United Nations Scientific Committee on the Effects of Atomic Radiation

ELECTRONIC ATTACHMENT 4

SENSITIVITY STUDIES IN SUPPORT OF THE METHODOLOGY DEVELOPMENT

UNSCEAR 2016 Report, Annex A,
Methodology for estimating public exposures due to radioactive discharges

Notes

Contents

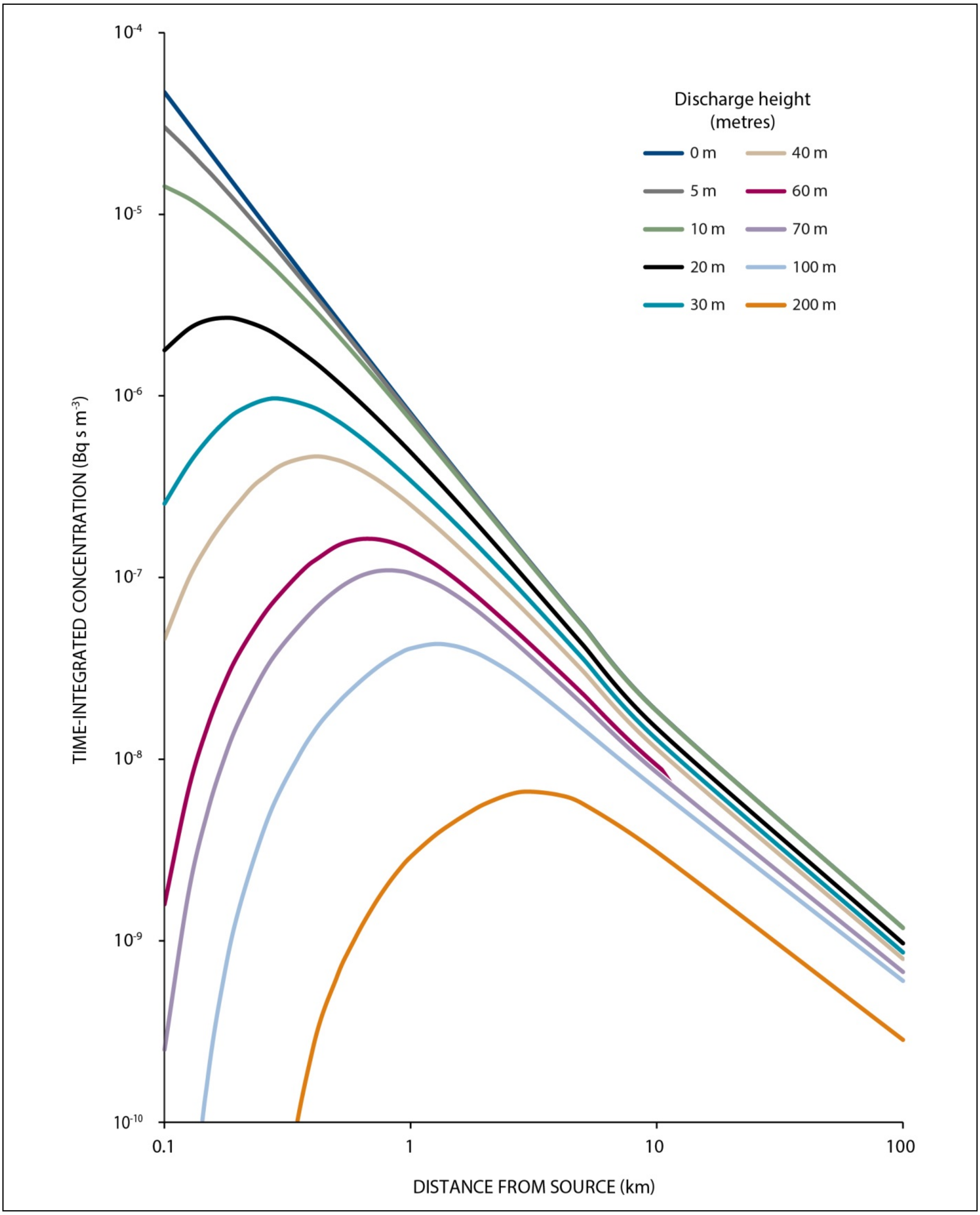
1. As noted in the main text, some limited sensitivity studies were carried out in support of the decisions made by the Committee in developing the current methodology. This attachment outlines the studies and gives the key results. Two sets of sensitivity studies are presented: those relating to atmospheric dispersion modelling and those related to the assessment of doses due to the ingestion of terrestrial foods.

I. ATMOSPHERIC DISPERSION MODELLING

2. The activity concentration of a radionuclide in air as a function of distance depends on the height of the discharge. There are many other factors that also affect the degree of dispersion in atmosphere and hence the concentration in air. For the purposes of this sensitivity analysis, a standard atmospheric dispersion model and approach was used with just the height of the discharge being altered and all other parameter values kept the same. The activity concentrations in air (at ground level) resulting from a continuous discharge of a radionuclide as a function of distance were calculated using a simple Gaussian model [S1], and assuming a uniform wind rose and a range of atmospheric conditions with Pasquill Category D for 65% of the time. The results are shown in figure I for a range of discharge heights from 0 (ground level) to 200 m.

3. This figure demonstrates that, for continuous discharges, the differences in the calculated concentrations in air with discharge height become smaller with increasing distance from the discharge point. A distance of 5 km is used for estimating characteristic individual doses and long distances (100 km or more) are relevant for the estimation of collective doses. At a distance of 5 km, the difference between the concentrations in air for a 30 m discharge height compared to discharge heights of 0, 100 and 200 m is about a factor of around 1.6, 2.3 and 6, respectively. At a distance of 100 km, the differences in the calculated concentrations in air between a discharge height of 30 m and discharge heights of 0, 100 and 200 m falls to factors of around 1.4, 1.3 and 2.7, respectively. This indicates that it would be reasonable to simplify the methodology by adopting a single discharge height. A stack height of 30 m is therefore applied for all sites. For many electricity generation sites, the effective discharge height is between 0 and 100 m and therefore the uncertainty associated with using a single discharge height of 30 m is around a factor of 2 or less, even at 5 km distance. However, some coal-fired power stations discharge effluents from tall stacks with an effective height approaching 200 m; in these cases, the estimated individual doses may be overestimated by around a factor of 6 (at a distance of 5 km) but the effect on collective doses is much smaller (less than a factor of 3). Similar results are obtained if different percentages of Pasquill Stability categories are assumed.

Figure I. Illustration of the variation in time-integrated activity concentration in air as a function of distance for a range of discharge heights



4. Mill and mine tailings tend to be spread over areas of tens of hectares and therefore are not strictly point sources in the way that stacks are. In order to investigate the influence of the difference between a point and an area source, the Numerical Atmospheric-dispersion Modelling Environment (NAME) model was used to model the discharge of particles from a point and an area source [J1]. A discharge height of 30 m was assumed for the point source and the area source was assumed to have an area at the surface of 100 hectares ($1\ 10^6\ m^2$). A

discharge rate of 500,000 particles per hour was assumed and the time-integrated activity concentrations in air were calculated for various distances from the discharge point. The results are presented in table 1.

5. At a distance of 5 km, there is a 10% difference between the values for the point and area sources, while at 10 km the difference is around 5%. At greater distances, there is no significant difference between the activity concentrations associated with point and area sources. Thus, as these differences are small compared with the uncertainties associated with the methodology and, given the larger distances involved in assessing collective doses, the Committee considered it reasonable to apply the same approach to assess the dispersion of radionuclides from mine and mill tailings as from other facilities. An effective discharge height of 30 m for a point source is therefore also used for the calculation of doses from mine and mill tailings in this methodology.

Table 1. Comparison of time-integrated air concentrations arising from an area and point source as a function of distance

Distance from release point (km)	*Time-integrated air concentration (Bq s)/m^3*		
	Area source	*Point source*	*Ratio of area/point source*
0	1.4×10^{-1}	2.2×10^{-1}	0.64
1	1.4×10^{-1}	2.1×10^{-1}	0.67
5	3.4×10^{-2}	3.7×10^{-2}	0.90
10	1.5×10^{-2}	1.6×10^{-2}	0.96
20	6.2×10^{-3}	6.2×10^{-3}	0.99
30	3.6×10^{-3}	3.6×10^{-3}	1.00
40	2.4×10^{-3}	2.4×10^{-3}	1.0
50	1.7×10^{-3}	1.8×10^{-3}	1.0

II. ASSESSMENT OF DOSES DUE TO INGESTION

6. The Committee agreed that some additional regional data should be included in the current methodology, particularly for estimating individual doses. There were two main aspects that were considered: the use of region-specific consumption rates for different foods; and the use of region-specific information in determining the transfer of radionuclides to terrestrial foods. A limited sensitivity analysis was carried out as part of the development of the current methodology considering these two aspects.

A. Study of the effect of regional differences in diet

7. Generic factors relating deposition of radionuclides from atmosphere to the levels in various terrestrial foods were used with the different regional diets given in table 7 of the main text to estimate doses from ingestion for each region. Also, the effect of changes in the uptake of radionuclides from soil to plants was determined. This analysis suggested that, among the radionuclides considered, differences between the transfer of radionuclides from soil to different terrestrial foods would lead to a variation in dose of around a factor of two greater than that from differences in the quantity of foods consumed alone.

8. These results also indicated that the calculated doses were relatively insensitive to variations in the composition of the diet, although the influence of differences in the total

quantities of food consumed were apparent (notably from the higher mass of food consumed in North America). The analysis also indicated that it would be reasonable to simplify the food and regional groupings (e.g. for the comparison of the radiological impact of different energy sources).

9. Given the importance of ^{14}C in the calculation of collective dose from discharges to atmosphere, the possible variations in the uptake of ^{14}C in foods arising from the different composition of diets in different regions was considered. For the purposes of illustration, the differences between the components of a European (United Kingdom) and Asian (Japan) diet were considered.

10. This analysis indicated that the average daily intake of carbon for the two diets was very similar (at around 420 g/d), although the foods from which the carbon was derived varied. In Japan, the intake is primarily associated with starchy products (such as rice, wheat and root vegetables), while in the United Kingdom, the intake is associated with sugar, milk and milk products, meats, oils and fats. As the dose from ^{14}C is related to the intake of stable carbon, this indicates that the doses would be very similar in the two regions despite the differences in diet.

B. Study of the effect of regional differences in uptake characteristics of foods

11. There are possible differences in the transfer of radionuclides to foods grown in different regions of the world owing to differences in the foods produced, the soil and agricultural practices. As an input to the Committee’s assessment of doses arising from the accident at the Fukushima-Daiichi nuclear power station, the FARMLAND model [B1] was modified to allow uptakes of radionuclides in the main components of the Japanese diet to be estimated. The results of using the FARMLAND model with modified soil–plant concentration ratios were compared with the standard output from FARMLAND for the United Kingdom diet. Activity concentrations were calculated for unit deposition of a range of radionuclides, including ^{90}Sr, ^{137}Cs, ^{210}Po and ^{226}Ra. In most cases, the differences between the two sets of results were small compared with the uncertainties associated with the methodology as a whole. The greatest differences between the estimated activity concentrations for the United Kingdom and Japanese foods were found for unit discharge of ^{90}Sr. These results are presented in figure II. The differences in the results for the transfer of a range of radionuclides to cereals are illustrated in figure III.

12. In summary, for the radionuclides considered, there are only relatively small differences between the activity concentrations in terrestrial foods arising from the use of different transfer parameters (particularly soil–plant concentration ratios) appropriate for conditions in the United Kingdom and Japan. For ^{90}Sr, some differences were identified, as shown above, most notably for beef, liver and milk, where a difference of up to about a factor of seven in the activity concentrations between Japan and the United Kingdom were found. However, for the radionuclides that are likely to give rise to the greatest contribution to doses for routine discharges, differences in uptake do not significantly affect the results, as demonstrated by the similarity in estimated activity concentrations for key radionuclides in cereals (see figure III).

Figure II. Activity concentrations of ^{90}Sr in foods from a continuous deposition rate at 1 (Bq/s)/m^2 using transfer parameters for United Kingdom and Japan

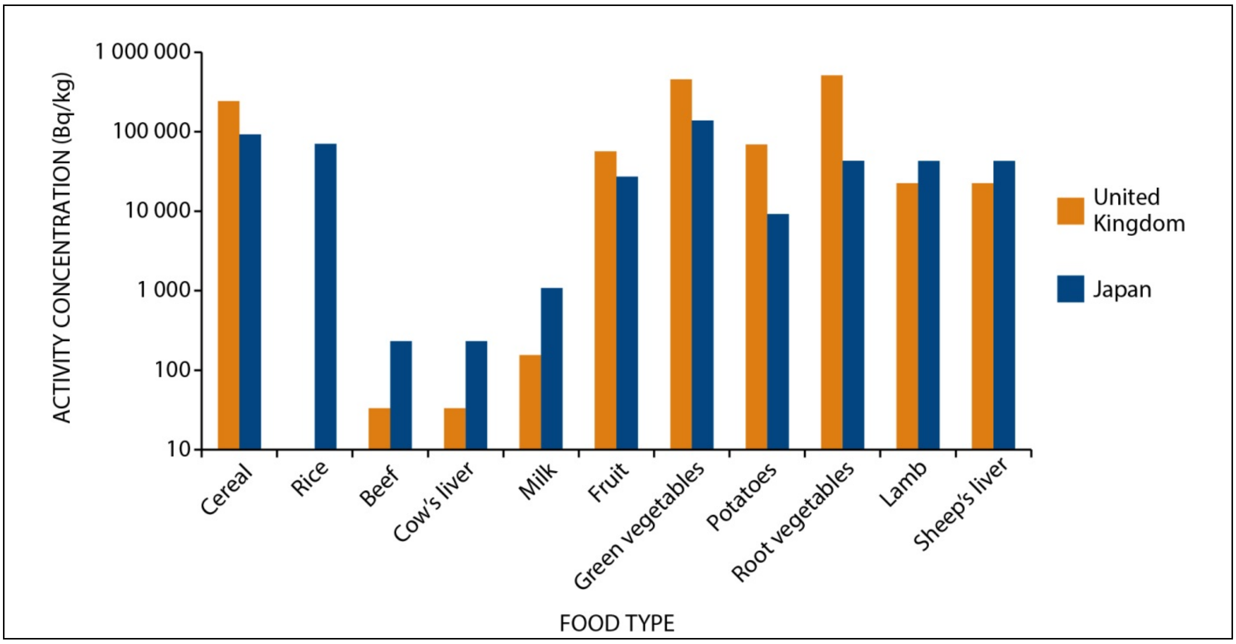
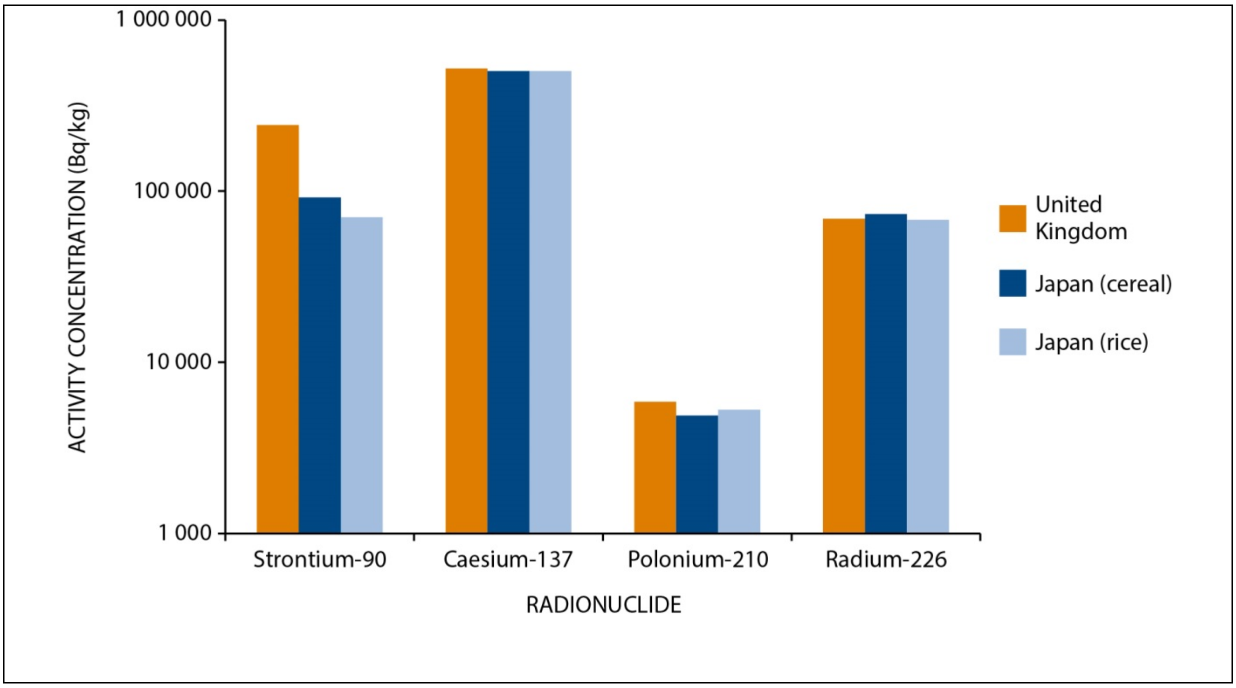


Figure III. Estimated activity concentrations of radionuclides in cereals from continuous deposition rate at 1 (Bq/s)/m^2 using transfer parameters for the United Kingdom and Japan



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S1 Smith, J.G. and J.R. Simmonds. The methodology for assessing the radiological consequences of routine releases of radionuclides to the environment used in PC-CREAM 08. HPA-RPD-058. Health Protection Agency, Chilton, Didcot, 2009.