Issues Arising Over The Continued Use Of NRPB-R91

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1 INTRODUCTION

In 1977 the UK Atmospheric Dispersion Modelling Working Group (ADMWG) and a Steering Committee were established to recommend dispersion models for use primarily in the licensing process of the nuclear industry. The Committee included organisations from the nuclear industry and government departments with responsibilities for the industry. The Working Group's recommendations were published in seven reports of the NRPB report series. The Steering Committee was re-organised in 1995 and became the UK Atmospheric Dispersion Modelling Liaison Committee (ADMLC).

The first report NRPB-R91 (Clarke 1979) described the basic formulation of the Gaussian Plume Diffusion model and its application, while subsequent reports described how effects such as plume depletion, plume rise, the impact of buildings and coastal effects could be taken into account (Jones 1981a,b,c, 1983, 1986a,b). These reports will be referred to collectively as the R91 model. When considering dispersion models only those applicable to short and medium range dispersion (i.e. less than 100 km) were included. Based on a comparison of model predictions for a range of meteorological conditions and using limited experimental data, the Gaussian Plume model was proposed for use in the calculation of the dispersion of radioactive releases. Although other more detailed models were available it was felt that the Gaussian Plume model was more suitable for the following reasons:

a Computer time required to run the model was reasonable
b Meteorological data and dispersion parameters are simplified
c Reasonable agreement with experimental data
d Can be developed mathematically to include additional processes
e Consistent with random nature of turbulence
f Can be easily conceptualised.

It is important to recognise that the model, including its extensions, is only applicable in certain conditions and outside these conditions the results may be unreliable. Information taken from a US workshop (Crawford 1978) indicating the levels of uncertainty associated with the application of the model in various conditions is given in Table 1. The first entry in the table shows the ability of the model to predict the peak activity concentration at a particular distance downwind of the release point but not the location of this peak. In this application appropriate on-site meteorological data were available and a difference in predicted to observed concentrations of 20% might be expected. ADMWG felt that uncertainties of the order of 20% were likely to be optimistic estimates and that predictions from such models could only be expected to be within a factor of 2 or 3 of the observed values given the meteorological data that are typically available. Under the same conditions the uncertainty associated with predictions of air concentrations at a specific point in space and time increased to a factor of 10. The third entry in the table shows that if time averaged air concentrations are calculated the uncertainty could be reduced to a factor of 2. Finally, if the model is extended to between 10 and 100 km from the site uncertainties of a factor of 4 might be expected in long-term average concentrations.

Table 1 Estimates of uncertainty in Gaussian dispersion model predictions

Conditions	Range of predicted/observed concentration
Flat terrain, steady atmospheric conditions, peak air concentration along plume centre line at ground level within 10 km of low level release. Hourly average conc.	0.8 – 1.2
Flat terrain, steady atmospheric conditions, peak air concentration at specific time and receptor point within 10 km of release point. Hourly average conc.	0.1 – 10
Long term average air concentration at a specific point within 10 km of the release point, flat terrain.	0.5 – 2
Monthly and seasonal average air concentrations, 10 to 100 km from the site, in flat terrain	0.25 – 4

2 APPLICATIONS OF R91 AT NRPB

At NRPB a capability for modelling atmospheric dispersion is required in three main areas: accident consequence assessment (ACA), emergency response and assessments of doses from planned discharges.

ACA codes are designed to carry out a risk analyses of potential future accidents. The aim is to assess the range of possible consequences of an accident allowing for the range of atmospheric conditions that might occur. There is a probability distribution of possible meteorological conditions and a corresponding probability distribution of potential consequences in the exposed population. Gaussian plume models are used to predict time integrated ground level air concentrations from short releases over short to long range for a variety of meteorological conditions. Because the emphasis is on the consequences for the whole of the exposed population, site-specific features are not considered in detail.

For emergency response the aim is to provide useful information to decision-makers so that countermeasure strategies can be implemented effectively to reduce the radiological impact of an accidental release of radionuclides to the atmosphere. Many decisions will be based on the results of monitoring data and therefore information directing the monitoring teams is required. The trajectory of the plume is the minimum information that is needed to achieve this. However, models could be used with limited measurement data to estimate the source term and predict downwind air concentrations. On the basis of these predictions some short-term countermeasures that are easy to carry out and have little detrimental impact eg sheltering may also be implemented. Estimates of ground level time integrated air concentrations for short releases over short to medium range are obtained from R91 for the most suitable stability category. Emergency planners are interested in peak concentrations and where they occur downwind but not necessarily their exact location and time of occurrence. Remedial action can be planned based on the magnitude of potential doses, from various exposure pathways, as a function of distance from the site.

For assessments of the radiological impact of continuous and constant discharges the modelling approach is described in NRPB-R91. The modelling approach makes use of a joint frequency distribution of wind direction and stability category. Annual average ground level air concentrations are calculated for a continuous release over short to long range. Doses to population groups and individuals residing near to the site are calculated and so the impact of buildings on the dispersion can be important.

In general, doses are calculated based on peak activity concentrations at given distances downwind of the release point. It is assumed that individuals will receive these doses at some point in space and time.

3 REASONS FOR RETAINING R91

NRPB and other organisations have been using the R91 model over the last 20 years. Consequently, considerable experience has been built up and the strengths and weaknesses of these models are well understood. The models are relatively simple and as a consequence are unlikely to behave unexpectedly and can be considered to be robust. Even though they may not be the most accurate representation of the dispersion process the uncertainty in the model predictions can be expected to remain within certain bounds depending on the type of application (see section 1). An understanding of model behaviour and associated uncertainties is essential for anyone who must make decisions based on the results from the model.

Considerable time and effort have been invested to make the R91 model fit for purpose. Implementations of the model for each of the applications described in section 2 have been carried out such that the appropriate input data are available and the model output fulfils the requirements of the assessment methodology. In some cases the models have been incorporated into assessment software. This software generally comprises a chain of models, with carefully defined interfaces, which is used to estimate the radiological impact of atmospheric discharges.

The basic formulation of the R91 model and its extensions are accompanied by advice and guidance on their use. Many of the model extensions, such as consideration of building wakes, are not included as defaults in the available codes and if they do need to be considered then the user is required to make judgements on the suitability of the models for various applications. This approach involves the user directly in the modelling process and as a consequence he/she is more likely to have an appreciation of the reliability of the results.

The model is stable and not undergoing development, which can lead to changes in model predictions.

4 REASONS FOR REPLACING R91

New generation models such as ADMS (CERC) implement many new features that are based on an improved understanding of atmospheric dispersion processes. Many of these features are not included in R91. These include the skewed Gaussian distribution of concentrations for dispersion under convective meteorological conditions, a description of the atmospheric boundary layer by its depth and Monin-Obukov length and the variation of sigma y and sigma z with source and plume height. In addition, improved models governing the impact on dispersion of plume rise and building effects have been developed.

New generation models no longer describe the boundary layer by a limited number of stability categories. In R91 weather conditions are categorised depending on parameters such as heat fluxes, wind speed and cloud cover. Representative values of the dispersion parameters σ_y and σ_z are then ascribed to each weather category. Consequently, a single set of model predictions will apply to all weather conditions in a particular category and this will contribute to the overall uncertainty. The choice of scheme for classifying the boundary layer stability will affect the frequency with which certain categories occur and thus influence model predictions.

In R91 dry deposition is modelled using a source depletion model in which it is assumed that atmospheric turbulence is sufficient to maintain the plume's Gaussian vertical profile as material is removed at the ground. This may not be the case in conditions of low turbulence, i.e. in stable conditions characterised by categories F and G. In these conditions the air concentration at ground level may be over predicted leading to greater depletion of the plume when it initially comes into contact with the surface. Ultimately, the amount of material remaining in the plume and available for transport further downwind will be reduced. In such conditions the user is advised to treat model results with caution if it is predicted that a significant fraction of material will be removed from the plume. For this same reason the model is not applicable to plumes of material that have travelled for long periods in stable conditions or for which deposition velocity is moderately high. The R91 model makes no allowance for gravitational settling and it is suggested that consideration of aerosols is restricted to those of an AMAD of less than about 10 µm. In contrast, ADMS modifies the airborne concentration by reducing the plume strength and adjusting the vertical profile because removal of activity occurs only at the ground surface. It also incorporates gravitational settling so the choice of particle size is less restricted.

In R91 the recommended choices of σ_y and σ_z are for low-level sources and assume typical variations in wind direction with height and should not be used for cases with very large wind shear, as may occur in very stable conditions or near complex terrain. In most situations vertical dispersion will be a function of release height and this limits the application of the model to effective release heights of less than 200m for sources within the mixing layer. In ADMS the vertical variation of quantities such as wind speed and turbulence are calculated and therefore this limitation on release height does not exist.

Short timescale concentration fluctuations can be modelled in ADMS. These are important for modelling odours and making comparisons with National Air Quality Standard objectives.

5 PROBLEMS IF R91 IS REPLACED

If a new generation dispersion model is adopted then it is important that users have access to information that will enable them to become familiar with the model. It is important that users have an understanding of the model so it is used appropriately and the results are treated with the appropriate amount of confidence or caution.

It is inevitable that new models will produce results that differ from previous model predictions. Areas where the predictions of R91 and the new models diverge need to be identified and explanations of model behaviour provided. In extreme cases these differences may have an impact on NRPB advice, in which case use of the revised predictions must be justified.

New models will have to be incorporated into the existing assessment tools. It will be necessary to ensure that the appropriate model input data are available and that the required model endpoints are calculated and that they are in the correct format. In some cases, for example if historic meteorological data only include stability category and not the basic observations, there could be problems getting the data into a format for use by newer models. It is likely that endpoints will have to be manipulated for use by other programs and this process will have to be automated in cases where large amounts of data are being transferred. The work program required to achieve model integration is likely to be significant. Consequently, it is important that it is carried out only when the model to be used is considered to be stable ie development has finished and proposed model functionality is in place and working. If the new generation model is still under development this will hamper attempts to assimilate it into existing assessment tools.

6 THE WAY FORWARD

Evidence suggests that new generation models are better representations of the dispersion process and frequently provide improved predictions of air concentrations. This in itself is a good reason for using new models. The implementations of new models with user friendly interfaces make it easy to carry out complex assessments with only a limited understanding of the processes involved. It is therefore very important that detailed guidance on the use of the models is provided so that judgements on the reliability of the results can be made. This guidance should include recommended sources of input data that are up to date and best suited to the model requirements.

Evaluation studies are very useful in determining the suitability of new models for our applications. At NRPB studies have involved the use of ADMS in assessments typical of those usually carried out using R91.

7 REFERENCES

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