ASSESSING THE RADIOLOGICAL CONSEQUENCES OF SURFACE CONTAMINATION IN URBAN AREAS - AREAS OF UNCERTAINTY AND THEIR RESOLUTION

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INTRODUCTION

In the preparation of contingency plans for accidents involving releases of radioactive materials to the atmosphere it is necessary to have an appreciation of the likely effects of any countermeasures which may be employed. The effects to be considered are the radiation dose saved by, and the social economic costs of, the implementation of countermeasures. This type of basic information is also necessary for predictive assessments of accident consequences. The basic data necessary for the assessment of the consequences of land contamination by long-lived radionuclides are incomplete. The deposition of radionuclides from atmosphere and their retention on surfaces in urban areas are not well understood; neither is the effectiveness of large scale decontamination techniques well-known for other than deposits of large insoluble particles. In this paper a summary is presented of the results of a review study into the available data on these subjects[1]. Areas of data shortage are identified and the outline of a research programme to remedy some of these data deficiencies is presented.

POTENTIAL SOURCES OF LONG-LIVED ENVIRONMENTAL CONTAMINATION

In any industrial, medical or research application involving the use of significant quantities of radioactive materials there exists a small but finite potential for an accident to occur which may lead to the dispersal of radionuclides in the environment. Potential accidents at nuclear reactors, and particularly water-cooled reactors, have received considerably more attention than many other types of accident. This is, in part, due to the increasingly large numbers of such reactors in the world, some sited close to large population centres and because of the existence, in a reactor system, of mechanisms which under fault conditions can lead to the release and environmental dispersal of significant quantities of radioactive material albeit with very low probabilities of occurrence. For many other types of installation it is more difficult to conceive similar large scale releases largely due to the absence of a potential energy source which could disrupt the protective enclosures provided.

Where mixtures of radionuclides are involved in an accidental release, for example, one involving nuclear fuel, it is generally predicted that the largest fractions of released nuclides will be of those which are volatile in nature, for example, isotopes of iodine and caesium. The volatility of caesium and the long-lived nature of its radioisotopes is likely to result in their constituting the major long-term environmental problem in the majority of accidental release scenarios which can be envisaged from nuclear installations. This has been demonstrated in an analysis of exposure pathways to man from ground deposits of radionuclides released in representative hypothetical reactor accident sequences[2]. The radiation dose to man from external irradiation and from ingestion of foodstuffs grown on the contaminated soil is seen in figure 1 to be dominated, at times beyond the first year, by the contributions of the isotopes of caesium. Attention is therefore focused in this review on the environmental problems associated with radio-caesium although much of the discussion is likely to be applicable to other environmental contaminants.

The most probable forms of release for caesium from thermal reactors are as a sub-micron aerosol formed from coagulated fume or as one of several fission products absorbed on to particles of iron or other materials present in the containment[1]. At distances of more than a few kilometres from the reactor the deposit is likely to be predominantly of small (< 10 μm) particles.

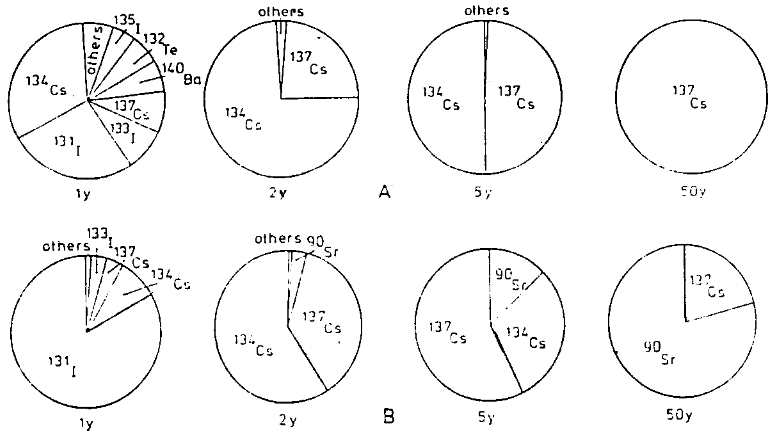

Figure 1 Fractions of annual effective dose equivalent due to (A) external irradiation and (B) ingestion

DEPOSITION OF PARTICLES ON VARIOUS SURFACE TYPES

The radiological consequences of an accidental release may be strongly influenced by the pattern of distribution of deposited material in relation to centres of population. Rainfall during the passage of the plume may cause higher areas of ground deposit, resulting in relatively higher radiation doses to people living in these areas. Uneven patterns of deposition may also occur in dry conditions mainly due to differences in the nature of the terrain over which the plume passes. Experimentally, the variations in deposition behaviour with particle size, wind velocity and surface roughness are measured using the deposition velocity, Vg.

Most measurements of Vg have been made over vegetated surfaces and, in particular, over grass. Few measurements have been made in urban areas and as a result, considerable uncertainty exists in the prediction of dry deposition in urban areas. From a theoretical viewpoint, vegetated surfaces have a greater surface area per unit ground area than smooth urban surfaces and therefore a greater deposition per unit area due to interception and impaction processes might be expected. This has been observed on bare soil surfaces and other smooth surfaces placed in rural areas for small particles of various materials. In an urban area the extra turbulence created by the presence of buildings may counteract this effect although it has been suggested, on the basis of caesium fall-out data that deposition velocities on walls, roofs and roads in urban areas is less by an order of magnitude than for rural vegetated surfaces(3).

The radiation dose to people inside buildings depends upon the level of surface deposits inside as well as outside the building. However, the available data on the subject strongly suggest that in the event of an atmospheric release of small particles there will be significantly lower deposition inside houses as compared with surfaces out of doors(1).

RUN-OFF IN URBAN AREAS

The scavenging action of rain passing through an airborne plume can be very effective in depositing a large fraction of its contents over a small area. If there is a significant amount of rainfall in a short time some of the deposited material may be washed away from the place where it was deposited and in urban areas be transported via gulleys into drains and eventually into sewerage systems. For accidental releases of caesium to atmosphere, wash-out from the plume into urban areas is one of the scenarios which produces large environmental consequences[4]. Run-off is therefore potentially important as a mechanism for removing caesium from man's immediate environment, but is not considered in most accident consequence assessments due to the absence of suitable models.

SHIELDING FACTORS IN URBAN AREAS

Recent studies indicate that most external dose models used in generic calculations tend to underpredict the average amount of shielding provided by buildings in urban areas[5]. The shielding factors vary depending upon the nature of urban building structures and need to be evaluated on a national basis.

THE NATURAL WEATHERING OF SURFACE DEPOSITS

Weathering, due to the action of wind, rain and temperature change, can be effective in removing contaminants from environmental surfaces. The removal processes vary depending upon the nature of the surface and are very different for urban as compared with rural surfaces. A quantitative estimate of the rates of the weathering processes for the most important of the long-lived radionuclides would be valuable for the purposes of prediction in relation to accidental release consequence and in pre-planning.

There appear to have been no studies directed at observing the natural weathering of radionuclides on urban surfaces and what little information is available has to be gleaned from a few measurements made of fall-out caesium on building surfaces. Measurements on roofing materials and bricks indicate that only a few per cent of the total fall-out caesium deposit remains on these surfaces[1]. However, the rate of weathering shortly after deposition cannot be determined from these studies.

DECONTAMINATION OF ENVIRONMENTAL SURFACES

A substantial amount of information on some aspects of this subject became available as a result of studies conducted during the 1950's and 60's to provide information for use in planning recovery operations for the event of a nuclear attack[6]. Decontamination was attempted using comparatively simple and inexpensive techniques which could be applied on a large scale; the most commonly applied techniques were mechanical sweeping (roads and pavements), fire hosing, compressed air blowing and vacuum cleaning. Other more sophisticated and expensive techniques were also applied, for example, sand blasting and steam cleaning. Decontamination factors of 10 or more were readily achievable for most surfaces tested with the simpler techniques for particle sizes greater than about 75 μm diameter although, as might be expected, the efficiency was lower on rough surfaces. It was observed that the same techniques applied to surfaces contaminated with simulated fall-out in the 20-75 μm range were much less effective; decontamination factors of two or three were all that could be achieved. Only one study appears to have been reported in which the results may be directly applicable to the estimation of the likely effectiveness of decontamination techniques for small particle caesium deposits in urban areas[7]. Solutions of rubidium-86, as an analogue for caesium, were deposited on asphalt road surfaces by watering-can spray and left to dry. Their removal was attempted by fire-hosing at various times afterwards. In no case was a decontamination factor greater than 2 achieved even after several hosings.

SIGNIFICANCE OF THE IDENTIFIED UNCERTAINTIES

The uncertainties in the topics identified in the preceding sections may have a significant influence on the predicted consequences of an accidental release. For example, the suggested values for dry deposition velocity in urban areas, and for the average shielding factor in urban areas could lead to overall reductions in dose by up to two orders of magnitude, compared with calculations based on standard assessment models. Similarly in wet conditions, although the ground deposition would not necessarily be underpredicted by current models, when account is taken of that which may be lost due to run-off, doses in urban areas may be significantly reduced.

For a given hypothetical release the scale of the plans necessary to implement this countermeasure would be influenced by any uncertainty in the factors affecting dose assessment and, in addition, by the assumed effectiveness of decontamination procedures.

A RESEARCH PROGRAMME TO RESOLVE SOME OF THE IDENTIFIED DEFICIENCIES

This experimental programme is currently under way at the Atomic Energy Research Establishment, Harwell and at the National Radiological Protection Board, Chilton. The work is receiving support from the United Kingdom Nuclear Installations Inspectorate, London.

The topics to be studied in the research programme may be summarised as follows:

(i) the development of techniques for contaminating surfaces that can be readily applied in investigations of both natural weathering and forced decontamination.

(ii) measurements of the retention of surface contamination on a variety of urban materials as a function of time after contamination (natural weathering).

(iii) evaluation of the effectiveness of techniques for decontamination of urban materials in which caesium, in representative physico-chemical forms, has been deposited (forced decontamination).

(iv) measurement of the long-term retention of fall-out Cs-137 on urban surfaces.

(v) assessment of run-off in an urban environment by investigating the behaviour of fall-out Cs-137 and other non-radioactive materials.

(vi) assessment of shielding factors in UK urban areas.

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