A METHODOLOGY FOR THE EVALUATION OF COLLECTIVE DOSES ARISING FROM RADIOACTIVE DISCHARGES TO THE ATMOSPHERE

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INTRODUCTION

The usual approach to protecting the public from exposure to radioactivity in the environment has been based on identifying the critical pathways to man for particular radionuclides. By controlling the radiation exposure of the critical organs of individuals in the population who were most highly exposed the remainder of the population could be assumed to be adequately protected. The system of dose limitation proposed by the International Commission on Radiological Protection (ICRP) in Publication 26 (1) is based on the consideration of the total risk associated with radiation exposure and it has become necessary to evaluate the radiation exposure of individuals by all pathways from all radionuclides to which they are exposed. At the same time the total health detriment from a radiological practice has become recognised as an important quantity by which the radiological harm to exposed populations can be judged. The ICRP also recommends (1) that once a radiological practice has been shown to be justified, any resulting radiation exposure should be kept as low as reasonably achievable. The dual emphasis on total dose to an individual and on optimisation with the latter implying the need to evaluate total health detriment means that the exposure of the whole population must be considered, through all pathways and for all radionuclides for as long as they persist in mans environment. To achieve this objective when considering releases to the atmosphere it is necessary to have an understanding of the way in which radioactive effluents are dispersed in the environment, of the transfer processes which take place from the environment to man and of the spatial distribution of the population and of agricultural practices around the discharge point.

It is difficult to define a single radiological quantity which adequately describes the total number of health effects which will appear in an irradiated population. The collective effective dose equivalent commitment as defined in ICRP Publication 26 (1) has been used elsewhere as a first approximation to such a quantity although the limitations of this approach have been recognised (2).

In this paper a methodology is described for evaluating collective dose from the major routes of exposure following a release to atmosphere. The routes considered are inhalation both of the material in the initial cloud, and that resuspended from the ground, external irradiation from the radioactive decay of the material both in the cloud and deposited on the ground, and ingestion of radionuclides transferred through the foodchain.

ENVIRONMENTAL MODELLING

An atmospheric dispersion model (3) is used to derive the spatial distribution of the activity around the release point taking into account the height of the release and the meteorological parameters specific to that site. The radiation exposure of an individual from inhalation is evaluated from the air concentration at any point using an appropriate breathing rate and a knowledge of the dose distribution to human organs and tissues per unit of activity inhaled.

The individual exposure from external irradiation by both electrons and photons from the material in the cloud is also evaluated from the air concentration. A semi-infinite cloud model is used to evaluate the absorbed dose in air from electrons; since the sensitive basal layer of the skin is at an average depth of 70μm, a correction factor is necessary to obtain the relevant dose equivalent. The absorbed dose in air from photons is evaluated by means of a finite cloud model which takes account of the distribution in space of the material in the cloud. The absorbed dose in air is converted to dose equivalent in body tissues using factors derived by Poston and Snyder (4).

The amount of activity deposited on the ground by both wet and dry deposition mechanisms is evaluated and the radiation exposure from external irradiation from the deposited material is calculated taking into account the migration of the activity down into the soil (2). The air concentration from resuspension processes and hence the dose from inhalation of resuspended material is evaluated using a time dependent resuspension factor (2).

The radioactivity appearing in foodstuffs is estimated by using a time dependent foodchain model (5) which relates the level of contamination in the foodstuffs produced at a specific location to the amount of material deposited there. The dynamic nature of the model enables time dependent processes, which may be important for long lived radionuclides, to be represented : these include the build-up of activity in soil and animal tissues and the migration of activity through the soil. Other important mechanisms involved in the transfer of activity to foodstuffs derived from plants and animals are represented in the model; they are interception and retention of deposited activity on plant surfaces, resuspension, translocation and root uptake into plants, transfer to animals by consumption of contaminated pasture, inadvertent consumption of soil, inhalation of the initial cloud and resuspended activity and the metabolism of radionuclides in the animals following intake.

POPULATION AND AGRICULTURAL DATA

The models described above allow the radiation exposure of individuals to be calculated from a variety of routes and the activity appearing in various foodstuffs at all points around the discharge site to be evaluated. To complete the estimation of collective dose it is necessary to know the distribution of the population and of agricultural practices around the site of interest. In assessing the collective dose from the ingestion pathway it is assumed that all activity reaching foodstuffs is consumed by man; it is therefore

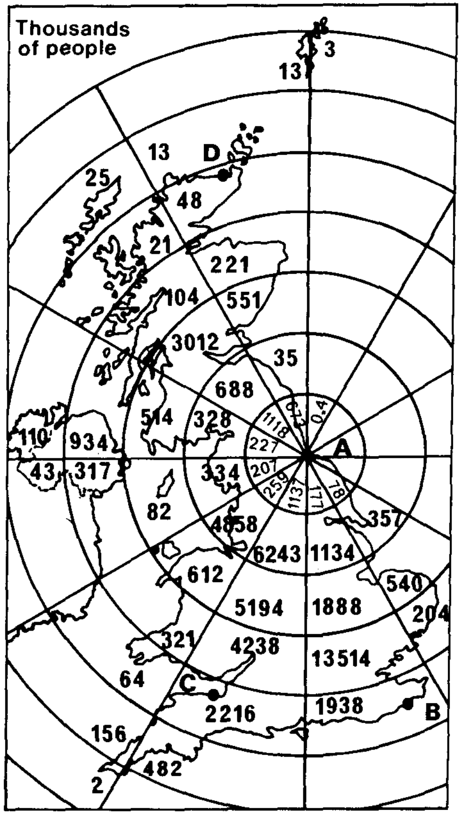

Fig 1 Location of sites and the population distribution around site A

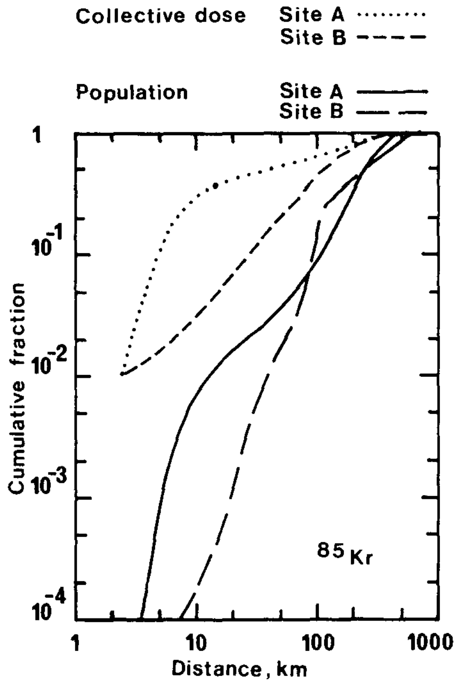

Fig 2 Cumulative population and collective dose from skin β irradiation v distance

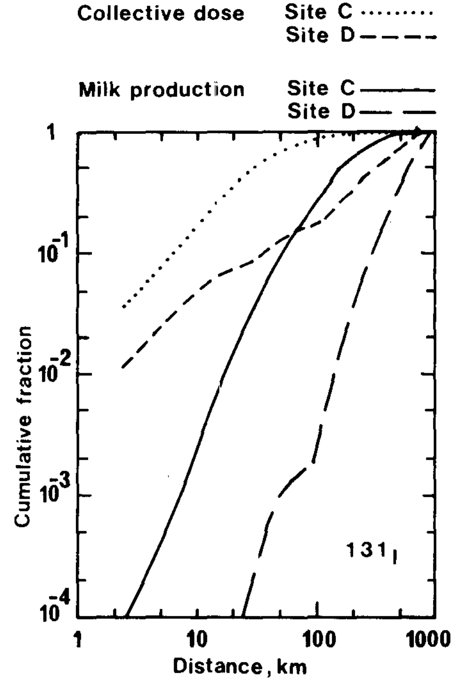

Fig 3 Cumulative milk production and collective dose from ingestion v distance

unnecessary to make assumptions concerning individual dietary intakes.

Population data in the form of a listing of the numbers of people living in each 1km square of the National Grid of Great Britain, as recorded at the 1971 census, together with similar data for Northern Ireland, are used to determine the number of people at a given distance in a given direction from the site, as shown in figure 1.

Similarly, grids of agricultural production have been generated based on national agricultural statistics. 5km grids exist for the most important agricultural products as identified in the foodchain model ie grain, green vegetables, root crops, beef, cows liver, mutton/lamb, sheeps liver and cows milk.

EXAMPLES OF CALCULATIONS

The contribution by each exposure pathway to collective dose from a small segment of area is calculated by combining estimates of the individual dose with the population of the segment or the dose per unit mass of foodstuffs with production in the segment. The total collective dose for each exposure pathway is the sum of the contributions from all such segments around the point of discharge. This process is repeated for each nuclide and pathway to evaluate the total collective dose from a discharge.

An example of the results of collective dose calculations is shown in figure 2. The variation of the cumulative populations and collective doses from β irradiation with distance from the point of discharge are contrasted for the discharge of krypton-85 from two sites A and B whose population characteristics are quite different. The ratio of the total collective dose from unit discharge at site A to that at Site B is 1.7. The rate of accumulation of collective dose with distance is very different for the two sites. The majority of the collective dose at site A comes from quite close to the site and consequently the individual doses contributing to the collective dose are generally higher than is the case for site B.

A similar example is shown in figure 3 where the variation with distance of cumulative milk production and collective dose from the ingestion of contaminated milk and milk products from the release of I-131 is given. Here the difference in the total collective doses from the two sites C and D which are located in markedly different agricultural areas is even more pronounced, the ratio being 20.

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