COMPARISON OF ATMOSPHERIC DISPERSION MODELLING ACCORDING TO OLD AND NEW REGULATIONS IN THE NETHERLANDS

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INTRODUCTION

From 1998 onwards the Dutch National Model (NM), which had been the national regulatory model for atmospheric dispersion since 1976 (*Small Commission for Models,* 1976), has been replaced by what has been termed the New National Model (*Project group Revision National Model,* 1998). This New National Model (NNM), which constitutes a conceptual probabilistic model for short range dispersion (up to 25 km) has been implemented into two commercially available software packages: PC-STACKS and PLUIM-PLUS. Recent versions of these applications have been shown to yield similar results (*Erbrink, J.J. and. G.A.C. Boersen,* 2001).

At RIVM the NM was implemented in the computer code OPS version 1.2 (*Van Jaarsveld, J.A.,* 1995). It is used for the calculation of radiation doses to the general public due to emissions of radionuclides by the Dutch industry. This calculation is performed by the software package KREM that models the entire chain from discharge of radioactive substances to individual radiation dose to members of the public due to inhalation, ingestion and ground- and cloudshine. Over the years the OPS1.2 model has been improved to OPS4.0.

In order to comply with the new regulations, we have implemented PLUIM-PLUS (version 3.0) into the KREM software. Apart from that, we have, besides OPS1.2, also implemented OPS4.0. In this paper we compare OPS (versions 1.2 and 4.0) with PLUIM-PLUS in the following way. For a series of scenarios we compare the resulting concentration and deposition values using the Model Validation Tool (MVT) of *Eleveld, H. and H. Slaper* (2002). This tool was initially designed to compare model results with observations, but with some simple adaptations it could be used for intercomparisons of model results. Apart from this, we investigate the consequences of the implementation of the NNM for the calculated radiation dose in the Netherlands. For this purpose we compare the radiation doses calculated with OPS4.0 and PLUIM-PLUS3.0 for a prominent industrial contributor to the radiation dose received by the Dutch population, a phosphor production plant in the southwest of the Netherlands (*Janssen, M.P.M., R.O. Blaauboer, and M.J.M. Pruppers,* 1998).

METHODS

The OPS model is a Gaussian plume model which calculates dispersion for a large series of typical weather situations for the Netherlands. The model is probabilistic in the sense that concentration and deposition values are calculated for a frequency distribution of weather situations. For OPS1.2 long-term averages are obtained using meteorological conditions for the Netherlands from 1979 to 1989, whereas for OPS4.0 meteo from 1990-1999 is used. OPS versions 1.2 and 2 have been compared with the Kincaid data set by *Van Jaarsveld, J.A.,* (1995). This comparison turned out more favourable for OPS2. It may be expected that this also holds for OPS4.0, which constitutes a further improvement of OPS2.

PLUIM-PLUS (currently version 3.0) is a Gaussian plume model as well, but unlike OPS it does not use frequency distributions of weather situations. Instead it uses meteorological data for every hour from 1995-1999. Default for all hours the dispersion is calculated and then averaged. For the evaluated scenarios the runs lasted 4 to 5 days on a 600 MHz Pentium II PC, whereas computation times for OPS amounted to a few minutes. The developers of PLUIM-PLUS acknowledged the heavy computational burden of their approach and therefore also built in the possibility to use a random sample of 5% of all hours. This so-called Monte Carlo approximation leads to 20 times shorter computation times and has been given the status of 'recommended approximation' to the NNM (*Project group Revision National Model,* 1998). Similar to OPS, early versions of PLUIM-PLUS have been validated with the Kincaid data set.

Within the KREM software package input and output of both models are kept as similar as possible to enable a meaningful comparison. However, there are some differences between the models that lead to different inputs for model calculations. These differences are summarized in Table 1.

Table 1. Differences in calculation inputs for PLUIM-PLUS3.0, OPS1.2, and OPS4.0

Model	PLUIM-PLUS3.0	OPS1.2	OPS4.0
Meteo period	1995-1999	1979-1989	1990-1999
Meteo location	Schiphol	Holland+Zeeland	Holland+Zeeland
Receptor grid size	44×44 (max)	65×65 (default)	65×65 (default)
Surface roughness	0.1 m	0.1 m	Variable (25 km^2 cells)

The difference in meteo period was already mentioned, but the difference in meteo locations can also be important. However, Schiphol (Amsterdam airport) is located in the province (North) Holland, where the OPS meteo should also be valid. The different receptor grid sizes are unimportant because we shall only compare receptor points that are in the same locations. Finally, the surface roughness of 0.1 m is an acceptable value for the Netherlands that is not very different from the values in the variable roughness grid used by OPS4.0.

RESULTS

OPS(1.2 and 4.0) and PLUIM-PLUS3.0 (with and without Monte Carlo approximation) are compared using the scenarios defined in Table 2. All scenarios use an emission rate of 1 kg/s and 100 m spacing between receptor points, except for scenario L4b that required 1000 m spacing to cover a substantial part of the dispersion. Note that the classification of aerosols is taken from OPS (*Van Jaarsveld, J.A. and F.A.A.M. de Leeuw,* 1993).

Table 2. Computed scenarios for atmospheric dispersion

Scenario	L2a	L2b	L3a	L3b	L4a	L4b
Stack height (m)	10	10	30	30	150	150
Heat content (MW)	0.1	1	1	10	10	100
Aerosols	medium	medium	medium	Medium	Fine	fine

Figure 1 gives an example of the model results for scenario L3a. Several observations can be made from Figure 1. First of all, there is quite a large difference between the results obtained with OPS1.2 and PLUIM-PLUS. Concentration values calculated with OPS1.2 are significantly higher and they cover a larger area. Secondly, the OPS4.0 result is much more similar to the PLUIM-PLUS result with similar dispersion characteristics, but significant differences in amplitudes are still visible. Finally, the recommended Monte Carlo approximation shows similar amplitudes but a more leafy dispersion pattern.

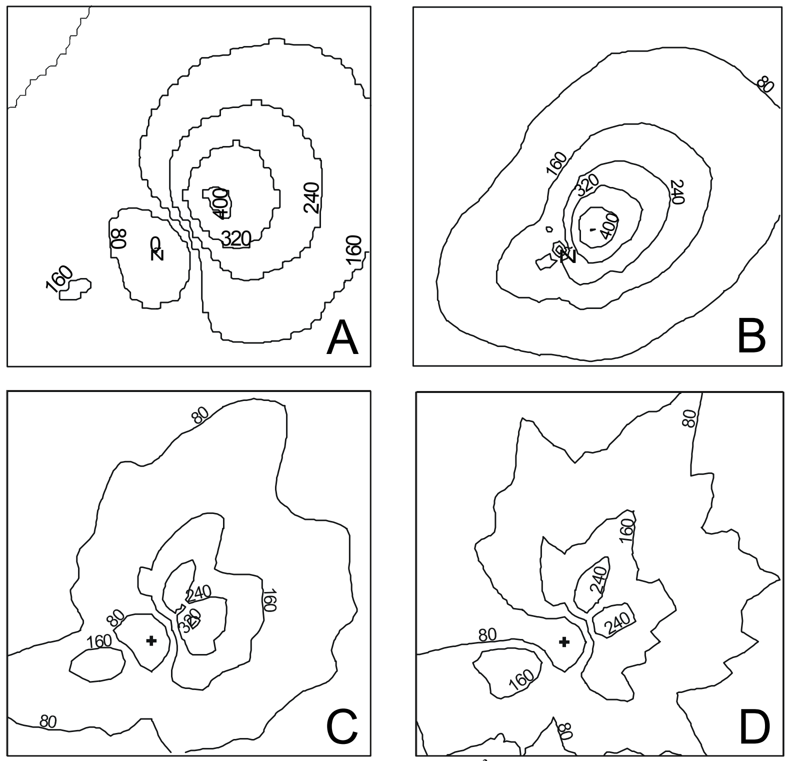

Figure 1. Comparison of concentration values (in $\mu g/m^3$) on a surface area of 3.6×3.6 km^2 for scenario L3a computed with (a) OPS1.2, (b) OPS4.0, (c) PLUIM-PLUS, and (d) PLUIM-PLUS with Monte Carlo approximation. The location of the stack is indicated with +.

To quantify these qualitative statements about similarities and differences of the modelling results, we have applied the MVT. The MVT calculates a series of similarity measures such as the bias, the geometric mean variance, the correlation coefficient, etcetera, and computes a sort of average similarity measure called the ranking (ranging from 0 for identical models to 100 for a total misfit). The rankings for the results in Figure 1 are calculated with respect to the PLUIM-PLUS (without Monte Carlo approximation) result using the overlapping receptor points in the OPS and PLUIM-PLUS grids. The rankings are 35 for OPS1.2, 12 for OPS4.0, and 11 for PLUIM-PLUS with Monte Carlo approximation. This shows that for L3a OPS4.0 and PLUIM-PLUS with Monte Carlo approximation can both be viewed as approximations of the NNM of similar quality. OPS1.2 clearly gives more different results.

In a similar fashion, we have also calculated rankings for the other scenarios in Table 2, both for the concentration values as well as the depositions: see Table 3. Note that rankings have been calculated with different numbers of overlapping receptors. This means that rankings for L2a cannot be compared with rankings for L3a and so on (see *Eleveld, H. and H. Slaper,* 2002). Several conclusions can be drawn from these rankings. First of all, the Monte Carlo approximation yields results closest to PLUIM-PLUS, both for concentration and deposition values. This is not surprising since the Monte Carlo approximation uses part (5%) of the data PLUIM-PLUS without the Monte Carlo approximation also uses. Secondly, the rankings for the concentrations calculated with OPS4.0 are lower than those calculated with OPS1.2 and sometimes nearly as low as those of the Monte Carlo approximation. Thirdly, this is different for the deposition values: for L2a, L3a and L4b the OPS1.2 ranking is lower than the OPS4.0 ranking and for L2b, L3b and L4a vice versa. And finally, the deposition rankings for OPS1.2 and OPS4.0 are much more higher than the PLUIM-PLUS rankings (with and without Monte Carlo approximation) than is the case with the concentration values. This can have (as we will show) a profound influence on the calculated radiation dose.

Table 3. Rankings for different models with respect to PLUIM-PLUS according to the MVT

Scenario	L2a	L2b	L3a	L3b	L4a	L4b
Overlapping receptors	21×21	21×21	36×36	44×44	44×44	44×44
Rank OPS1.2 (conc.)	45	23	35	46	46	34
Rank OPS4.0 (conc.)	27	22	12	21	33	13
Rank Monte Carlo (conc.)	14	21	11	13	20	4
Rank OPS1.2 (depo.)	31	49	36	76	67	55
Rank OPS4.0 (depo.)	38	42	52	61	50	59
Rank Monte Carlo (depo.)	16	23	15	16	24	17

The relatively high ranking of OPS4.0 with respect to PLUIM-PLUS with Monte Carlo approximation is reflected by the bias (the average difference between two grids), which is incorporated in the rankings. For concentration values the bias is large and positive for OPS4.0 and around 0 for the Monte Carlo approximation, whereas for deposition values it is large and negative for OPS4.0 and again around 0 for the Monte Carlo approximation, indicating significantly higher concentration values and lower deposition values for OPS4.0 with respect to PLUIM-PLUS (with or without Monte Carlo approximation). The higher concentration values for OPS4.0 are in good agreement with the results of *Cosemans, G., R. Ruts, and J.G. Kretzschmar* (2001). They compared concentration values resulting from the Belgian dispersion model IFDM and the NNM (the PC-STACKS implementation) and found that at distances beyond a few hundred meters away from the stack the NNM concentrations were systematically 60-70% of the IFDM results. They did not compare deposition values.

In practice the atmospheric dispersion models are used within KREM that calculates radiation doses to the general public. In the framework of regulations and associated permits for discharges, it is interesting to look at a realistic case and see what the consequences can be when using different dispersion models. A significant contributor to the radiation dose received by the population is a phosphor production plant in the southwest of the Netherlands (Zeeland) that like many contributors to the radiation dose in the Netherlands is almost of the L3a type. We have calculated the radiation dose due to the plant's discharges of Po-210 and Pb-210 in 2000 with PLUIM-PLUS3.0 and with OPS4.0. The results are shown in Figure 2.

It is clear from Figure 2 that the dose calculated with the NNM is rather different from the one calculated with OPS4.0. The maximum dose is lower in the NNM case, but the higher deposition values lead to higher doses over a much larger area. In view of the Dutch regulations this can have a severe impact on the granting of permits, and possible measures to be taken by the inspection.

CONCLUSIONS

In general we find that the NNM (in the form of PLUIM-PLUS3.0) gives slightly lower concentration and significantly higher deposition values than both OPS1.2 (an implementation of the NM) and OPS4.0. This is consistent with the findings of *Cosemans, G., R.Ruts, and J.G. Kretzschmar* (2001), who found lower concentration values with the NNM than with the Belgian model IFDM. Mainly as a consequence of the higher deposition values we find significantly different values for the radiation dose to the Dutch population. Maxima are lower, but the relatively high dose is spread over a larger area.

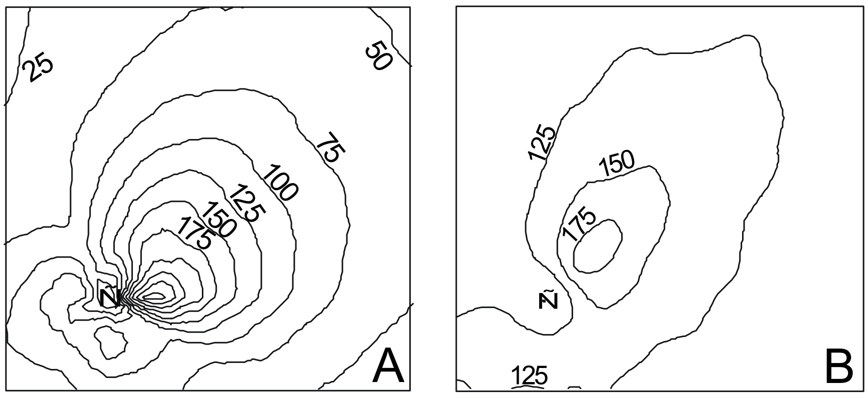

Figure 2. Radiation dose (identical arbitrary units) to the public due to the emission of radionuclides by a phosphor plant (+) calculated for an area of 4.4×4.4 km^2 with atmospheric dispersion (southern Netherlands meteo) according to (a) OPS4.0 and (b) PLUIM-PLUS.

In the near future we hope to compare the results of the NNM (PLUIM-PLUS) and OPS4.0 with real data by incorporating the meteo data from the Kincaid data set. Since only early versions of both models were compared with the Kincaid data set, this would give a more absolute indication of the performance of the current versions of these models.

REFERENCES

Cosemans, G., R. Ruts, and J.G. Kretzschmar, 2001: Impact assessment with the Belgian dispersion model IFDM and the New Dutch National Model, Proc. 7th int. conf. on Harmonisation within atmospheric dispersion modelling for regulatory purposes, Belgirate, Italy, 125-129.

Eleveld, H. and H. Slaper, 2002: Development and application of an extended methodology to validate short-range atmospheric dispersion models, in: Quantitative methods for current environmental issues, eds. C.W. Anderson et al., Springer.

Erbrink, J.J. and. G.A.C. Boersen, 2001: Benchmark PC-Stacks and PluimPlus, a comparison for 25 cases (in Dutch), KEMA report 99560456-KPS/SEN 01-3020, Arnhem, the Netherlands.

Janssen, M.P.M., R.O. Blaauboer, and M.J.M. Pruppers, 1998: Geographical distribution of radiation risks in the Netherlands, *Health Physics*, **74** (6), 677-686.

Project group Revision National Model, 1998: The New National Model, research report of the project group Revision National Model (in Dutch), TNO Environment, Energy and Process Innovation, Apeldoorn, the Netherlands.

Small Commission for Models, 1976: Models for the computation of dispersion of air pollution with recommendations for the values of parameters in the long term model (in Dutch), Staatsuitgeverij, Den Haag, the Netherlands.

Van Jaarsveld, J.A., 1995: Modelling the long-term atmospheric behaviour of pollutants on various spatial scales, PhD thesis, Utrecht University, the Netherlands.

Van Jaarsveld, J.A. and F.A.A.M. de Leeuw, 1993: OPS: An operational atmospheric transport model for priority substances, *Environmental Software*, **8**, 93-100.