

7.19 METHODOLOGY FOR ASSESSING DOSES FROM SHORT-TERM PLANNED DISCHARGES TO ATMOSPHERE

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INTRODUCTION

In the United Kingdom radio nuclides are discharged to the environment from a range of controlled sources, under a system of authorisation and regulation which includes the comparison of estimated doses (both current and prospective) against dose limits and constraints. It is therefore a fundamental part of the system of radiological protection to be able to assess current and future doses from releases of radio nuclides. In assessing these doses it is usually assumed that the releases are continuous and reasonably homogeneous over a year, which means that annual average parameters can be used to assess the consequences. The predicted dose can also be compared with appropriate annual dose criteria. However, during normal operations it is possible to have short-term enhanced releases of radio nuclides to atmosphere due to routine maintenance operations or particular features of the operations of plants.

These short-term enhanced releases are normally covered by the site's authorisation for discharge and short-term limits or notification levels may apply to such situations. However, it is possible that short-term discharges may lead to doses that are higher, or indeed lower, than would be expected from an assessment which assumes that releases are continuous. A need has therefore been identified to develop an appropriate methodology for the assessment of doses arising from short-term releases. The aim of this methodology is to provide realistically cautious, rather than exceedingly cautious, predictions of the dose to members of the critical group.

To fully understand the impact that variability in model input parameters has on dose estimates a probabilistic approach is required. However, constraints on the availability of data and time demand that a simpler approach is needed for carrying out dose assessments. This paper concentrates on the methods recommended for dealing with the variation in meteorological conditions and the derivation of a representative atmospheric stability category.

METHODOLOGY

The atmospheric dispersion process was modelled using ADMS 3.1 (CERC, 2002) which predicts ground level activity concentrations in air, deposition rates and cloud gamma doses. The release scenarios were based on a review of discharge practices carried out by several UK organisations authorised to make discharges to atmosphere of radioactive material. From this review there was evidence to suggest that short-term planned releases in the UK occur only during the normal working day and generally for periods of a few hours.

Release duration

Durations of 30 minutes and 12 hours were considered in this study to scope the typical range of short-term releases. For all releases, regardless of their duration, it was assumed that the meteorological conditions remained constant during the release. However, it was felt important that the impact of wind meander during longer release durations should be

adequately represented. The crosswind concentration profile formulation in ADMS 3.1 broadens with decreasing wind speed but further broadening of the plume to account for variations in the mean wind direction over time is also included. Plume broadening has been included in the sigma y term using a model derived by Moore (Moore, 1976), given by:

$$\sigma_y^2 = \sigma_{yt}^2 + \sigma_{yw}^2 \quad (1)$$

where σ_{yt} is a boundary layer turbulence component and σ_{yw} is a wind direction unsteadiness component, evaluated from:

$$\sigma_{yw} = \sigma_\theta x \quad \text{or} \quad \sigma_{yw} = 0.065x \sqrt{\frac{7T_a}{U_{10}}} \quad (2)$$

where σ_θ is the standard deviation of the horizontal wind direction, x is the downwind distance from the source, T_a is the required averaging time (in hours) for evaluating lateral spread, and U_{10} is the average ten metre wind speed over the same period. However, ADMS 3.1 has been shown to be relatively insensitive to release duration particularly in comparison with similar implementations of this model, for example in NRPB-R91 (Clarke, 1979). One reason for this is that the component σ_{yt} is so much bigger in ADMS than in NRPB-R91. Nevertheless, it is felt that the duration of the release is not adequately represented in ADMS and therefore a sector width of 60 degrees has been explicitly modelled to represent the variation in mean wind direction during a 12 hour release. This was achieved in ADMS by considering a number of adjacent equally spaced plumes and averaging over them. This wind sector width was derived by applying the following formula to meteorological data for Heathrow.

If A and B are the maximum and minimum wind angles (in degrees from North) in any day then the total angle D over which the wind blows is given by $D \geq A-B$. This formula is appropriate unless the wind varies around 360 degrees. In this case the variation over the 12 hour period is calculated by $D \geq 360-(A-B)$. The result is the wind sector width for each 12 hour period for Heathrow. A histogram of the wind sector widths is shown in Figure 1.

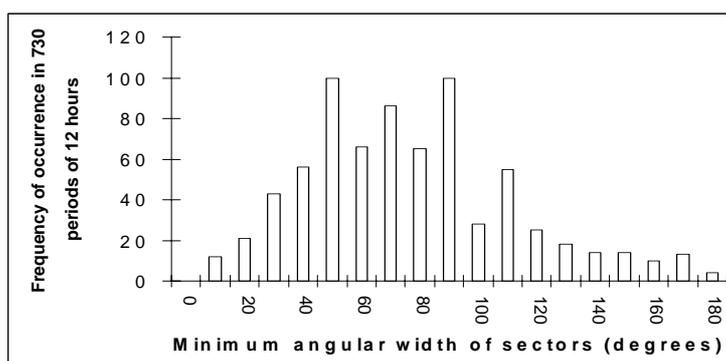


Figure 1. Minimum angular width of wind sector for each 12 hour period in an hourly sequential file for Heathrow (730 periods of 12 hours)

The angular widths calculated here are minima because there may be some situations where the change in wind direction has been greater than 180 degrees. Based on this analysis it was decided that a 60 degree wind sector width should be used to model a release duration of 12 hours. This was thought to be more realistic while still retaining the required degree of caution with respect to the activity concentration in ground level air on the plume centre line used in this methodology. This result can be compared to those derived using the formulations for σ_{yw} given in Equation 2 and in Appendix B of Clarke (1979). These suggest that wind

direction fluctuations averaged over a 12 hour period for a wind speed of 3 m s^{-1} would be confined to a sector of angular width 68 and 84 degrees respectively. Over the distances of interest to this study differences in activity concentrations in air at ground level of up to a factor of 3 might be expected between 30 minute and 12 hour releases.

Representative meteorological data

For continuous discharges it can be assumed that releases will occur in the full range of meteorological conditions experienced at a particular site. However, for a short-term release the meteorological conditions experienced by the dispersing plume will be limited. This may result in predicted air concentrations significantly different from those expected as a result of average meteorological conditions. Consequently, it is important that the meteorological conditions are represented in an appropriate way. The uncertainty associated with the choice of meteorological data and the potentially significant consequences for dose prediction suggest that a cautious but realistic approach should be taken.

The variation in critical group dose, due to different but constant meteorological conditions, was estimated for a 30 minute release from a 30m stack. It was assumed that the critical group was located at 300 m and 1 km downwind of the release on the plume centre line and that all their food was derived from these locations. The habits of the critical group are based on annual average data and for calculating activity concentrations in foods the release was assumed to occur in July. Details of the assumptions made are not given, it is the relative variation in dose as a result of changing meteorological conditions that is of interest. A meteorological data file was obtained for Heathrow which contained hourly sequential measurements of wind direction, stability category, precipitation rate, wind speed and boundary layer height for a single year. This file was modified to restrict the wind direction and the Pasquill-Gifford stability categories were replaced with a representative Monin-Obukhov length but in doing so no account was taken of the influence of other meteorological parameters. Atmospheric dispersion was modelled using ADMS 3.1 with the modified meteorological file as input. The activity concentrations in air at ground level, deposition rates and cloud gamma doses on the plume centre line were output for each hour, and critical group doses calculated. The critical group doses were sorted in ascending order of magnitude and a percentile value assigned to each dose (0-100th).

Illustrative results of the dose estimates are shown below for ^{90}Sr and the 1 km distance only. In Figures 2 and 3 each point on the blue line represents a critical group dose calculated using a line of meteorological data from the annual hourly sequential file (over 8760 lines of meteorological data are included in the file). The figures show a very large variation in the critical group dose following a 30 minute release. This variation is up to 6 orders of magnitude at 1 km downwind and even greater closer to the release point. However, dose estimates at both 300 m and 1 km downwind exhibit a plateau region where a large number of different meteorological conditions give rise to similar critical group doses. This implies that if a particular meteorological condition is chosen which gives rise to a dose within this plateau region it will be representative of many other meteorological conditions which occur throughout the year. These figures also show the annual average dose and the dose arising from particular meteorological conditions. These conditions have been labelled A to F for convenience and to indicate the stability conditions considered (Clarke, 1979). However, for input to ADMS these stability conditions are modelled using the Monin-Obukhov length. The order in which these categories occur reflects the dispersion and deposition processes important for the relevant dose pathways.

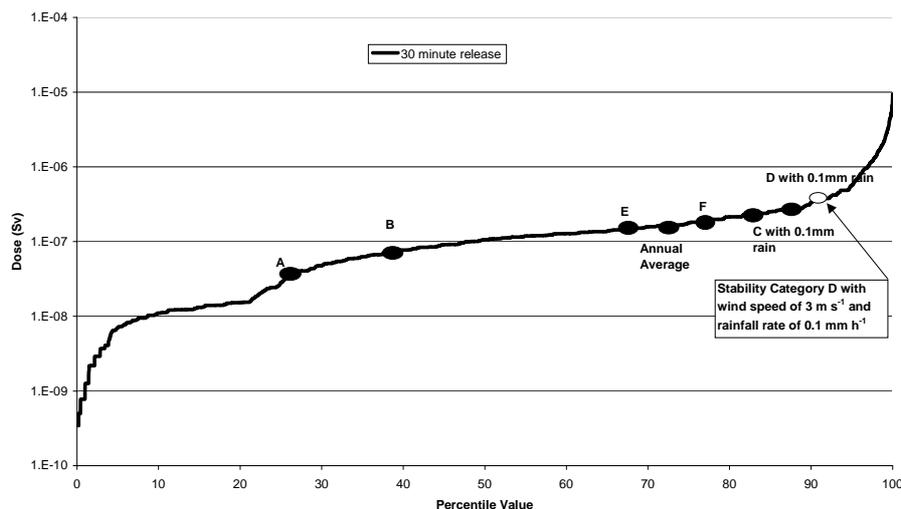


Figure 2. Ingestion dose from ^{90}Sr . Stack height of 30 m and receptor point at 1 km. Variation in critical group dose from a 30 minute release due to changing meteorological conditions over one year.

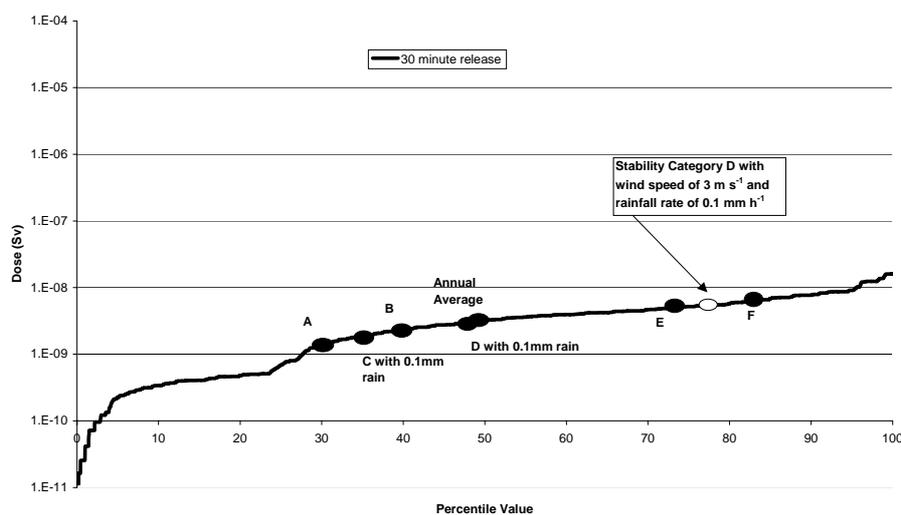


Figure 3. Inhalation dose from ^{90}Sr . Stack height of 30 m and receptor point at 1 km. Variation in critical group dose from a 30 minute release due to changing meteorological conditions over one year.

The assessment methodology developed under this project needs to be reliable, robust and not too complex to apply. Therefore, the variation in meteorological conditions described above must be accounted for in fairly simple terms. The results of the studies described above were used to develop a suitable approach.

The aim was to identify a single set of meteorological conditions that would reproduce critical group doses in the upper part of the dose distribution for the majority of radio nuclides. Initially, the default parameter values for the stability categories A to F described by Clarke (1979) were used although the rainfall rate and duration were modified for Categories C and D such that rain was assumed to occur all the time at a rate of 0.1 mm h^{-1} . The percentile results for Categories C and D with rain are indicated in Figures 2 and 3. For ingestion dose, percentiles of about 80 to 90 are predicted but for inhalation the dose percentile is lower at

about 35 to 50 for 1 km downwind. Reducing the wind speed to 3 ms^{-1} in Category D gave results at somewhat higher percentiles i.e. between about 65 and 95 for 1 km downwind. It is judged that given all the uncertainties inherent in a critical group dose calculation, these meteorological conditions represent an appropriately robust basis for this methodology. Specifically the meteorological conditions are: a Monin-Obukhov length of 0 (representing Category D), a wind speed of 3 m s^{-1} , boundary layer depth of 800 m and rainfall rate of 0.1 mm hr^{-1} for the duration of the release. However, further studies are needed to more fully test the robustness of this approach by considering other distances downwind of the release, other sites and other dispersion models. This approach can be used to produce other meteorological categories with different levels of pessimism. If site-specific meteorological data are available then the procedure described above can be followed for the site of interest.

CONCLUSIONS

The meteorological conditions derived here are similar to those commonly used to represent annual average conditions. However, this methodology puts the choice of meteorological conditions into context by demonstrating how representative they are of the full range of conditions at a site. It also highlights the fact that the degree of caution associated with the choice of meteorological conditions depends on the dose pathway under consideration.

ACKNOWLEDGEMENTS

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