ATMOSPHERIC DISPERSION IN THE VICINITY OF BUILDINGS-APPLICATION OF ADMS 3.1 AND A SIMPLE R-91 TYPE MODEL

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INTRODUCTION

In the United Kingdom the Food Standards Agency (FSA) has statutory responsibility for protection of the food supply from radioactive contamination. If a building or another large obstacle is situated close to a stack, air flow and the associated plume dispersion can be disturbed. Government agencies must therefore consider situations where the dispersion of the released material is significantly influenced by the effects of buildings, and need to use a model that does not significantly under or over-predict the off-site concentration that is likely to occur in such situations. This paper describes work undertaken and published under a contract for FSA to identify suitable dispersion models for use in the situations of interest to FSA and to make recommendations on the most appropriate way of using those models (Walsh and Jones, 2002). This paper considers the modelling of both air concentration and deposition, from releases at a constant rate over a period of months or years.

The detailed description of dispersion in the immediate vicinity of the buildings is likely to require a complex model. However, it may be possible to calculate concentrations at larger distances off-site with sufficient confidence using a simpler model. Therefore the most appropriate simple and complex models were identified. Calculations were undertaken using the simple and complex models, and comments made on the areas where the simple models could be expected to give reasonable results. The study also considered the extent to which details of the buildings on the site need to be considered when using the complex model. On the basis of the results of the study, recommendations are made concerning the circumstances for which simple models are appropriate and those for which it is necessary to use a model that explicitly takes account of the influence of buildings.

FSA asked that detailed guidance should be given for two sites, namely the Nycomed Amersham plc site at Amersham and Dungeness A. Therefore results are presented only for these sites. The findings for these sites were then examined to see if any more general conclusions, likely to be applicable to other sites, could be drawn.

COMPLEX MODEL CHOSEN

On the basis of a review of complex models (Walsh and Jones, 2002), it was concluded that ADMS (CERC, 2002) was the most appropriate building wake model for application by FSA and for exploring the reliability of simple Gaussian models. ADMS provides a comprehensive means of calculating dispersion allowing for the effects of buildings on dispersion. It is based on an atmospheric dispersion model which incorporates current understanding of dispersion and stability, rather than using Pasquill stability categories. It has been extensively validated and seems to perform better than other models in validation studies.

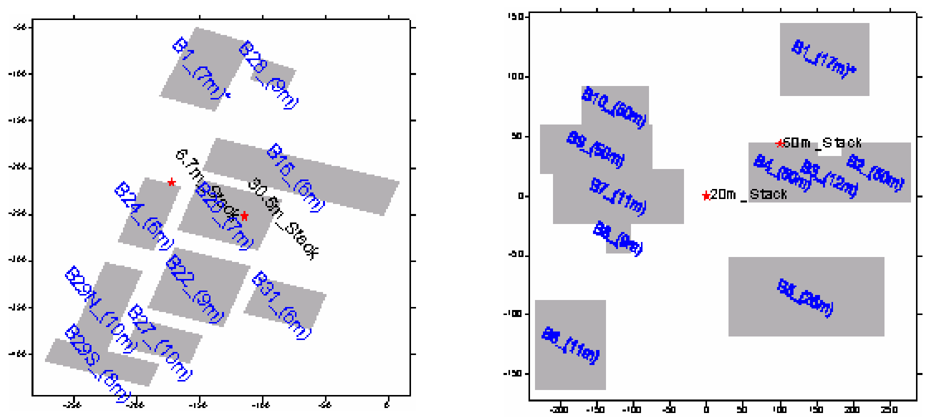
METHODOLOGY

Meteorological Data

A number of atmospheric conditions were considered to represent the complete range of possible conditions, with the frequency of each condition specified for each wind direction. This was based on a uniform windrose (in sectors of 30˚), assuming rain occurs 10% of the time, with the frequencies of each Pasquill stability category appropriate for each site. This format for meteorological data is termed "statistical data" in ADMS.

Size and location of buildings and stacks

Plans of the Amersham and Dungeness sites were provided by FSA for use in this project. These are shown in Figure 1 and the heights of the different buildings are included. At Amersham, the buildings are small with the tallest being about 10 m tall. At Dungeness the buildings range in height from about 10 to 50 m tall. The calculations for Amersham considered two stacks of 30.5 m and 6.7 m height as indicated on the plan. The calculations for Dungeness considered releases from a 20 m and a 50 m stack on Reactor 2.



a) Amersham Site Plan *b) Dungeness Site Plan*

Figure 1. Amersham and Dungeness Site plans. Grey areas represent modelled buildings and an asterisk represents a point source.

Release conditions

ADMS requires the user to specify values for a number of parameters, such as the plume temperature and efflux velocity, that describe the buoyancy of the plume. In general, appropriate values for these parameters are unlikely to be known. ADMS provides "default" values for the parameters (an exit velocity of 15 m s^{-1} and a temperature of 15°C); these were used for most of the ADMS calculations. The calculations using the Gaussian plume models were undertaken on the assumption that the plume was released at ambient temperature and with a negligible efflux velocity. The small differences in the modelled release conditions are unlikely to have any major effects on the comparisons.

CALCULATIONS WITH SIMPLE GAUSSIAN PLUME MODELS

Calculations were carried out using simple Gaussian plume model, as described in NRPB-R91 (Clarke 1979), ignoring the effects of buildings and treating the release as if it was from a point source. A simple extension of the Gaussian plume model is described in NRPB-R157 (Jones, 1983), which suggests simple models for use with non-buoyant releases near buildings. This was the second simple method considered.

The model suggested in R157 modifies the R91 model in two ways to describe the effects of dispersion from sources close to buildings. The first is to use an effective release height equal to one third of the building height and the second is to increase σ_z to allow for the enhanced turbulence around the building. NRPB-R157 discusses the situations when this model is appropriate. The model is only appropriate when essentially all of the released material is entrained into the building wake. The old rule of thumb known as the "two and a half times rule" suggests that air flow from stacks is not affected by buildings if the stack height is more than 2.5 times the height of nearby buildings (see ADLMC, 2001). This and the guidance in NRPB-R157 suggest that the R157 model is unlikely to be appropriate for the 30.5 m stack at Amersham. However, the model is also applied there to investigate the effects it might have.

REPRESENTING BUILDINGS IN ADMS

ADMS calculates dispersion from the group of buildings assuming that it is equivalent to the dispersion from a single "effective building". It allows the user to specify the size and position of up to 10 buildings, one of which must be specified as the "main building"; CERC suggests choosing the building that has the most significant effect on dispersion. ADMS uses an algorithm to determine the size and location of the effective building, which is always at right angles to the wind direction and has the same height as the main building specified. The effective building therefore may be a different size for each wind direction considered in the calculations. The size and position of the effective building is included in one of the ADMS output files, for each wind direction.

There are therefore two problems to resolve when using ADMS to calculate dispersion from large groups of buildings, namely specifying the main building and deciding how to represent the other buildings on the site. For a site such as Dungeness, with some large buildings, it was not difficult to determine which buildings are likely to be significant. However for Amersham, a site with many small buildings, it was necessary to run ADMS several times (specifying a different main building each time) to determine which building was most significant. The results of the comparisons are not presented here, but showed differences in predicted concentrations of up to about 20% (Walsh and Jones, 2002). The choice of which building to specify as the main building in the runs is somewhat subjective. In this case it is not very important as the differences in predictions for different main buildings are not large.

A series of calculations was carried out to investigate the most appropriate description of the group of buildings, and the sensitivity of ADMS predictions to different choices of buildings. Following an examination of the effective buildings chosen for different groupings of actual buildings, building configurations were selected for Amersham and Dungeness which appear to be plausible, but there does not seem to be a clear-cut method of selecting the most appropriate description of the site to use. ADMS calculations using these combinations of buildings are referred to as the "standard run".

RESULTS

The differences between the various models considered are changes of the effective release height and changes of the method of calculating σ_z. Gaussian models are not very sensitive to variations of these quantities if σ_z is about equal to, or greater than, the effective release height. Therefore Gaussian models will predict that building effects for the Amersham site are only found in the region where σ_z is less than about 5 m. R91 shows that σ_z reaches this value in category F at about 200 m from the source, and at shorter distances in categories A to E. Gaussian models will predict that building effects for the Dungeness site are only found in the region where σ_z is less than about 20 m. R91 shows that this value is reached in category F at about 1500 m from the stack, in category E at about 600 m from the stack and at shorter distances in categories A to D. This argument could also be applied to buildings of other sizes. It suggests that the Gaussian plume model will only predict that buildings have large effects on predicted concentrations at distances within a few hundred metres of the release point. Similar arguments should also be appropriate for the model in ADMS. This is borne out by the results of this study, which show that there are no large differences for the Amersham site and that building effects at Dungeness are only found within a few hundred metres of the release point. Figure 2 shows predicted concentrations at ground level along a line through the 50m stack at Dungeness. It shows that there is little difference between modelling the main building only and modelling a group of buildings in ADMS. It also shows there is little difference in the ADMS predictions at distances greater than 500m if buildings are modelled compared to an ADMS run with no buildings modelled. R91 and R157 predict different concentrations to greater distances due to different release height modelled (actual stack height and 1/3rd building height respectively).

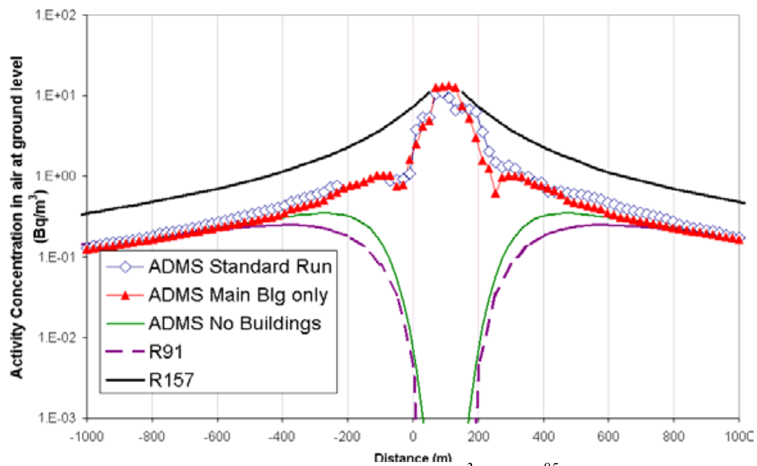
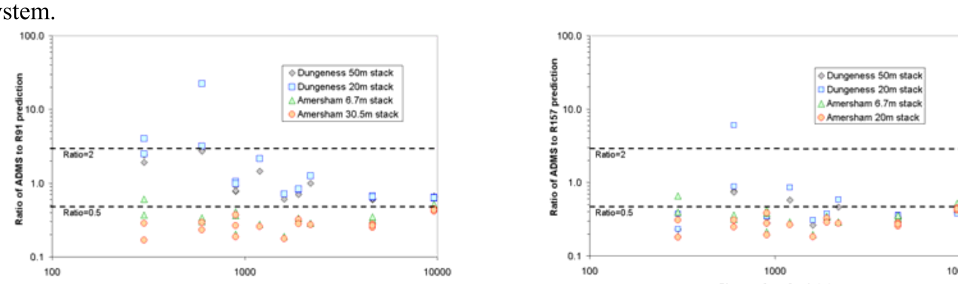


Figure 2. Predicted activity concentrations in air (Bq m^{-3}) of Kr^{85} along a line through the 50m stack at Dungeness (see Figure 1b-line is along the edge of buildings B4 and B2 and through building B9)

The comparisons between the Gaussian models and ADMS are presented graphically in Figure 3, which show ratios of the model predictions at a series of distances. Note that these figures present results in terms of distance from the stack, rather than at specified points on the grid system.



a) Simple model used is the R-91 type model (no building effects modelled, using actual stack height)

b) Simple model used is the model described in R-157

Figure 3. Ratio of the activity concentration in air predicted by ADMS 3.1 (using the building effects module and actual stack height) and by a simple model with increasing distance from the stack.

ADMS predicts different concentrations in different wind directions, while R91 and R157 do not describe the variation of air concentration with wind direction. The figures show the maximum and minimum values of the ADMS results at each distance considered. These figures show that there is a wider spread in the predictions at shorter distances, with the predicted concentrations generally becoming close to each other beyond a few km from the stack.

CONCLUSIONS

The main findings of this project can be summarised as follows. The predictions of R91 and ADMS for air concentration within about 10 km of the release if buildings are not considered are generally within a factor of 2 to 3. This is similar to the difference which could be expected between observed concentrations and predictions of Gaussian plume models (Jones, 1986). Building effects only modify predicted concentrations by more than a factor of 2 at distances within less than about 1 km of the site. It is reasonable to conclude that building effects in general are only important at distances of a few hundred metres from a site, and so buildings need not be considered in assessing doses at larger distances. Within this distance range, some predictions are sensitive to particular features of the model, and results of any calculations in this region should be treated with caution. ADMS is considered to be a more appropriate model than a simple Gaussian model if building effects must be considered as it treats a number of effects that cannot easily be considered in simpler models (plume rise, position of stack relative to buildings, stack height).

This study suggests that ADMS must be used with care. Results obtained with ADMS should be examined carefully before they are used. The study also showed that ADMS can be more sensitive to quantities such as the parameters describing plume buoyancy than to the description adopted for the grouping of buildings on the site. The results were also found to be very sensitive to the position of the stack relative to the buildings. Therefore it is recommended that sensitivity studies should be undertaken wherever possible before ADMS results are used.

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