VALIDATION STUDIES WITH RODOS /ATSTEP

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INTRODUCTION

The aim of this study is to validate the results of the ATSTEP Gaussian puff dispersion model. The ATSTEP code is used in the RODOS (Real-time On-line Decision Support system for nuclear emergencies) (*J. Ehrhardt, A. Weis,* 2000) for diagnostic and prognostic dispersion and deposition calculations following a release of radioactive material to the atmosphere. The source may be accidental (nuclear power plant or transport accident) or a dirty bomb. The range of the dispersion calculations is 100 km. Calculations with higher resolution can be carried out in the near range up to 25 km distance.

Data from dispersion experiments in the Copenhagen area and from series of hourly measuring runs of tracer dispersion carried out at the Kincaid and Perry K. (Indianapolis) power stations (as contained in the Model Validation Kit package) were used for comparison with ATSTEP results. Altogether 86 hours of measured dispersion cases were simulated with RODOS/ATSTEP. The measured near ground maximum tracer concentrations and cross wind distributions depending on source distance were compared with corresponding calculated data. Although a statistical analysis wit all Validation Kit data was not carried out a wide range of well fitting as well as significantly deviating results is covered. The influence of plume rise, stability, wind speed, and the choice of dispersion parameters on the results is discussed. Deviations between model results and measured data are explained.

THE ATMOSPHERIC DISPERSION MODEL ATSTEP IN THE RODOS SYSTEM

ATSTEP is a Gaussian puff model for distances up to 100 km. It was developed as part of the RODOS system especially for quick simulation calculations in the case of accidental releases of airborne radioactive contaminants. The model can calculate real-time diagnoses of the radiological situation during or after a release without limitation of duration and interactive dispersion prognoses/episodes for up to 47 days. The radiological situation is derived from the results calculated with ATSTEP. They are the basis of further assessments of the RODOS model chain, like doses, food contamination, early and late countermeasures.

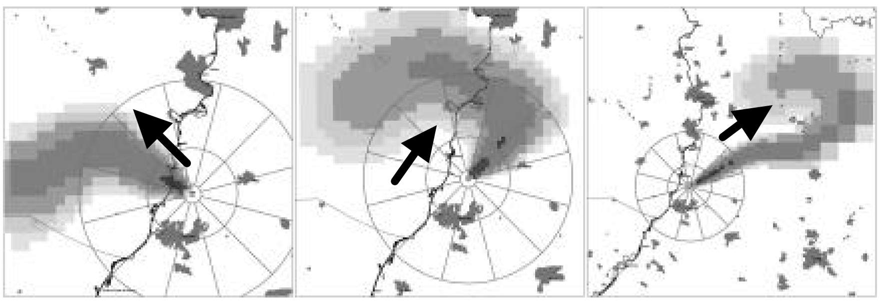

Fig. 1; Calculated maps of near ground Kr 88 activity concentration in air of a spreading cloud from a continuous release of noble gas under changing wind and stability conditions. The radius of the outer circle is 25 km (Result of a RODOS/ATSTEP exercise run).

Different to classic puff models in ATSTEP no short puffs but time-integrated elongated, cigar-shaped puffs with duration of 10 or 30 minutes are released. The transport of each elongated puff is achieved by two trajectories attached to both ends of the puff. The elongated puff approximation reduces the computing time of the model code, so that during less than 10 minutes real-time a complete dispersion and contamination prognosis can be performed with releases over several hours. Nevertheless the spatial and temporal resolution of the results is fully sufficient for the applications in the RODOS system (Fig. 1).

INPUT OF METEOROLOGICAL AND RELEASE DATA INTO RODOS

The RODOS system can be operated in an automatic and an interactive mode. In the automatic real-time on-line operation the ADM ATSTEP is fed with measured meteorological and release data from nuclear power plants, additionally with regional numerical weather prediction data of national weather services. The Validation Kit data do not fit to the real-time weather and release data required by RODOS, so the interactive mode of RODOS was chosen. In this mode RODOS offers detailed windows for user input of sequences of meteorological and release data. Therefore manual input of the source term and weather data of selected episodes of measuring data of the Validation Kit was chosen.

VALIDATION CALCULATIONS WITH RODOS

For a comparison with results of RODOS / ATSTEP the following data sets from atmospheric dispersion experiments contained in the Validation Kit were used: All Copenhagen data sets (9 hours), 3 Kincaid days (17 hours), and 8 Indianapolis days (60 hours). Each hour section of these data sets contains corresponding meteorological data, release rates of SF_6 in g/s, and, in case of stack releases, temperature, volume flux, and initial buoyancy of stack gases, and SF_6 sampling data in ng/m^3 measured in the air near ground.

The hourly data were broken down to 10 minutes data to be used in the RODOS system. All validation calculations were carried out with a time step length of 10 minutes and so were the temporal puff lengths. Measured SF_6 tracer release rates in g/s were substituted in RODOS by releases of the radioactive noble gas Xe-133 in MBq/s. In the case of Kincaid and Indianapolis the released thermal power P relevant for buoyancy was calculated from the given stack effluent temperature Ts, the ambient Temperature Ta, and the volume flux V of the released hot gases:

$$P[MW] = V \cdot r_a \cdot T_a / T_s \cdot c_p \cdot (T_s - T_a) / 10^6 \qquad (1)$$

The stack effluent velocity v_s and the stack area define the volume flux V:

$$V\ [m^3/s] = A_s \cdot v_s \qquad (2)$$

For application of Briggs plume rise formulas the buoyancy flux F_b and the vertical momentum flux F_m were calculated:

$$F_b = \frac{g}{p} \cdot V \cdot (1 - T_a/T_s) \qquad (3)$$

$$F_m = \frac{A_s}{p} \cdot v_s^{\,2} \cdot (T_a/T_s) \qquad (4)$$

The formulas of Briggs are used in the RODOS module FINRISE to calculate the rising and the final height of the trajectories the released puffs are coupled to.

RESULTS: COPENHAGEN EXPERIMENTS

The whole Copenhagen data set comprises 5 hours with Pasquill-Gifford (PG)-category D and 4 hours with category C. The roughness length is z_0 =1 m. The release height was 115 m without any plume rise. Arcs of samplers were positioned downwind of the source at distances of about 2, 4 and 6 km. From the measured data of each arc horizontal plume widths

$\sigma_y(x)$ were derived. These $\sigma_y(x)$ data points fit quite well with the corresponding σ_y-curves of the Karlsruhe-Jülich (KJ) and the Mol parameterization used in RODOS/ATSTEP (Fig. 2).

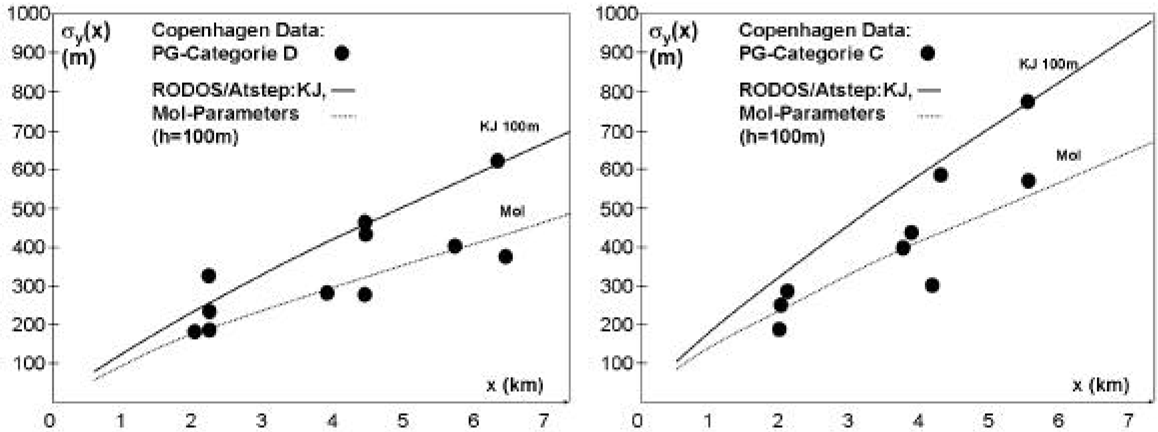

Fig. 2; Measured $s_y(x)$ compared with RODOS/ATSTEP s_y-curves, PG cat. D and C

The next comparison refers to how the near ground concentration under the plume axis changes with source distance. Therefore the maximum measured concentration of each arc was compared with the calculated crosswind maximum concentration at the distance of the arc. Each RODOS/ATSTEP curve corresponds to a dispersion experiment of 1 hour duration. The symbols are the measured maximum arc values. Fig. 3 shows the results for the 5 and 4 experiments with neutral PG-category D and C.

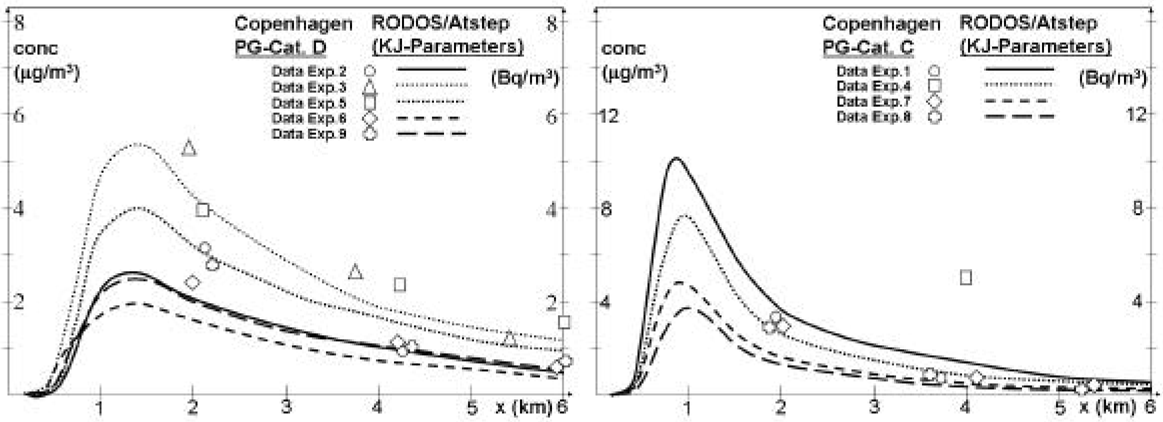

Fig. 3; Measured max. Arc Concentrations Compared with RODOS/ATSTEP using KJ-Parameters, PG cat. D and C

RESULTS: INDIANAPOLIS EXPERIMENTS

The whole Indianapolis data set comprises 170 hours of SF_6 tracer releases and immission measurements during 19 runs. The roughness length is z_0 =1 m. The release height was 84 m. Thermal power of released gases from the stack of the coal fired power station produced additional plume rise. Arcs of samplers were positioned downwind of the source at distances between 0.25 and 10 km. Eight experiments with a total duration of 60 hours were used for the validation study. From the measured data of each arc horizontal plume widths $\sigma_y(x)$ were derived. These $\sigma_y(x)$ data points fit quite well with the corresponding σ_y-curves (Fig. 4) of the Karlsruhe-Jülich (KJ) parameterization used in RODOS/ATSTEP. With neutral stability (class D) the calculated plume widths are similar to the measured data, with convective (B) and stable (E) conditions the calculations overestimate the data. The Karlsruhe-Jülich dispersion parameters are derived from dispersion experiments carried out in Germany. The experiments with stable stratification conditions and release heights up to 100 m were carried out with directional wind shear, swinging direction, and low statistics.

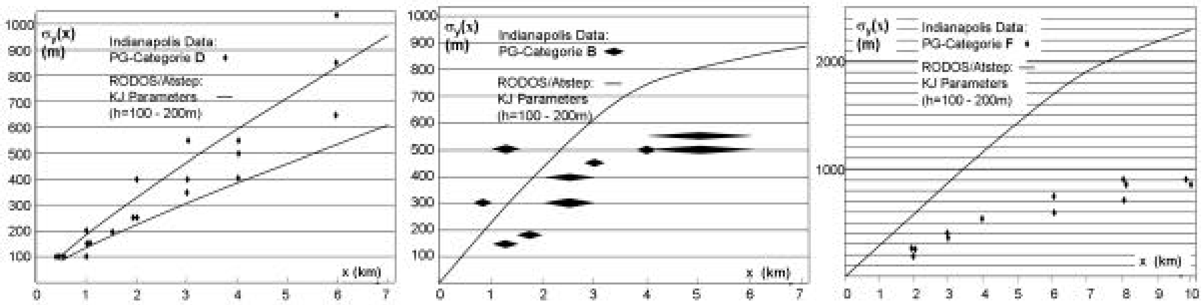

Fig. 4; $s_y(x)$ Indianapolis data and RODOS / ATSTEP results: PG stability B, D, and E.

In the following 3 diagrams the comparisons of measured near ground SF_6 concentrations in $\mu g/m^3$ and corresponding calculated ATSTEP results (activity concentrations of Xe133 in Bq/m^3) are shown. The concentration is on the vertical axis with *linear scale*, the source distance is on the horizontal axis. The measured data (dots) are the maximum arc values at different source distances. The calculated results (curves) represent the near ground air concentration under the plume axis varying with source distance.

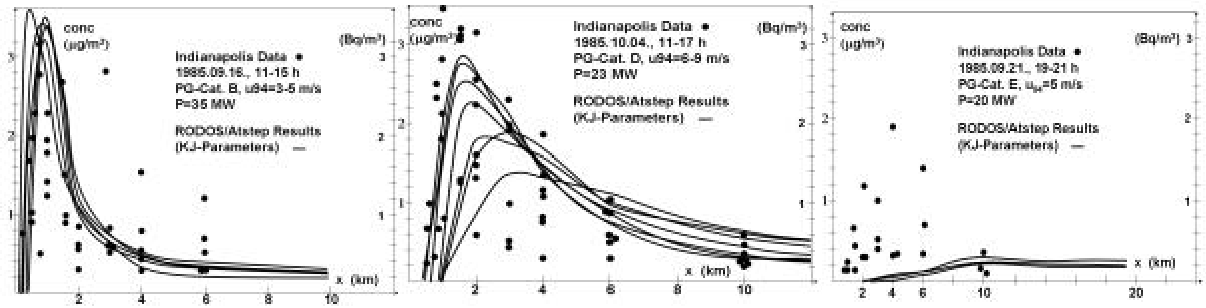

Fig. 5; Indianapolis data and RODOS / ATSTEP resultst: PG stability B, D, and E.

Fig. 5 , cases B and D, shows a satisfactory correlation between calculated and measured data with unstable and neutral stratification (PG categories B and D). The released thermal power of 35 MW and 23 MW produced plume rise of a few hundreds meters. The diagram on the right shows cases with stable stratification (category E). Below 10 km there is a large discrepancy between measured data and calculation. Plume rise lifts the plume centreline to a height of about 200 m within the first 2 km of source distance. The Karlsruhe-Jülich σ_z parameters for stable categories are obviously far too small and therefore the calculated plume does not "touch" the ground early.

RESULTS: KINCAID EXPERIMENTS

The whole Kincaid data set comprises 24 experiments with a total of 171 hours of SF_6 tracer releases and immission measurements. The roughness length is z_0 =0.1 m. The release height was 187 m. Thermal power of released gases from the stack of the coal fired power station produced strong additional plume rise. Arcs of samplers were positioned downwind of the source at distances between about 1 and 20 km. 3 experiments with a total duration of 17 hours were used for the validation study.

In Fig. 6 the results of the experiments 80.05.09 and 81.05.22 are shown (symbols) together with calculated results (curves). The left diagram shows fitting of data only beyond 10 km of source distance. The initial release height of 187 m and the released thermal power of 130

MW are very high. The calculated plume axis height rose from 187 m to 600 m within the first 2 km downwind. The effect of underestimated near ground concentration in the near range appears here already with category B ad C. (see Fig. 5 E and corresponding explanations).

Much better results are shown in the right diagram of Fig. 6 (Kincaid data 1981.05.22.). Here we have also high thermal power releases but the wind speed at 100 m height was higher, between 8 and 10 m/s. Therefore the calculated plume axis height was lower (between 350 and 450 m) thus leading to higher, not underestimated calculated near ground concentrations fitting the measured data quite well.

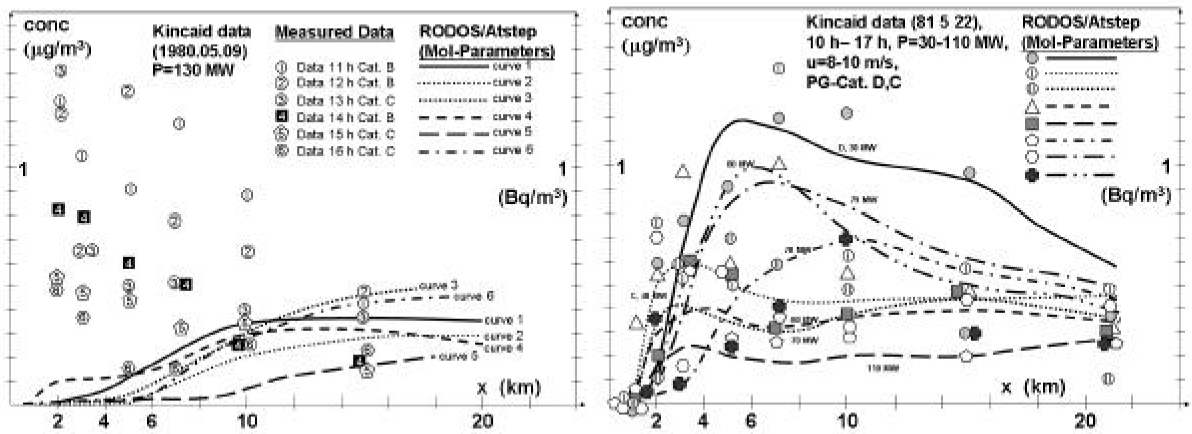

Fig. 6: Kincaid data (1980.05.09.), (1981.05.21.), and RODOS / ATSTEP results

CONCLUSIONS

Satisfying results were achieved with neutral or unstable dispersion situations (PG categories D, C, B) and not too low wind speed and moderate thermal power of the release.

If wind speed was low the enhanced plume rise lead to plume axis heights far above 200 m. At these heights the height dependent KJ σ_z parameters of PG categories C and D are obviously narrower than the vertical width of the real plume.

The same effect shows up with stable stratifications (PG categories E and F) already at heights around 200 m. The KJ σ_z parameters of the stable categories are much narrower than the vertical width of the real plume, and therefore calculated near ground air concentrations are smaller than measured.

Tentative multiplication of σ_z by factors of 2 to 3 in these critical cases results in much better adaptation of the data.

REFERENCES

J. Ehrhardt, A. Weis (eds), 2000, RODOS: Decision Support System for Off-site Nuclear Emergency Management in Europe, European Commission, Brussels, Report EUR 19144