THE RESUSPENSION MODEL

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INTRODUCTION

The particles contained in the ambient air present one of the biggest problems. Their air quality limit values are exceeded on many regions in the Europe. Fine fractions have significant influence on the man's health.

In general, we can distinguish three main particle sources: 1. *primary particles* (emitted directly to the atmosphere), 2. *secondary particles* (created by oxidation and consequent reactions of gaseous compounds in the atmosphere) and 3. *resuspended particles* (raised from the surface by the wind).

Ordinary Gaussian models consider usually only primary emission sources. That's why their results underestimate the real concentration of suspended particles in the atmosphere. Eulerian models incorporate chemical submodels and can take into account also secondary particles. The contribution of resuspended particles is often omitted although it can represent important part of total air pollution. Therefore we will concentrate on the resuspended particles in this paper.

Factors influencing resuspension

The amount of particles raised from the surface depends on many factors, which is roughly possible to divide into following groups:

- *character of particles on the Earth's surface* (particle size, density, total amount of available particles on the surface, their chemical composition…)
- *meteorological conditions* (wind speed and direction, frequency of wind gusts, surface humidity, presence and intensity of rain, snow cover, surface temperature…)
- *Earth's surface properties* (landcover, terrain configuration – slope of terrain…)
- *additional activities* (movements – eg. vehicles moves, manners of land cultivation, building or mining activities…)

RESUSPENSION MODEL

Model presented in this chapter is designed to be compatible with SYMOS'97 method (SYstem for MOdelling of Stationary sources – the Czech regulatory model), see *Bubník, J., Keder, J., Macoun, J. and Manák, J.,* 1998.

Resuspension intensity depends on the ratio of the force lifting an individual particle from the surface and its weight. This ratio is called parameter of resuspension (R). It can be expressed by the equation (1).

$$R = \frac{3\pi \nu.\rho}{C_2.\rho_c.g}.\frac{u_*}{d^2} + \frac{C_3.\rho}{C_2.\rho_c.g}.\frac{u_*^2}{d} \qquad (1)$$

where C_2, C_3 are empirical constants (C_2 = 0,8; C_3 = 0,6); d is a characteristic dimension of particle [m]; $u*$ is the friction velocity [m.s^{-1}]; ν is a kinematic viscosity of air [m^2.s^{-1}]; ρ is an air density [kg.m^{-3}] and ρ_c is a particle density [kg.m^{-3}].

The limitary condition for lifting of particles from surface is $R = 1$. The emission of particles will be zero, if the value of parameter of resuspension is lower than 1.

The friction velocity increases in a surface layer linearly according the logarithmic law. This is valid only for wind speeds insufficient for the dust stir (in accord with experiments about 4.3 $m.s^{-1}$). The aerodynamic surface roughness rapidly increases during the situations with wind stronger than 4.3 $m.s^{-1}$ and the friction velocity accrual is faster than linear. The equation (2) expresses the relation between wind speed and friction velocity. It is based on experiments and statistical methods.

$$u_* = a.u^b + 0{,}12 \qquad (2)$$

$$a = a_0.(1 + a(r_c - 2700)) \qquad a_0 = 0{,}0028\ (m/s)^{1-b},\ a = -1{,}91 \,.\, 10^{-4}\ m^3.kg^{-1}$$

$$b = b_0.(1 + b(r_c - 2700)) \qquad b_0 = 2{,}016, \qquad ß = 4{,}65 \,.\, 10^{-5}\ m^3.kg^{-1}$$

where u is wind speed velocity [$m.s^{-1}$].

The amount of particles resuspended from the Earth's surface Q can be calculated by the equation (3).

$$Q_i = \frac{a_{pi}}{100}.E.C_2.u_*.d_i^2.(R-1) \qquad (3)$$

where d_i is a characteristic dimension of particle in the particle size class i [m]; E is a constant ($E = 1957\ kg.m^{-5}$) and α_{pi} is a incidence of particles in the size class i [%].

The total emission from the area of extent S is given by equation (4).

$$M_E = S.\sum_{i=1}^{m} Q_i \qquad (4)$$

DESIGN OF STUDY

We selected the locality Prgaue – Libus, CZ for the evaluation study. The reasons for this choice were following:

1. There is placed the automatic air quality monitoring station.
2. Meteorological surface and sonde measurements are also available for this place.
3. The chosen area includes many different terrain types (built-up areas, forest, agricultural land…).

One of the most important factors for the evaluation of resuspension is a land type. The size distribution of particles, the total amount of available dust etc. depends strongly on this type. The study area has been divided into six categories for the purposes of this study: forest, grass land, agricultural land, uncovered surface, hard soil and buildins.

We can see the study area on Fig. 1 (left). The air quality monitoring station is marked by the white square in the middle of the picture. The calculations were done for this point. The right picture shows the terrain. The heights above see level are in the range from 220 to 310 m asl. The calculation point is on the height 304 m asl.

The resuspension has been evaluated in emission squares 25 x 25 m based on hourly meteorological conditions.

The calculations have been made for the year 2004. Model values were subsequently compared with total measured concentrations of suspended particles fraction PM_{10} and $PM_{2.5}$.

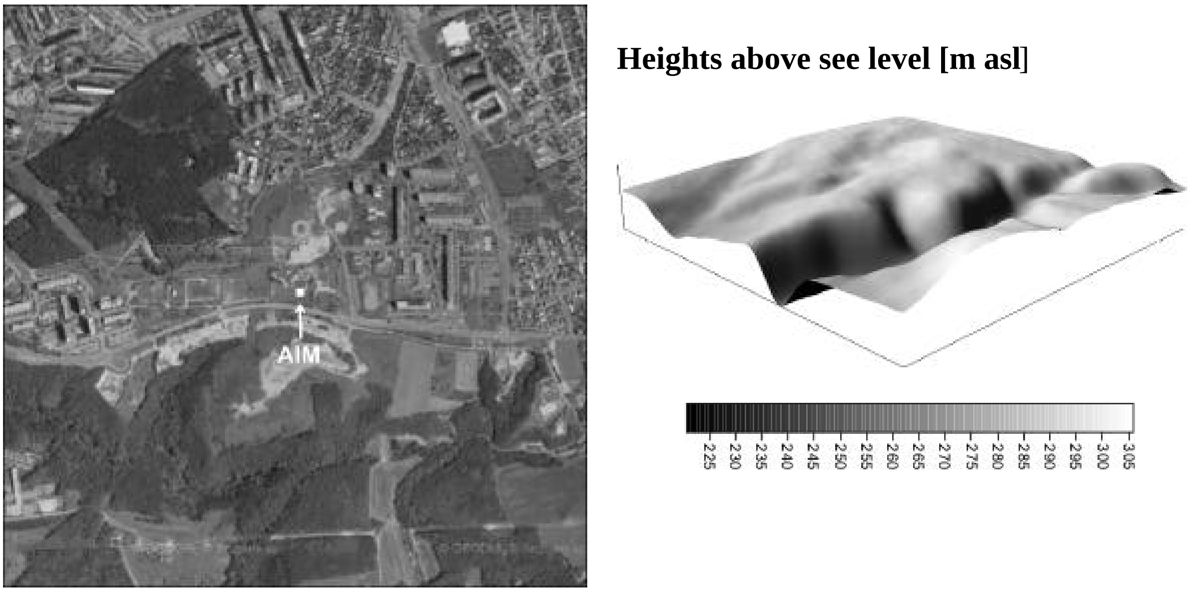

Fig. 1; The study area

RESULTS

There are presented the comparison of model values and measurements on the graphs on Fig. 2. Both PM_{10} and $PM_{2.5}$ concentrations are shown.

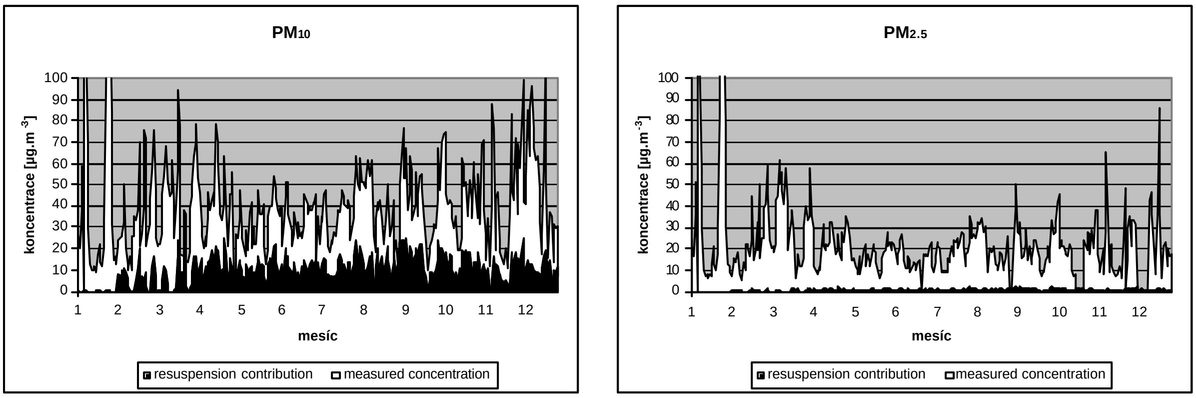

Fig. 2; Comparison of modelled contribution of resuspension and total suspended particles concentrations

The dependency between total PM_{10} concentration and contribution of resuspension is relatively weak (R^2 = 0.16). It is not surprising because the total concentration is influenced by many other sources. Regardless it is clearly visible good correspondence between the changes of total concentration and resuspension contribution. The portion of resuspension on total concentration of PM_{10} is about 30%, what is in good agreement with expectations.

The correlation between total concentration of $PM_{2.5}$ and resuspension in this fraction is close to zero. It has been also expected because the size of particles on the Earth's surface is mostly bigger. The modelled contribution of resuspension to the total concentration $PM_{2.5}$ is about 5%.

There are presented the monthly, seasonal and annual average values of PM concentrations and meteorological characteristics in Table 1. In general, the higher contribution of resuspension was calculated during warm and dry seasons and also the correlation between resuspension and total concentration is more important during these situations. The resuspension was strongly limited during the cold season (especially during January – the month with snow cover).

Table 1. Comparison of measured concentration of PM10 and the resuspension contribution; meteorological parameters

Season	Air quality					Meteorology		
	PM_{10} measur. $\mu g.m^{-3}$	PM_{10} resusp. $\mu g.m^{-3}$	$PM_{2.5}$ merení $\mu g.m^{-3}$	$PM_{2.5}$ resusp. $\mu g.m^{-3}$	PM_{10} R^2	T °C	srážk. úhrn mm	nr. of days w. rain
year	31.2	9.9	22.9	1.0	0.164	9.4	679.7	172
cold s.	34.9	7.1	28.1	0.8	0.108	3.3	292.9	87
warm s.	26.3	12.5	18.1	1.2	0.330	13.9	386.8	85
Jan	49.7	0.3	44.8	0.1	0.133	-2.6	81.2	23
Feb	29.0	6.1	22.4	0.6	0.129	2.7	29.4	12
Mar	36.0	5.9	30.2	0.6	0.085	4.2	56.2	14
Apr	30.7	13.0	22.3	1.2	0.227	10.2	20.2	9
May	21.0	11.4	14.6	1.1	0.506	12.7	51.8	14
Jun	24.2	6.1	15.5	1.1	0.170	16.6	116.7	22
Jul	24.9	11.8	17.1	1.1	0.311	18.9	54.7	14
Aug	29.8	12.7	20.5	1.2	0.155	20.1	81.2	14
Sep	27.7	15.0	18.9	1.4	0.720	14.8	62.2	12
Oct	31.1	13.6	22.0	1.3	0.224	10.4	29.6	14
Nov	29.7	8.3	20.5	0.8	0.286	4.5	76.5	19
Dec	31.7	10.9	21.1	1.0	0.302	0.4	20.0	5

CONCLUSIONS

The introduced model provides relatively good results for the model evaluation of resuspension contribution to the total concentration of suspended particles. Presented results are in agreement with expectations and correspond to measured concentrations.

The higher resuspension contribution in fraction PM_{10} than in $PM_{2.5}$ is in accordance with particle size distribution. Meteorological conditions strongly influence the amount of resuspended particles.

There is still lot of work for future development of this model, especially in the field of justification of meteorological processes. We plan to use results of this model as one of bases for the construction of air quality maps.

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