1.35 COMPARISON OF RESULTS FROM DISPERSION MODELS FOR REGULATORY PURPOSES BASED ON GAUSSIAN- AND LAGRANGIAN-ALGORITHMS: AN EVALUATING LITERATURE STUDY

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INTRODUCTION

Powerful tools to describe atmospheric transport processes for radiation protection can be provided by meteorology; these are atmospheric flow and dispersion models. Concerning dispersion models, Gaussian plume models have been used since a long time to describe atmospheric dispersion processes. Advantages of the Gaussian plume models are short computation time, good validation and broad acceptance worldwide. However, some limitations and their implications on model result interpretation have to be taken into account, as the mathematical derivation of an analytic solution of the equations of motion leads to severe constraints. In order to minimise these constraints, various dispersion models for scientific and regulatory purposes have been developed and applied. Among these the Lagrangian particle models are of special interest, because these models are able to simulate atmospheric transport processes close to reality, e.g. the influence of orography, topography, wind shear and other meteorological phenomena. The interaction of input data, meteorological preprocessors dispersion models and data output focusing on radiation protection actions can be seen in Fig. 1.

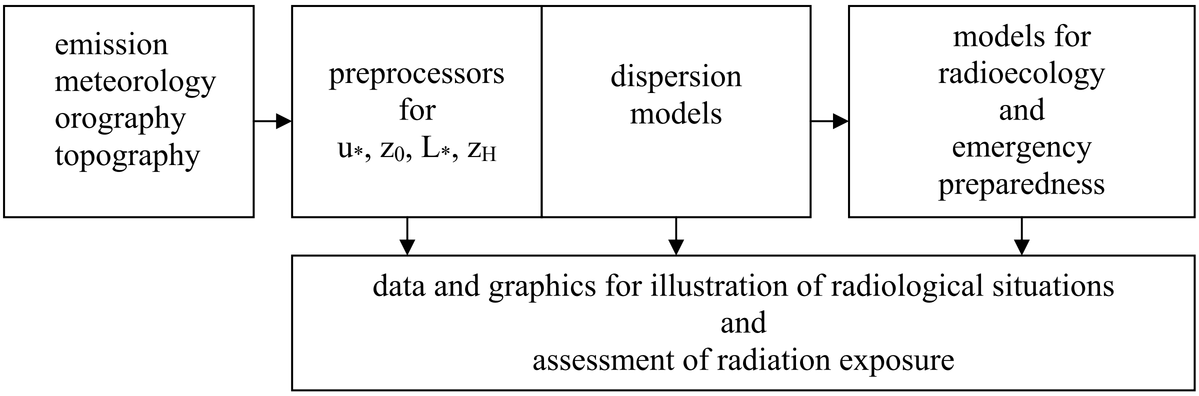

Figure 1. Interaction of input data models and output for radiation protection actions

Within this study, the characteristics and computational results of Gaussian dispersion models as well as of Lagrangian models have been compared and evaluated on the base of numerous papers and reports published in literature. Special emphasis has been laid on the intention that dispersion models should comply with EU requests (Richtlinie 96/29/Euratom, 1996) on a more realistic assessment of the radiation exposure to the population.

LITERATURE STUDY FOR ATMOSPHERIC DISPERSION MODELS

Atmospheric dispersion represents the link between sources that release radioactive substances in the atmosphere and the deposition to the terrestrial and aquatic environments with resulting radiation exposure. The relevant atmospheric processes include convection, turbulent diffusion, deposition as well as the consideration of the different types of sources (point, area, volume), the characteristics of sources with respect to time (longterm or shortterm release) or the influence of orography or topography.

A wide variety of models to describe atmospheric dispersion has been developed in the past, depending on the meteorological scale that is regarded; consequently, the models can be classified in:

- Gaussian plume models,
- Gaussian puff models,
- Lagrangian models, particle-in-cell models, Eulerian models.

Since a long time, Gaussian plume models have been used to describe atmospheric processes; for example, they have been introduced in German guidelines for the assessment of the design of PWR nuclear power plants (Leitlinien, 1983). Main advantages of the Gaussian plume models are short computation time, extensive validation and broad acceptance world wide. The applicability of this kind of models, however, is restricted by the assumptions on which the deduction of the mathematical equations for the Gaussian model from Newton's equations of motion is based. The most important assumptions are constant emission rates, flat and homogeneous sites and a horizontally homogeneous wind field.
As a further consequence of the limitations the literature study has shown, that the applicability of Gaussian plume models is questionable, if

- the meteorological conditions vary (in time and in space),
- the wind speed is low,
- the release height is low,
- positive temperature gradients do exist,
- the vertical wind profile is unsteady or wind shears do exist,
- the site is not flat, not homogeneous or has buildings and
- the emission rate is time-dependent or not constant.

Under these conditions, a Gaussian model may lead to unreliable results especially for shortterm applications, as long as the model is not adapted to these conditions; differences in the results of dispersion calculations using different modelling methods or flat / complex terrain have been shown in literature (Wichmann-Fiebig, 1999, Thehos et al, 1994).

In order to minimise the impact of these constraints, especially in the meteorological mesoscale representing a typical distance to the source of approximately 20 km to more than 200 km, various dispersion models have been developed and applied. These models simulate atmospheric transport processes more realistically. Most of these models require specific dispersion input parameters additional to the basic input data (e.g. wind direction and wind velocity as function of height). These dispersion parameters, e.g. friction velocity u_*, Monin-Obukhov Length L, mixing height z_H and roughness length z_o in general are based on the similarity theory and can be gained from separate preprocessors, which have to be applied before the atmospheric dispersion can be simulated, or from meteorological services. Various meteorological preprocessors, based on different input data sets, for example using SODAR-systems, are available (e.g. Martens et al., 2000).

Using the input data mentioned before it is possible to apply more sophisticated dispersion models, e.g. based on the Lagrangian formulation which describes the motion of particles in the turbulent planetary boundary layer. A detailed description, e.g. of the Lagrangian particle model LASAT, can be found in the internet (Janicke, 2000). These type of model has shown in the past to be a happy medium between the well known simple Gaussian plume model and more sophisticated nonhydrostatic models. Lagrangian particle models represent an increasingly attractive tool for atmospheric dispersion computations of radionuclides in the near and far surroundings of a nuclear facility under the aspect of simulations close to reality. The use of Lagrangian particle models should be favoured especially for shortterm accidental releases, meteorological conditions characterised by high wind shear, low wind speeds, if rapid variations occur during the emissions and dispersion phases, for releases close to the ground, for areas with complex orography and for sites showing inhomogeneous topography in the near vicinity of the facility.

With this pre-considerations, the literature study has been focused mainly on the direct comparison of Gaussian plume – and Lagrangian particle models and respective articles have been identified.

Based on this choosing an analysis has been made on

- the application of the models in Gaussian compliant situations (this means situations, where one could expect, that the environmental situations are in compliance with the Gaussian model application requirements,
- the application of the models in Gaussian non-compliant situations (explanation see above, vice versa)
- and the "conservativity" of the Gaussian model results (the model should never underestimate real concentration or activity of airborne substances).

Within an appendix of the literature study, special focus has been led on the validation of Lagrangian models.

CONCLUSIONS

The results of this literature study has led to the following conclusions. With consideration of the mathematical derivation of the Gaussian equation it can be determined, that the Gaussian plume model shows some significant restrictions which can not be solved or passed over in principle and have to be regarded if the model will be applied professional and appropriate. These restrictions appear especially during:

- non continuous cases (e.g. windfield, source),
- complex orography,
- inhomogeneous topography,
- low altitude sources,
- low wind speed.

Depending on the physical contents, the Lagrangian particle models possesses a greater significance compared to Gaussian plume models and in general do not have the restrictions mentioned above.

Our literature study has shown, that Lagrangian particle models have been developed, validated and used intensively in recent years and are available for the assessment of radiation exposures due to releases from nuclear facilities within a wide range of applications. The tremendous technical development of computer power within the last decade has solved problems concerning excessive computation times for this kind of models.

The study leads to the conclusion, that Lagrangian particle models can fulfil the tasks e.g. defined by German regulatory authorities concerning the assessment of radiation exposure to population and are applicable in practical operation for online assessment of environmental consequences as well as for the existing regulations on the planning of new facilities. Examples for the application of Lagrangian models in general or for nuclear emergency preparedness have been shown (e.g. Ferrero et al, 1995, Souto et al, 2001; Walter, 2001).

What's more, according to EURATOM Guideline 96/29 for the realistic computation of the radiation exposure to the population it is subject to review in Germany the use of existing dispersion model applications for this purpose. Keeping in mind, that realistic computation means the assessment of radiation exposure not only for single points but also for defined areas or groups, it seems to be necessary to examine the introduction of Lagrangian particle models within decision support systems or respective guidelines.

However it should be kept in mind that Lagrangian particle models require more measurement input data to be able to use the full physical strength contained in this kind of models. But as most of these data can be provided either by dispersion parameterisation, by the use of preprocessors or weather services, further investigations on the introduction of Lagrangian particle models for regulatory purposes in Germany can be strongly recommended.

Even though this study reveals a positive attitude to further investigations for the introduction of Lagrangian particle models into German regulations concerning the computation of radiation exposure to population in the vicinity of nuclear installations it should be nevertheless kept in mind, that most of the advantages of this type of models only can be gained if a suitable wind field model is applied in combination. But introducing a new model chain, e.g. based on meteorological preprocessors with SODAR data on the emission site, windfield model and Lagrangian particle model, a new level for the assessment of radiation exposure can be realized.

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