GROUND CONTAMINATION FOLLOWING AN ACCIDENTAL RELEASE

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Summary: Some long-term problems of ground contamination are discussed. It is concluded that the release of a plausible mixture of fission products from a reactor to the atmosphere can lead to γ-ray doses from the ground comparable in significance with the initial inhalation hazard, if no countermeasures are taken.

1. INTRODUCTION

For reactors operated by the CEGB, the emergency plans concerning hazards to the general public are aimed first at obtaining a rapid assessment of dosage that may arise through inhalation. Later on, measurements of ground contamination are made over a wider area of country to establish the possible need for a temporary ban on certain foodstuffs. The greatest individual doses arise potentially from I-131 in milk, but the priorities for action place inhalation hazards first, because prompt evacuation may be needed in order to avoid them. In some cases ground contamination can give rise to additional radiation dosage accumulating over periods of several years, so that further countermeasures may be required on a less urgent time scale. In this paper we discuss the nature and implications of some of these long-term hazards.

2. CRITERIA FOR EMERGENCY ACTION

In the UK, the possible need for action to protect the public after an accidental release is assessed on the basis of Emergency Reference Levels (ERLs) of dose to the various organs of the body (1): where these doses are unlikely to be exceeded, action is deemed unnecessary. For practical purposes derived ERLs of more readily measurable quantities are used. In particular, ground contamination levels are specified for the nuclides I-131, Cs-137, Sr-89 and Sr-90, assuming that dosage to the thyroid, whole body and bone marrow respectively, occurs through the consumption of milk from cows grazing on contaminated pasture. These derived levels are appropriate criteria for deciding whether control of milk supplies is necessary.

The time for which such restrictive measures must continue is highly relevant to their practicability and cost. Contamination in milk from I-131 and Cs-137 can be effectively avoided by a ban of a few weeks duration, because of the short half-life of I-131 and the low rate at which caesium is transferred to vegetation once it has become fixed in the soil. Contamination with Sr-90 is more persistent, but strontium is unlikely to be released in significant proportions from a reactor accident because of its low volatility.

Significant dosage can also arise through γ-irradiation from nuclides on the ground. Here Cs-137 is of special importance on account of its long half-life (30 y) and its tendency to become fixed in the soil (2). A deposit of 1 $\mu Ci/m^2$ Cs-137 can give an exposure of 0.6 Roentgens in air at 1 m above ground in the 50 years following deposition (3), which may be compared with the 0.6 rem whole body dose (to a six months old child) that may arise from the same nuclide through the milk chain. The essential difference is the time for which the hazard persists, so that either decontamination or many years restriction of access would be required in order to avoid γ-ray dosage from deposited Cs-137. Other nuclides that may be released and lead to significant γ-dosage are Cs-134, Ru-106 and Ru-103, but their shorter half-lives result in a less persistent hazard.

A third mechanism for radiation dosage from ground contamination is resuspension as a respirable aerosol, which is mainly of concern in the case of long lived actinides. Although this complex process is hard to treat satisfactorily, a recent model (4), which allows a rate of resuspension gradually falling to a constant residual level, may be tentatively applied. It then appears that 1μCi/m^2 Pu-239 on the ground would give 10 rem to the child's lung over a few weeks, and a lung dose of 0.1 rem per lifetime to each succeeding generation. On this basis the possibility of contaminating significant areas with plutonium is well outside the range of accidents normally considered credible for a gas-cooled thermal reactor.

3. IMPLICATIONS FOR REACTOR ACCIDENTS

To put these matters in perspective, we now consider a hypothetical release. All the volatile and 1% of the non-volatile fission products are released from 1 kg of oxide fuel irradiated for 1000 days at 20 MW/t in a thermal reactor. The released materials are dispersed in average atmospheric conditions (neutral stability, Pasquill Category D, with 5 m/s wind speed) and dry deposition takes place with a deposition velocity of 3 mm/s. From these assumptions it is possible to calculate the extent of areas where doses in excess of the ERL may arise by the various routes. Some of the release data and the results of the calculations are shown in Tables 1 and 2; the accumulation of γ-exposure with time is shown in Figure 1.

Nuclide	ERL(μCi/m^2)	Release (Ci)
Sr-89	190	4.9
Sr-90	6.6	0.46
Ru-103	-	760
Ru-106	-	280
I-131	1.8	550
Cs-134	11	34
Cs-137	18	60

TABLE 1: Derived ERLs for ground contamination*, and activities of main nuclides released.

*From Reference 1, except for Cs-134.

Criterion	Route	Downwind (km)	Area (ha)
30 rem Lung	Inhalation≠	0.72	5.2
30 rem Thyroid		0.60	3.6
30 rem Thyroid	Milk≠	8.3	460
10 rem Whole Body		0.65	4.3
10 rem Bone marrow		0.06	0.05
15 R γ-exposure	Ground-γ	0.52	2.8
Same, Cs-137 only		0.35	1.4

≠ Dose to 6 months old child

TABLE 2: Extent of areas where ERLs may be exceeded.

The calculated areas fall into three groups. The largest area is for an ERL of I-131 through milk. Secondly, the areas for caesium isotopes through milk, γ-irradiation from the ground, and the early inhalation hazard are all roughly similar in size. Finally, strontium contamination is relatively limited in extent. In some circumstances higher rates of deposition can be expected, increasing the importance of ground contamination relative to inhalation doses. For example, if the deposition velocity is raised to 10 mm/s, the area contaminated above the ERL for γ-exposure is increased by

a factor of three, and a similar increase results from the addition of rainout at the fractional rate of $1/10^4$ per second.

In this example, the γ-irradiation from the ground is of special interest, because it is the only predicted source of significant dosage that is not effectively avoided by emergency action based on temporary evacuation and the control of food supplies. It is mainly of concern in areas where frequent access is required by a large number of people, and would be of particular relevance if a release from an urban sited reactor led to the contamination of neighbouring industrial plant. In this case, large-scale decontamination might be required in order to restore safe working conditions.

The principal conclusion to be drawn from this work is that a release of fission products from a reactor can lead in the long term to γ-ray doses from the ground that are comparable in significance with the initial inhalation hazard, if no countermeasures are taken. Accidents in which other long-term effects would become important are less readily envisaged.

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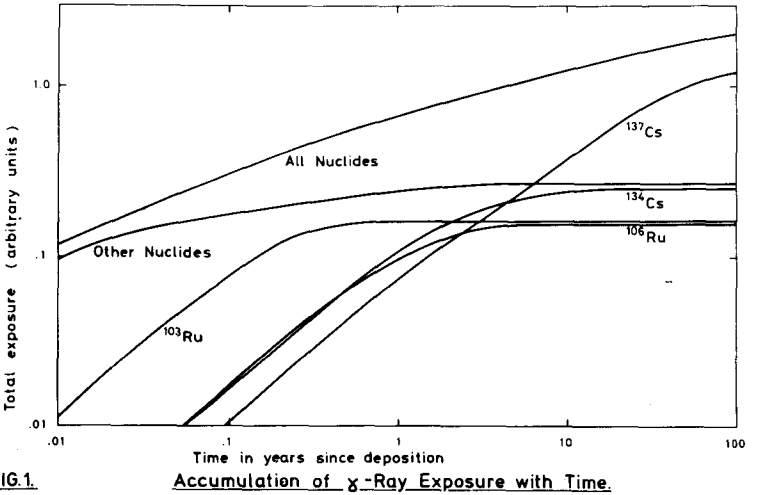

FIG.1. Accumulation of γ-Ray Exposure with Time.

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