STOCHASTIC MODELLING OF CONCENTRATIONS RESULTING FROM SHORT TERM RELEASES OF RADIONUCLIDES TO THE ATMOSPHERE

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1. Introduction.

The MESOS model for transport and dispersal of radioactive releases to the atmosphere over distances of up to 1000 km or more has been descibed at a previous IRPA meeting (1).

Databases of meteorological data (from synoptic stations and ships at 3 hourly intervals over Europe throughout 2 years - 1973 and 1976), have since been completed, and used with MESOS to provide realistic meteorological scenarios for accident releases. An extensive program of calculation has led to a large number of results for specific sources, nuclides and receptor points. These results are now being analysed to provide a simple stochastic model which for any source and receptor point, given the release duration, will provide cumulative probability distributions of exceeding different levels of contamination per unit release of a specified nuclide. Such a tool is of direct application in accident risk analysis; and also in particular to transfrontier consequences of a nuclear accident, relevant to requirements of Article 37 of the EURATOM treaty. Of particular interest are the highest levels of contamination predicted at remote receptor points and the atmospheric conditions leading to them. Proper statistical analysis of these highest values requires the application of extreme value theory.

2. Calculations with the MESOS Model.

The MESOS model has been described in detail in (2). It simulates dispersion of sequential 3 hour releases using meteorological data over W. Europe to estimate trajectories and dispersion according to evolving atmospheric conditions along those trajectories. A validation study simulating the Windscale release of 1957 was outlined in (1). Results for hypothetical unit releases of various nuclides (Kr^{85}, Xe^{133}. Xe^{135}, Cs^{137},I^{131}) over 3 hours have been generated for several source locations in Europe using both the 1973 and the 1976 data bases. Since 1973 was meteorologically a fairly average year, and 1976 rather extreme with several severe blocking situations, comparison gives an indication of the variation which may occur from year to year. Results for releases of longer duration have been obtained by combining sequential 3 hour releases, since release duration is an important parameter. Time integrated atmospheric concentration (TIC), and dry and wet deposition where relevant, have been calculated at a range of receptor points round each source, and used to generate predicted frequency distributions of different levels of contamination (see (1) for

3. Statistical Analysis.

In order to make these results more directly useful it was necessary to analyse them statistically and produce a simple stochastic model to predict probability distributions of contamination for a general source and receptor point. This simple model divides the calculation into 2 parts; the probability that a release leads to any positive contamination at the receptor (i.e. that it passes over or near that point), and the cumulative probability distributions of different levels of contamination when such exposure does occur, appropriate to the specified nuclide and release duration.

The exposure probabilities for 3 hour releases are independent of the nuclide but differ for wet deposition; they are estimated using a geostrophic wind rose at the source and the source-receptor distance via a straightforward log-regression equation estimated from the MESOS-generated data. For longer release durations probabilities of exposure are obtained from the 3 hour release probabilities using another empirical formula based on the data. An idea of the accuracy of the prediction equations is given by the comparison of MESOS results and statistically predicted probabilities in table 1. Overall agreement is good.

Receptor	Release duration (hours) 3	6	12	24	72	168
1 100 km N	10.6 13.7	15.1 19.3	21.8 28.5	31.7 40.7	56.5 65.3	85.2 83.9
2 200 km N	7.4 12.3	10.0 17.5	16.1 25.9	23.8 37.4	46.2 61.3	72.8 80.5
3 400 km N	5.3 9.9	8.0 14.3	12.1 21.4	18.2 31.3	38.1 53.3	62.4 73.1
4 800 km N	4.1 6.4	5.9 9.5	9.1 14.4	15.1 21.5	27.0 38.8	41.6 57.1
5 100 km E	16.4 18.2	23.4 24.8	34.4 35.9	48.3 50.1	76.1 75.5	94.7 91.2
6 200 km E	15.5 16.3	22.0 22.5	31.7 32.9	44.7 46.3	74.0 71.6	91.6 88.6
7 400 km E	12.3 13.1	18.4 18.5	27.3 27.4	40.8 39.3	69.7 63.6	89.2 82.5
8 600 km E	11.2 10.5	16.2 15.2	25.3 22.6	38.0 33.0	62.9 55.6	83.2 75.3

TABLE 1. Comparison of MESOS and statistically predicted %-probability of exposure at 8 receptor points for several release durations : Hanover dry deposition
MESOS } %-probability
Statistical prediction

The mean and variance of the distribution of contamination at the receptors when exposed can be predicted from a few simple variables such as source-receptor distance, source geostrophic wind rose, and nuclide half-life, desposition velocity and wash-out coefficient. They are then used to prescribe the distribution itself, which is represented by a Weibull distribution. Figure 1 shows an example of distributions produced directly by MESOS and the corresponding cumulative exposure distributions predicted by the simple stochastic model; they agree very well.

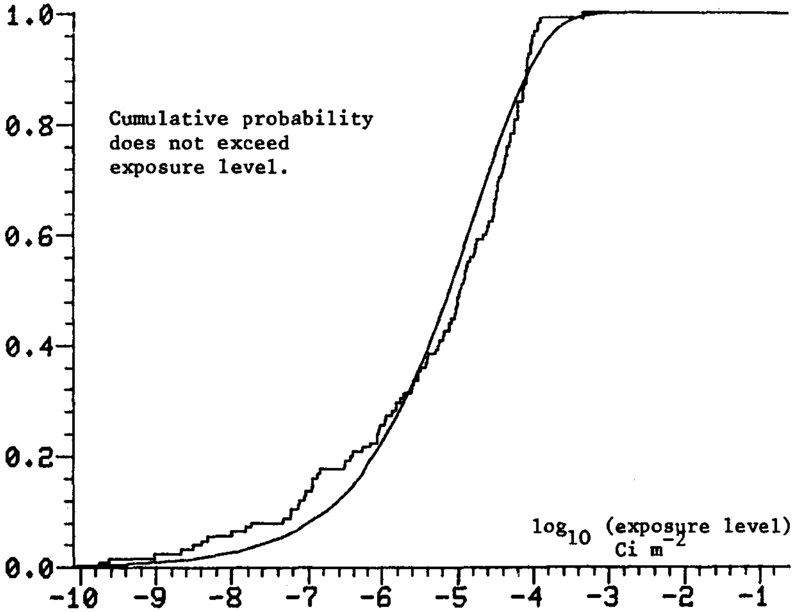

FIGURE 1. Comparison of MESOS and statistically predicted exposure cumulative probability functions for 3-hour release duration : Mol 1976 I^{131} (P) wet deposition, receptor 5, 100 km East.

The potential user of the stochastic model will require geostrophic wind roses at or near the source; these are being extracted at a grid of points over Western Europe from the MESOS databases.

4. Situations Leading to Relatively High Levels of Contamination

Of particular interest are those meteorological conditions which are likely to result in high levels of contamination at a receptor point. A special study has therefore been made of the situations leading to the highest values predicted with MESOS.

At distances up to the order of 100 km the same releases tend to give high TICs for all nuclides simultaneously; many of the most critical exposures were associated with slow anticyclonic conditions in late summer and autumn, and evening and night time releases in stable conditions predominated. At longer distances time of release was less significant and critical conditions varied more with the decay and deposition characteristics of the nuclides. In several cases the wind speed dropped during passage over the receptor giving longer exposure times. Lateral spreading due to divergence in the synoptical scale windfield was often minimal with persistent trajectories in a stationary meteorological situation. High exposures tended to occur clustered in episodes, examples of which are discussed in (2). Situations leading to high wet deposition are rather different, since anticyclonic conditions are generally dry; they depend far more on the location of the receptor point relative to the source.

Statistical analysis of the highest levels of contamination is being undertaken by considering only the occurrence of excesses over high threshold levels. It is important to allow for the clustering of these high exposures; since ignoring this can lead to very misleading conclusions. For example, it is usually incorrect to take the few highest values and assign a probability proportional to the fraction of the total sample that they represent. The application of extreme value theory is appropriate, and a fairly simple method for describing these rare episodes can be applied. This is described in (3).

5. Conclusions

Results generated using the MESOS model have been used to derive a simple stochastic model which, given a release of a nuclide over a defined period from a specified source, may be used to derive a cumulative probability distribution of exceeding various levels of contamination at a chosen receptor point. Attention is now being focussed on the higher levels of contamination which may occur, and the application of extreme value theory.

6. Acknowledgements

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7. References

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