumstances.

In applying these concepts to the evaluation of environmental contamination, the tissue doses with which we are concerned are defined by ICRP as the *dose delivered per year* and many authorities agree that the manner in which it is distributed through the year need not be considered.

A final and equally important question relating to the basis of protection

* See Addendum, p. 10.

criteria is whether the limits of dose recommended by ICRP for members of the population living in the neighbourhood of controlled areas (i.e. Group B (c)) are to be regarded as applicable to each separate individual or to the average for small groups living under comparable conditions. ICRP gives no specific ruling on this question but it may be considered to point the way to a sensible interpretation. It does *not* use the words "for *any* individual" in specifying limits of dose for Group B (c) though they are applied to the other special groups B (a) and B (b) (ICRP Recommendations[2], compare paras. 54 and 55). While it may be debated whether this small contrast in the usage of words was intentional or not, it must be concluded that the Commission did not specifically recommend that its criteria should be applied separately to single individuals in Group B (c). Common sense, the ultimate arbiter, points to the same conclusion. In the well chosen words of the White Paper on the control of radioactive waste[3]:

> "It is impossible to examine the habits of every individual. The normal procedure is to investigate the habits of a sample of the population involved. . . . There must always remain the possibility that somebody of such grossly different habits as to be unpredictable from the observed pattern in the sample may receive exposure higher than a tenth of the occupational maximum permissible level. However, since safety factors are generally retained in these estimates, the possibility is remote. In our view this approach is satisfactory."

The words "safety factor" are the key to the situation, though it might be argued that the words "the smallness of any risk to the individual" might have been as appropriate. ICRP have stated that any effects caused by exposure to the maximum permissible occupational level (that is to say, 10 times that set for Group B (c)) would be so small that they could be detected only by statistical methods applied to large groups (ICRP Recommendations[2], para. 31) and although accurate quantitative estimates of the risks associated with exposure at these low levels of radiation cannot be made, it is apparent that they are very small relative to the many hazards of everyday living against which the community takes no measures.

One obvious and unavoidable difficulty arises from the conclusion that we are concerned with the mean exposure of a small group, not individuals. The small group cannot be specified in rigid terms. The manner in which it is defined can only be decided in the light of local circumstances. There is, however, one aspect on which we can be specific, namely, that different age groups should be considered separately. In practice the risk to young children will usually be dominant, not only because they may be more sensitive to radiation injury but because frequently, as will be shown later, environmental contamination is likely to expose them to the highest doses.

To sum up, therefore, the basic radiological protection criteria which should guide the planning of environmental surveys is that the highest radiation doses which will be received by small groups of any age should be estimated; this task can be accomplished by measuring the critical nuclides in the critical foods.

3. CRITICAL NUCLIDES AND CRITICAL FOODS

The nature of the operations carried out in any establishment determines both the identity of the critical nuclides and the potential magnitude of risk. The critical foods vary depending on agricultural practices and dietary habits. In this discussion circumstances in the United Kingdom alone are considered, and we are therefore concerned with a single broad dietary pattern, the most important characteristics of which are that about 75 per cent of the total dietary calcium which is of biological origin is usually contained in dairy produce, and that milk is particularly important in the diet of children.

With regard to the system of agricultural production it is of great significance that whereas the entire milk supply of a localized community, particularly in country areas, may come from nearby farms, many other foods are normally obtained through commercial channels largely from distant sources. It follows that in a localized emergency, such as might result through the escape of radioactive materials from a nuclear establishment, the significance of contamination of milk will be enhanced relative to that of other foods.

The general behaviour of radioactive substances in food chains is now so well known (see, for example, Refs. 4, 5, 6) that only a brief summary is necessary:

A. *Release of Mixed Fission Products in Fission Yield*

It can rarely be expected that fission products will be released in fission yield, but this case is an appropriate starting point.

Iodine 131 will be the critical nuclide in the early period and, if the release occurs when cattle are grazing on open pastures, milk will be the critical food. The thyroid glands of infants fed on fresh milk may receive doses 20 times greater than those of adults. If deposition occurs during the winter months, when cattle are receiving stored food, the risk will be very greatly reduced.

Strontium 89 and strontium 90 are the other critical nuclides in mixed fission products. The former is the dominant source of concern if the mean age of the fission products is less than about 6 weeks and the release of such material in appreciable quantity from a nuclear establishment is highly unlikely. Milk will again usually be the critical food, though it is possible that cereals may sometimes deserve special concern, for example, if a release occurs shortly before the crops mature. With the passage of time strontium 90 may be present to some extent in all foods. However, if the deposited material is in a finely divided freely soluble form, and thus readily transferred to milk in the early period, the radiation doses then received will appreciably exceed those caused subsequently by its presence in other foods.

Caesium 137 is likely to be next in importance to the isotopes of iodine and strontium, though to a considerably smaller extent.

B. *Fission Products Released from Nuclear Reactors*

Because volatile nuclides are likely to escape into the environment considerably more readily than other fission products, the significance of iodine 131 relative to other nuclides is likely to be much enhanced and possibly also that of caesium 137 though it is not likely to be of major concern.

C. *Release of Other Radioactive Materials*

At chemical separation plants it may be necessary to consider the possibility that fission products not enumerated in the preceding sections, or other radioactive materials, may deserve particular consideration. No generalization can be made; each situation should be considered on its own merit.

D. *Special Problems due to Sparingly Soluble Materials*

In the preceding paragraphs it was assumed that the released radioactive material is in a freely soluble form so that it can enter readily into food chains. If, however, sparingly soluble materials are released, the maximum radiation dose rates may occur only after the passage of an appreciable period of time during which the material is rendered soluble in the soil. This is important only with long-lived nuclides, for example, strontium 90. In such cases it will be obviously desirable to obtain information on the possible magnitude of risk in advance of its occurrence and the examination of the critical food by itself will not provide this information. Where this type of situation is likely to occur it is therefore necessary to measure not only the critical food but also the total deposit on the ground surface.

E. *The Problem of Drinking Water*

In view of the importance which is rightly attached to the purity of water supplies, it is worthy of note that the omission of any reference to drinking water in this section is *not* accidental. It is well established that when radioactive substances have been released in the atmosphere the contamination of water or aquatic produce makes only a very small contribution to the total intake.

4. ORGANIZATION OF SURVEY

It was suggested in the Introduction to this paper that the object of continuing surveys in the environs of nuclear reactors is to satisfy both the operators and statutory authorities that unacceptable quantities of radioactive materials have not been released; surveys in emergencies present special, though technically simpler, problems which are not considered here.

It is sometimes suggested that reactor site surveys should be expanded above the minimum necessary for their primary purpose in the hope of also obtaining scientific information on food chain mechanisms. While it would be wrong to suggest that it is impossible to combine these two objectives, the difficulty of doing so should be emphasized. It is unlikely that important information on food chain mechanisms, or on the movement of radioactive substances in the soil, will be obtained unless the investigation has been specifically designed for these purposes and elaborate methods are employed; moreover, it is usually found that agricultural and meteorological information must also be assembled if interpretations are to be adequate.

When the objective of a survey has been determined, it is important to consider how the necessary information can be obtained with the *minimum expenditure* of effort. The following suggestions, made with this aim in mind, are directed to surveys the sole purpose of which is to ascertain whether an unacceptable release has occurred:

A. *Information Necessary to Guide the Planning of Surveys*

The appropriate starting point is an assessment of the mode of operation of the establishment to ascertain *firstly,* what nuclides merit investigation, *secondly,* at what distance from the establishment the maximum deposit would be expected and, *thirdly,* the distance beyond which no appreciable contamination can reasonably be expected. In this way "inner" and "outer" sampling zones can be defined. A comparison of the levels of activity found in them provides a basis for distinguishing the contamination due to the operation of the plant from that which arises from world-wide fallout or other causes. If an assessment of these matters leads to the conclusion that any appreciable contamination would always be adequately detected by monitoring equipment on the site it would be appropriate to consider whether a continuing environmental survey were indeed necessary. It is here assumed that this assessment leads to the conclusion that environmental levels of iodine 131 and strontium 90 should be examined.

Having defined the inner and outer sampling zones, the nature of agricultural enterprises must be examined to reveal the sites at which critical foods are produced. Local environmental factors which may influence the

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extent to which radioactivity is transferred to the critical foods must be recorded so that any sites of potentially high contamination can be given special consideration.

B. *Selection of Sampling Sites*

The aim is to select a number, possibly 4–6, sampling sites, which are as widely spaced as possible, in both the inner and outer zones. If the wind is usually in one direction it may be appropriate to pay special consideration to farms in the downwind sector. In practice, the obtaining of adequate coverage in the two zones may necessitate some adjustment of their boundaries. Since milk is the critical food for both iodine 131 and strontium 90, farms producing milk will normally be the chosen sampling sites.

C. *Frequency and Bulking of Milk Samples*

Because the levels of iodine 131 and strontium 90 in milk reflect contamination of pastures only in the previous few days, frequent sampling is desirable, for example, once every two weeks. Analyses of iodine 131 must be carried out after each collection because of its rapid decay. For the assay of strontium 90 it would, however, be appropriate to bulk samples over periods of up to 3 months. Assuming that negligible or low levels of radioactivity are released, and the analytical procedures are sufficiently accurate, it may be reasonable to combine samples from different sites in each sampling zone. If, for example, the produce of five farms were combined and the radioactivity in the bulked sample was shown to be not more than one fifth of the specified levels it would be established that an unacceptable level did not occur on any farm.

D. *Sampling of Materials Other than Milk*

If it were judged necessary to consider the possible release of strontium 90 in sparingly soluble particles, sampling of herbage and the root mat should be undertaken at annual intervals at each sampling site so that the total deposit per unit area can be investigated. More frequent sampling for this purpose lacks justification in normal circumstances, both because of the long integrating period on the ground surface and because tissue doses are assessed as annual averages.

Sometimes, owing to climatic factors, the supply of milk may cease for part of the year. If it is judged necessary to consider the possible contamination of diet during such periods the most convenient procedure may be to sample the type of grass which cattle would consume and infer the levels in milk which would arise from knowledge of the relationship between the contamination of herbage and that of milk. If this procedure indicates that radioactivity in the milk would not have exceeded an acceptable level it would be unnecessary to examine other foods. However, if there is only a short interruption of milk production the necessity for this work is doubtful, provided that the operation of the establishment is known to be normal.

Surveys of the type here suggested involve only a few dozen measurements per year.

Finally a question which, strictly, lies beyond the scope of this paper may be considered. Sometimes it is suggested that environmental surveys greatly exceeding those here suggested are both justified and desirable, if not for scientific reasons, because they have an excellent effect on public relations. As against this view, is it not possible that considerably greater public confidence might be encouraged if it became widely known that the major potential risk had been so clearly identified that a limited programme was wholly adequate? There may, indeed, be some justification for suggesting that the design of environmental surveys should only be entrusted to those who, though fully conscious of the importance of ensuring safety in the environment are, in modern parlance, strongly motivated to reserve their energies as much as possible for more productive tasks. These will necessarily be persons who see the problems of environmental surveys in true perspective.

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ADDENDUM

Since this paper was prepared ICRP have issued Publication 6 (1964). The designation of different groups in the population has been revised and other modifications have been introduced, but the general interpretations referred to in this paper are not affected.