Impact assessment with the Belgian dispersion model IFDM and the New Dutch National Model

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1 Introduction

The EU framework directive on air quality 96/62/EC calls for modelling as one of the methods for assessing air quality and it emphasises the need for common methods for air quality assessments.
In 1994, a comparison[1] was made of six Gaussian dispersion models used for regulatory purposes in different countries of the EU. In this comparison, the Dutch National Model (DNM) was found to systematically calculate the lowest concentrations.
Since then, a New Dutch National Model[2] has come into use. One of the commercially available versions of the New Dutch National Model is called PC-STACKS.
Do regulatory modelling with the Belgian IFDM-model and with the New Dutch National Model give comparable results? In order to find out, we use PC-STACKS to calculate the impact of some emission scenarios taken from recent environmental impact assessment studies that were conducted in Belgium with IFDM, and compare the model outcomes. The emission scenarios are given in Table 1.

Table 1 Characteristics of the emission scenarios [a]

Scenario Number	Source type	h_g (m)	d (m)	T_r (°C)	R (Nm³/s)	M (MW)	Q^1 (s^{-1})	Immission Parameter	T_{av}
S1a	area	0	100x100	ambient	-	0	100 000 o.u.	P99	1 h
S1b	area	0	100x100	ambient	-	0	85 000 o.u.	P99	1 h
	point	55	2.5	ambient	28	0	15 000 o.u.		
S2	point	70	3	25	68	1.4	31 g CS_2	maximum	1/2 h
S3	point	55	5	127	150	24	0.3 µg TEQ	average	year

[a] hg = physical stack height; d= internal stack diameter -or- size of area source; T_r = stack gas exit temperature; R = volumetric flow of stack gas; M = heat flow; Q = emission mass flux., T_{av} = averaging time;
[1] o.u. = odour units; TEQ = toxicological equivalent

2 The models

IFDM, the Immission Frequency Distribution Model, is used in Belgium since 1972 for assessing the impact of atmospheric emissions upon local air quality. Theory behind IFDM is the stability classification scheme of Bultynck-Malet[3] , who investigated atmospheric dispersion using the 120 m high meteorological tower of Mol, Belgium. Atmospheric stability is defined as the ratio of the gradient of the potential temperature between 114 m and 8 m over the square of the wind speed at 69 m. (This ratio is proportional to the Bulk Richardson number.) The dispersion parameters $\sigma_y(x)$ and $\sigma_z(x)$ are functions of the Bulk Richardson number, determined from the statistical evaluation, according to Taylor's statistical theory, of 3D-wind fluctuation measurements at 69m. For regulatory modelling, a time series of one year of hourly observations (potential temperature gradient between 114m and 8m , wind speed and direction at 69 m) measured at the Mol meteorological tower, is used.

The Dutch National Model has been revised in the period 1985-1988. Theory of the new model is based on the R&D-STACKS model[4] and uses amongst others sensible heat flux, friction velocity, Monin-Obukhov length, turbulence intensity, Eulerian and Langrangian time scales, mixing height, vertical profiles of wind speed, wind direction and temperature and Taylor dispersion theory. The surface layer parameterisation of Flesh *et al.*[5] has been added for the dispersion of near ground-level releases. For regulatory modelling, a time series of hourly observations (for up to five years) of wind speed and wind direction, measured at 10 m height on an airport location, global radiation, temperature and cloud clover, is used.

3 Meterological data

We use meteorological data of the year 1991. Data for PC-STACKS come from Eindhoven airport, the data for IFDM from the meteorologal tower in Mol. Both data-sets are fairly complete, with all parameters needed for dispersion calculations known for 88% of the hours in 1991 at Mol and for 92% of the hours at Eindhoven.
Mol and Eindhoven are 35 km apart, situated in a flat terrain with comparable land-use. Wind direction frequency roses for Mol (69 m) and Eindhoven (10 m) of 1991 are given in Figure 1. The most frequent wind direction over this region is south-west. (As the wind direction frequency roses are not for simultaneous hours of observation, further discussion on features of similarity or differences in the wind frequency roses would be in vain.)
In this paper, we compare model results for a line of receptors situated N.E. of the sources, that is, under the dominant wind direction. On this receptor line, some important aspects of similarity and difference between the output of both models might be detected in a clear way; but some particular differences between the calculated 2-dimensional immission fields might go unnoticed.

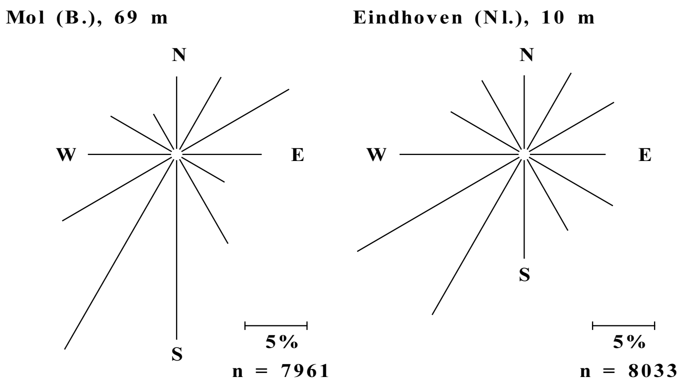

Figure 1 Wind frequency roses.

4 Results

*4.1 Horse manure composting (Senario's **S1a** and S1b)*

Odour emitted near ground level by a horse manure composting facility for the production of mushroom growing substrate can cause nuisance up to a distance of several kilometres. For this facility, the actual emissions are estimated by sensory campaigns to be 100 000 o.u. (odour units) per second, emanating from an area source 100 m x 100 m. Public places are as close as 128 m N.E. of the area source centre. In the future, most of the odour substances will be released through a proposed 55 m high stack. The 99th percentile of the hourly concentrations (P99,1h) is considered as one of the relevant immission parameters for odour prevention.

- *Emission scenario **S1a** (actual situation, no stack, Figure 2a)*: the P99,1h of the concentrations NE downwind the facility, calculated by IFDM and PC-STACKS, for distances from 128 m to 2 km, are within 10 percent; e.g.: at 2828 m, 0.68 o.u./m³ (IFDM) and 0.77 o.u./m³ (PC-STACKS).

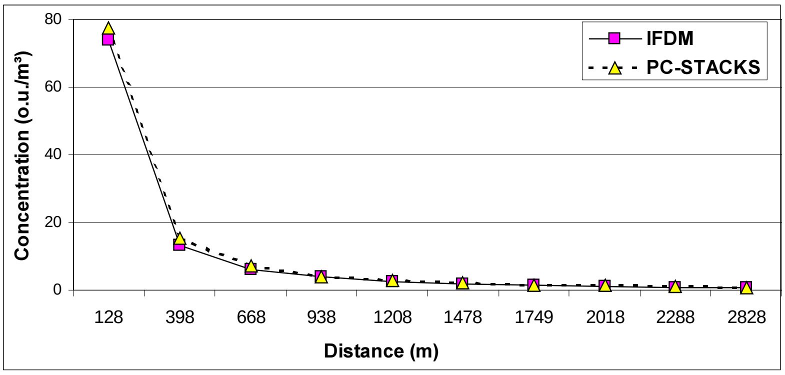

Figure 2a P99,1h of IFDM and PC-STACKS concentrations NE of 100 m x 100 m area source.

- *Future emission scenario **S1b** (85% through the stack and 15% by the area source, Figure 2b)*: calculated P99,1h values by the two models are almost identical till 400 meter NE of the composting facility. (The impact of the ground-level area source is dominant here). From 900 m on, PC-STACKS P99.9,1h values are around 67% of the IFDM values. The distance where 1 o.u./m³ is no longer exceeded is 700 m for PC-STACKS, and 1200 m for IFDM.

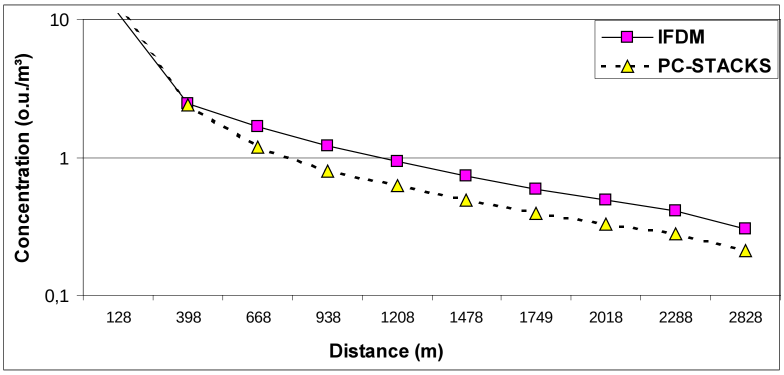

Figure 2b P99,1h of IFDM and PC-STACKS calculated concentrations NE of the 100 m x 100 m area source (15 000 o.u./s) and the 55 m zero MW stack (85 000 o.u./s).

*4.2 Viscose rayon industry (Scenario **S2** in Table 1)*

According to the WHO air quality guidelines, this kind of industry gives emissions of CS_2 and H_2S, resulting in odour problems due partly to H_2S but mainly to a number of rather undefined substances correlated with the CS_2-output. Emission is 110 kg CS_2/h through a 70 m high stack in a volumetric mass stream of 67.5 Nm³/h. WHO air quality guidelines are 100 µg CS_2/m³ as maximum day-averaged concentration to avoid health problems and 20 µg CS_2/m³ as maximum half-hourly concentration to avoid odour nuisance.

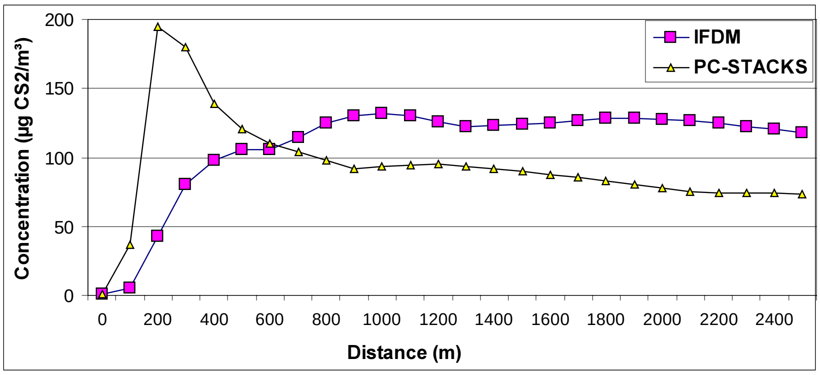

Figure 3a Maximum of half hourly concentrations NE of the 70 m viscose rayon industry stack.

The downwind profiles of the maximum half hourly concentrations (Figure 3a) show similarities and differences. Both models agree on that the WHO limit of 20 µg CS_2/m³ is exceeded over a long distance. PC-STACKS predicts a peak of 200 µg CS_2/m³ at 200 m from the stack, IFDM does not.
This peak value is not longer present on the P99.9,1h profile (Figure 3b), the concentration level that is exceeded in at most 8 hours a year. P99.9,1h concentrations calculated by PC-STACKS are 75% of IFDM-concentrations up to 1 km, then decreasing to 50% at 2 km distance.

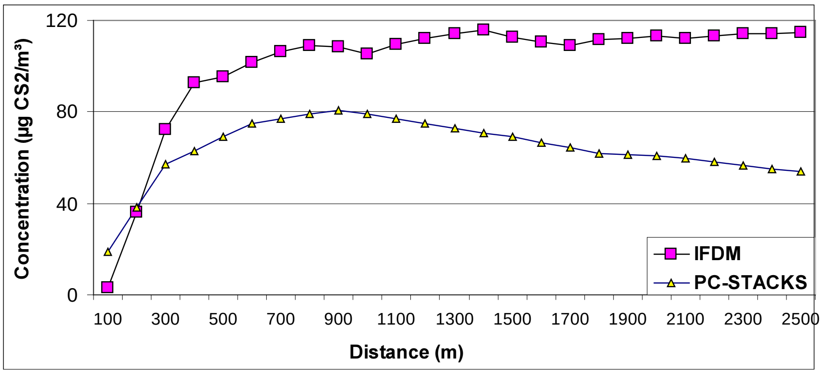

Figure 3b P99.9,1h profile NE from the viscose rayon industry.

*4.3 dioxins from a sintering process at a steel mill (Scenario **S3**, Table 1)*
In one of the emission scenario's to be calculated, 150 Nm³/s of gases, resulting from a sintering installation at a steel mill, is emitted through a 55 m high stack with 24 MW of heat. Dioxins and furans emission is 0.3 µg TEQ/s. The air quality standard to evaluate the impact of this emission is deposition. PC-STACKS does not report deposition, so we will look at the yearly averaged concentration instead (Figure 4). The units used are femtograms (fg), 1 fg = 10^{-9}µg. The largest values of the yearly average are pretty much equal for both models (6.6 fg/m³ for PC-STACKS, 7.4 fg/m³ for IFDM, or 7 fg/m³ ± 6%). The distance where the largest yearly average occurs is smaller for PC-STACKS (1.1 km) then for IFDM (2.2 km). From a distance of 2 km onwards, PC-STACKS calculated yearly averages are 70% to 60% of those calculated by IFDM.

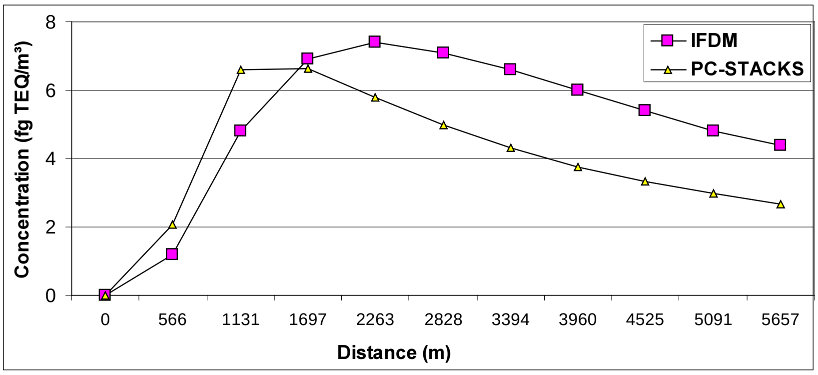

Figure 4 Yearly average NE of the 55 m 24 MW sintering stack.

4 Conclusions

The Belgian IFDM and the New Dutch National model were found to give results within a factor of two for the emission scenarios investigated. Typically, for most of the parameters considered, the down wind concentration profiles show peak values of comparable magnitude. However, PC-STACKS predicts the peak value to occur at only half the distance IFDM does. At larger distances downwind, PC-STACKS concentrations are systematically 60-70 % of IFDM results, at least for the statistical parameters investigated.

P98.1h concentrations downwind a ground-level area source were found to be equal. The models have a very different opinion about the 1h maximum downwind a 70 m stack.

All by all, the New Dutch National Model gives results that are much more similar to those of the Belgian IFDM model, as was the case with the Old Dutch National Model that investigated in reference 1.

References

1. Maes, G., Cosemans, G., Kretzschmar, J., Janssen, L. and Van Tongerloo, J. (1995), 'Comparison of six Gaussian models used for regulatory purposes in different countries of the EU', *Int.J. Environment and Pollution*, Vol.5, Nos.4-6, pp.734-747.
2. van Ham, J., Duijm, N.J., Erbrink, J.J., van Jaarsveld, J.A., Pulles, M.P.J, Schols, E. and Verver, G. (1997), 'Revision of the Netherlands National Model for short range dispersion of air pollutants', *Int.J. Environment and Pollution*, Vol.8, Nos.3-6, pp.771-777.
3. Bultynck, H. and Malet, L. (1972) 'Evaluation of atmospheric dilution factors for effluents diffused from an elevated continuous point source', *Tellus*, No. 24, pp. 445-472.
4. Erbrink, J.J. (1995) 'Turbulent diffusion from tall stacks. The use of advanced boundary layer meteorological parameters in the Gaussian dispersion model STACK', Thesis, Free University, Amsterdam.
5. Flesch, T.K., Wilson, J.E. and Yee, E. (1995) 'Backward-time Lagrangian stochastic dispersion models and their application to gaseous emissions', *J.Appl.Meteorol.*, Vol 34, pp.1320-1332.