Methods of modelling the pollutant emissions from the line emitters used in Slovak Republic

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Metódy modelovania znečistenia ovzdušia od líniových zdrojov používané v Slovenskej republike

V príspevku je prezentovaná aplikácia rozšírenia matematického modelu MODIM pre výpočet znečistenia ovzdušia od líniových zdrojov. Model bol rozšírený v súlade s metodikou US EPA -ISC a metodikou modelu CALINE odporučený úradom EPA USA. Pre upresnenie rozptylových podmienok konkrétnej lokality bol zavedený parameter drsnosti povrchu v súlade s odporučením podľa Lettaua. Výhodou navrhnutého modelu je rovnaké prostredie pre výpočet znečistenia ovzdušia od stacionárnych a mobilných zdrojov ako aj porovnateľné výsledky na medzinárodnej úrovni na základe metodiky US EPA. Model bol overený na zhodnotení lokality mesta Košice.

Key words : *air pollution modelling, dispersion model, line source, roughness lenght*

Introduction

Road transport is a major source of the local air pollutants. Pollutants from the road transport are particularly important in busy urban areas. Cutting the road transport emissions is therefore likely to be a key part of local air quality management. The air quality control and management is also one of the areas in which Europe has been the most active in recent years. Air quality assessment is the process of determining the nature of ambient air pollution using monitoring and supplementary techniques such as modelling. Validation of model results against local monitoring data (if available) is eligible.

The outcome required is an assessment of the relative contribution of different source types (typically traffic, industrial and background sources) to air pollution within the city area. This can then be used to help assess the effectiveness of different control options and identify or more source types to be addressed. During the assessment process, a variety of the models may have been used to assess the impact of different sources however this may lead to inconsistencies. It is important, therefore, that information used in the assessment process is based on the same assumptions.

Background

Mathematical modelling of air pollution effectively enlarges our information about the air pollution level. It is an efficient tool for the elaboration and control of projects for air sanitation in areas with the individual extra protection.

For the calculation of the pollutant concentration from stationary sources in Slovak Republic, is elaborated on the basis of the American model methodology from the Industrial Source Complex Dispersion Models (ISC), issued by the Environmental Protection Agency (EPA) in 1992 (SZABÓ, 1995). On the basis of the methodology, made by the Ministry for Environment of Slovak Republic, that is intended for mathematical modelling of air pollution was elaborated an user-oriented software product with the abbreviation immissions modelling MODIM. The Gaussian scattering model for the ground surface field determines the concentrations of gaseous pollutant substances in the air and the solid particles to 20 micrometers. MODIM serves for the calculation of short and long-term concentrations of harmful substances in residential and non-residential regions. It makes possible to calculate short and long-term critical concentrations of pollutants and the overfull of threshold values. To be possible to use the model for the calculation of harmful substance concentration field over an larger area where is deformed the field of wind due to the influence of terrain, the version with the possibility of using more wind roses was elaborated. Such model was successfully used for the calculation of concentration field of the baseline air pollution matters in the whole Slovakia area.

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Model description

The model entitled MODIM5 is presented in this paper. This model is in reality the application of the enhancement of mathematical model MODIM4 for the air pollution calculation from line sources. It was spread according to the methodology US EPA - ISC. For the specification of diffusion conditions in a particular locality of city the surface roughness parameter was loaded according to the recommendation in compliance with LETTAU. The advantage of the suggested model is the identical surrounding for the computation of air pollution from stationary and mobile sources as well as comparable results at the international standard (SZABÓ, 2001).

The suggested model will provide users with a background information, valuable tools to assess the levels of air pollution in a locality. It tries to provide a clear facility for the preparation of a Local Air Quality Action Plan and it will given information of the levels, causes and trends of the ambient air pollution. The ideal approach, if a sufficient information on release characteristics and a suitable model is available, is to model the impact of all sources. Provided that the information has been derived on a consistent basis, the annual average contributions from different sources can be added to provide an overall total. The relative contribution from each source type can then be calculated as a percentage of the total.

Given the source strength, meteorology, site geometry, and site characteristics, the model can reliably predict pollutant concentrations for receptors located at the chosen points (receptors). At present, the model can handle only pollutants such as carbon monoxide, nitrogen oxides and particular matter (particularly – PM 10), and within neutral condition for dispersion. It is anticipated that the ability for other dispersion conditions will be added yet to the end of this year.

Historically, the MODIM series (MODIM1 until MODIM4) of models required a relatively minimal input from the user. While MODIM5 has several added inputs as compared to MODIM4, it must still be considered as an extremely easy model to implement. More complex models are unnecessary for most applications because of the high uncertainties in terms of the input complexity.

This report should help the potential user of MODIM5 to understand how to apply the model. Users should become thoroughly familiar with the workings of the model and, particularly, its limitations. This knowledge will aid them in deciding when and how to use MODIM5. In addition, users should become familiar with the response of the model to changes in various input parameters. This information will be listed in the sensitivity analysis portion of MODIM5 User's Guide.

The traffic is the predominant source of pollution in cities. In busy streets of most countries it is to be expected that the Air Quality Guidelines, a.o. for NO_2, CO, benzene and suspended particulate will be exceeded. A continuous monitoring of the air quality in such streets however will be very costly and not feasible allways. Model calculation is an useful alternative to the measuring. However, the existing line source models have their limitation. Modelling traffic emissions in built-up areas is very complex and requires much input.

Most of the line source models assume a homogeneous terrain around the source or a street canyon configuration. In practice, the application is limited to highways in open and flat terrain and to street canyons. At most locations near the city traffic, including intersections, buildings do not form a street canyon. For this case our model can be exactly used. The variation of the pollutant concentration with the wind speed and stability is relatively well known for most conditions. It is well known that buildings have a very strong and complicated influence on the flow of air in the direct vicinity. The wind speed is a function of the surface roughness, i.e. in a different type of built-up area the wind speed will be different too. The user assesses the value of the roughness length for each side within area of the city. The surface roughness is assumed reasonably uniform throughout the each side within the city area. The meteorological variables of atmospheric stability and wind direction are also taken as constant over the whole city area.

In this model the traffic is represented by line sources divided in series of small volume sources according to ISC. The vertical wind profile is described by the logarithmic law and the dispersion parameters are those of Pasquill. The dispersion induced by traffic was taken into account by an initial vertical dispersion according to CALINE4. The user should keep this assumption of horizontal homogeneity in mind when assigning the section of roadway.

The model should not be used in areas where the terrain in the vicinity of roads is sufficiently rugged to cause a significant spatial variability in the local meteorology. The model should not be used for streets within a central business district where the so-called street canyon effect is significant. For this event the user can apply the model called STREET or KALIB (HESEK, 1997). In the modules KALIB and STREETS the distribution of the pollutant concentration in the street canyons is calculated. The pollutant concentration at 1,5-m height and at the top of the buildings on both sides of the street is printed out. The module KALIB does it only on one chosen street (where the calibration measurement is done) and for the actual meteorological parameters given interactively through the screen of the computer. In the module STREETS it is done for the mean meteorological parameters at eight basic wind directions. In both modules, the contributions of the individual streets and the resulting pollutant concentration from all streets being situated against the wind direction are calculated. STREET and KALIB is based on the numerical solution of the boundary problem with the specific boundary conditions. The dispersion of the pollutants from the line source is described by the stationary two-dimensional partial differential equation of turbulent diffusion. A street may be considered a canyon enclosed from either or both sides by buildings. The boundary problems referred have to be solved by the method of finite differences (Hesek, 1993). These models may be called from the MODIM4 as subroutines.

The results were incorporated in the former Gaussian plume type model for the dispersion of traffic exhausts, called MODIM4. It is a model using readily available input data and it calculates annual and short-term concentrations for non-reactive air pollutants and NO_2. The user assigns the decay half-life for the removal processes of NO_2. The program has been made more flexible and user friendly. User-defined system data, such as emission factors of passenger cars and trucks, city ambient and regional background concentration and anaverage regional wind speed and roses can now be changed interactively. The program automatically sums the contributions from each link to each receptor or grid point. After completing for all receptors, an ambient or background value assigned by the user may be added.

MODIM5 does not contain a method by which predicted concentrations may be adjusted for the pollutant deposition and settling.

Methodology

The Industrial Source Complex (ISC) model provides options of modelling emissions from a wide range of sources that might be present at a typical industrial source complex. The model estimates the concentration value for each source and receptor combination hourly and calculates user-selected short-term averages. The hourly concentrations calculated for each source at each receptor are summed to obtain the total concentration produced at each receptor by the combined source emissions.

Emission sources are categorized into four basic types of sources, i.e., point sources, volume sources, area sources, and open pit sources. The volume source option may be used to simulate line sources. Certain types of line sources can be handled in ISC using a string of volume sources. There are two types of volume sources: surface-based sources, and elevated sources. An example of a surface-based source is a surface road line. The effective emission height for the surface-based source is usually set equal to zero. An example of the elevated source is the elevated road line with an effective emission height set equal to the height of the road line. If the volume source is elevated, the user assigns the effective emission height; i.e. there is no plume rise associated with volume sources. The volume source algorithms are most applicable to line sources with some initial plume depth, such as conveyor belts and road lines. The ISC methodology provides technical information on how to model a line source with multiple volume sources.

The ISC models use a virtual point source algorithm to model the effects of volume sources, which means that an virtual point source is located at a certain distance upwind of the volume source (called the virtual distance) to account for the initial size of the volume source plume.

Representations of a line source

The ISC methodology suggested exact and approximate representations of a line source by multiple volume sources. In the case of a long and narrow line source such as a road line it may not be practical to divide the source into N volume sources, (N is given by the length of the line source divided by its width). The user can obtain an approximate representation of the line source by placing a smaller number of volume sources at equal intervals along the line source. In general, the spacing between individual volume sources should not be greater than twice the width of the line source. However, a larger spacing can be used if the ratio of the minimum source-receptor separation and the spacing between individual volume sources is greater than about three. In these cases, concentrations calculated by using fewer than N volume sources converge to the concentrations calculated using N volume sources as long as sufficient volume sources are used to preserve the horizontal geometry of the line source.

Element Formulation

ISC methodology divides individual highway links into a series of elements from which incremental concentrations are computed and then summed to form a total concentration estimate for a particular receptor location. The element is formed at this point as a square with sides equal to the highway width. This approach was altered according to the CALINE methodology. CALINE methodology modeled each element as an "equivalent" finite line source positioned normal to the wind direction and centered at the element midpoint. A local x-y coordinate system aligned with the wind direction and originating at the element midpoint is defined for each element. The emissions occurring within an element are assumed to be released along the finite line representing the element. The emissions are then assumed to disperse in a Gaussian manner downwind from the element. The length and orientation of the elements are functions of the element size and the angle (φ) between the average wind direction and highway alignment. Values of φ = 0° or 90° are alterable amount to avoid the division by zero during the elements trigonometric computations. Downwind concentrations from the element are modeled using the crosswind finite line source Gaussian formulation.

The initial dispersion parameters

It is needed to specify the initial lateral (σ_{yo}) and vertical (σ_{zo}) dimensions for the volume source. Lateral and vertical virtual distances are added to the actual downwind distance for the σ_y and σ_z calculations.

Initial lateral (σ_{yo}) dimension

The model makes no corrections to the initial horizontal dispersion near the roadway. The only roadway related alterations to the horizontal dispersion curves occur indirectly by defining the highway width as the width of the traveled way plus three meters on each side and assuming uniform emissions throughout the element. This definition is according to CALINE.

The general procedures suggested for estimating the initial lateral σ_{yo} dimension for multiple volume sources used to represent a line source.

Emissions from a line source represented by multiple volume sources are divided equally among the individual sources unless there is a known spatial variation in emissions. Setting the initial lateral dimension σ_{zo} equal to W/2.15 in the exact approach or 2W/2.15 in the approximate approach results in overlapping Gaussian distributions for the individual sources.

Initial vertical (σ_{zo}) dimension

The general procedures suggested for estimating initial vertical (σ_{zo}) dimensions for multiple volume sources used to represent a line source according to CALINE also.

CALINE treats the region directly over the highway as a zone of uniform emissions and turbulence. This is designated as the mixing zone, and is defined as the region over the traveled way plus three meters on either side. The additional width accounts for the initial horizontal dispersion imparted to pollutants by the vehicle wake effect.

Since traffic emissions are released near the ground level and the model accuracy is most important for neutral and stable atmospheric conditions, it is reasonable to model the initial vertical dispersion σ_{zo} as a function of the turbulence within the mixing zone. The pollutant residence time within the mixing zone, as dictated by the wind speed, significantly affects the amount of vertical mixing that takes place within the zone. CALINE arbitrarily defines the mixing zone residence time as

$$TR = W2/(U.\sin(\varphi))$$

Where *W2* is a highway half-width, *U* is the wind speed and φ is the angle between the average wind direction and line alignment. This definition dependes on the wind angle and the width of the roadway. It essentially provides a way of making the model compatible with the actual two-dimensional emissions release within an element. The equation used by CALINE4 to relate σ_{zo} to *TR* is

$$\sigma_{zo} = 1{,}5 + 0{,}1 \cdot TR$$

This relation was derived from the General Motors Data Base and it is valid for the averaging time of 30 minutes. This value of σ_{zo} is considered by CALINE4 to be independent of the surface roughness and the atmospheric stability class. The user should note that σ_{zo} accounts for all the enhanced dispersion over and immediately downwind of the roadway.

Site Geometry

A link is defined as a straight segment of roadway having a constant width, height, roughness length, traffic volume, and vehicle emission factor. The location of the link is specified its endpoint coordinates. The location of a receptor is specified in terms of X,Y,Z coordinates. The wind angle is given in terms of an azimuth bearing (0 to 360°) with the step of 10 degree within the run of the model. If the Y-axis is aligned with the due north then the wind angle inputs to the model will follow the accepted meteorological convention (i.e., 90° equivalent to a wind directly from the east).

Co-ordinate system

The x-axis is positive in the downwind direction; the y-axis is crosswind (normal) to the x-axis and the z-axis extends vertically. The fixed receptor locations are converted to each source's coordinate system for each hourly concentration calculation.

The roughness of a terrain

Topographical conditions have a major influence on the dispersion of emitted pollutants. These include local obstacles like buildings. It is well known that buildings have a very strong and complicated influence on the flow in the direct vicinity.

The roughness of a particular surface area is determined by the size and distribution of the roughness elements it contains. For land surfaces these are typically vegetation, built-up areas and the soil surface, which furthermore give the relation between the roughness length and the roughness class.

The roughness length

The roughness of a terrain is commonly parameterized by a length scale called the roughness length z_o. Formally, z_o is the height where the mean wind speed becomes zero. Lettau has given a simple empirical relation between the roughness elements and the roughness length. The surface roughness, z_o, may be computed according to the relationship developed by LETTAU (1970) is

$$z_o = \frac{H \cdot h}{2 \cdot A},$$

where H is the effective height of the roughness elements, h is the frontal or silhouette area seen by the wind, and A is the lot area (i.e. the total area of the region "S" divided by the number of elements). This relation gives reasonable estimates of z_o when A is much larger than S. It tends to overestimate z_o when A is of the order of a; this is because, when the roughness elements are close together, the flow is "lifted" over them, e.g. historical side of the city. Typically, z_o is 2-6 cm for an open country, 20-100 cm for a forested country, and 50-1000 cm for urban areas.

Wind velocity

The wind speed is described by the well -known logarithmic law. From the similarity theory by Monin-Obukhov, the velocity gradient is given by

$$\frac{\partial u}{\partial z} = \frac{u_* . \phi_M}{k.z}$$

The function ϕ_M depends upon z/L where L is the Monin-Obukhov length which depends on the atmospheric stability. For a neutral stability $\phi_M = 1$. Within the surface layer of atmosphere, the wind speed may by determined by integrating this equation from z_0 to $z+z_0$ for neutral, stable and unstable conditions. For the neutral stability with $z < k.u_*/f$, where u_* is the so-called friction velocity, k is the Karman's constant and f is the Coriolis parameter of the earth, then is

$$u = \frac{u_*}{k} \ln\left(\frac{z + z_o}{z_o}\right)$$

The emission of the road

Traffic has increased in recent years in Slovakia and is continuing to grow rapidly. The most relevant pollution source - the road traffic causes an excess air pollution in the city. Emissions are a function of the activity and emission factors. Emission factors are available for different vehicle classes and different modes of driving. Activity data should be available as a daily average number of vehicles (for different classes of vehicles) or might be obtained by traffic counts. For traffic sources this implies that traffic data need to be obtained for all major roads within the study area.

The emission is calculated from data on the annually averaged traffic density or working day activity, vehicle distribution and speed. To characterize the driving pattern (and emission strength) of the traffic three classes of average speed situations were defined (urban, rural and highway regime). In combination with the corresponding emission factors the user can define own speed classification. If the user set the exact traffic speed then the emission pre-processor will compute the responsive emission. For maximum short-term concentration estimation the emission will be made from daily average account.

The unit emission of each element is calculated by means of the emission factors of the passenger cars and duty vehicles and responsive numbers of the passenger cars and duty vehicles which pass the road in the time.

The emission factors were determined on the basis of the COPERT90 Program, elaborated by the Corinair working group . The method for calculating the emissions from the motor vehicles in the European Union countries is very detailed and it enables the determination of emission factors depending on the velocity of vehicle practically for each type of moving vehicles.

The graphic and analytic dependences of *CO,* NO_x *VOC,* and particular matter for all categories of passenger cars are given in the COPERT90 program. On the basis of the present vehicle park composition in the Slovak Republic were calculated the weighed arithmetical mean emission factors for passenger cars and duty vehicles according to the COPERT90 program. For the urban regime the speed of drive of 20 km.h^{-1}, for the rural regime, the speed of 60 km.h^{-1} ,and for the highway 100 km.h^{-1} speed was assumed. The results are shown in Tab. 1.

Tab. 1. Emission factors, calculated on the basis of the COPERT90 program for the urban, rural and highway regime of drive (in mg.m^{-1} car^{-1}).

Pollutant	**Urban regime**		**Rural regime**		**Highway regime**	
	Passenger cars	**Duty vehicles**	**Passenger Cars**	**Duty vehicles**	**Passenger Cars**	**Duty vehicles**
CO	19,00	15,29	8,10	6,59	6,00	4,38
Nox	1,39	7,25	1,80	6,78	2,61	5,55
VOC	2,92	2,55	1,47	0,96	1,01	0,69
PM	0,30	0,80	0,14	0,70	0,17	0,54

Model input and output

Input variable

- Link length defined by link endpoint coordinates (x_l, y_l, x_2, y_2). In setting up link dimensions, the link length should always be greater than the link width.
- For each section of the link (roadway), the following must remain constant: the side area within the city, the mixing zone width, the traffic volume, and the emission factor.
- The user specifies the surface roughness length or roughness class. For each receptor the user must define the location with respect to the origin of the grid using Cartesian co-ordinates.
- Atmospheric stability category. As in the preceeding examples, a worst case 1-hour stability class of D (neutral) is assumed.
- Wind speed (short-term) or wind roses for each calculated stability categories and speed classes (long-term). The wind speed must satisfy the assumption $u \geq 1$ m.s^{-1} relative to the standard condition.
- The mixing height is a default value according to the ISC methodology. As will be seen in the sensitivity analysis (CALINE), the mixing height must be extremely low to generate any significant response from the model.

Output results

- Output of computed data from the modelling can be provided in the form of contour plots or concentration information at key receptor sites within the urban area.
- Output from MODIM5 consists of printed listings containing a summary of all input variables and model results. The input variables are separated into site, link and receptor variables. Model results will be expressed in units of μg/m^3 for each receptor.
- The resulting output is contained in files for immediate viewing by means of built-in text or graphic editors, alternatively for printing, or plotting. These files may be used either for additional working-out.

Study case

The traffic contribution to the concentrations in city streets depends on emission (number of cars, vehicle distribution, driving mode and emission factors) and dispersion parameters (wind speed, wind direction, atmospheric stability, street geometry, distance from traffic and building structure).

The results of a verification study using two pollutants separate data bases are also contained in this report. Road transport is responsible for a significant proportion of nitrogen oxides and carbon monoxide. Each street – link, is divided into several stages. Either, for following curvature of the street – roadway or for strictly assigned each stage of links with representative parameters needed to the dispersion computation of the pollutant. This dividing of links is in accordance with dividing of the whole city into side with a specific roughness length. The link can intersect several sides of the city.

Twenty-two receptors are scattered all throughout the city area. We selected the receptors in accordance with rule that may be those associated with the highest concentrations or those where sensitive individuals may be living or present. The receptors labeling, distribution and roughness length for each locality is listed in Tab. 2. The computed network of roads can be viewed together with the receptor location in Fig. 1.

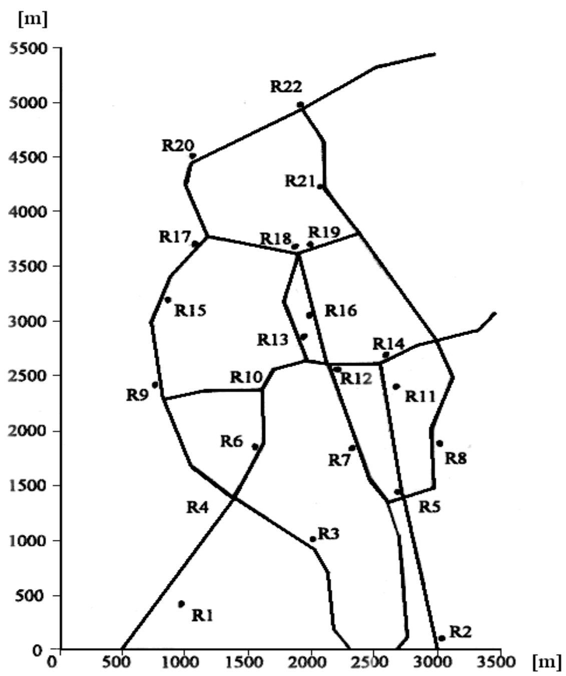

Fig. 1. The computed network of roads (links) and receptor location.

It is important that the point of maximum concentration, where exposure is likely, has been identified and the required improvement is calculated in relation to this location. Short-term impacts from different source types are unlikely to coincide spatially or temporally. For the assessment of the short-term objective for nitrogen oxides and carbon monoxide, it can probably be assumed that the peak contributions from the road traffic will not coincide with the peak contribution from industrial sources. It to by able say, that the peak contribution (maximum short-term concentration), from the road traffic will occur during the traffic peak time. The traffic peak time occurs twice during a day, namely in the morning and afternoon and stand about 2-3 hours. The neutral stability class is the most frequent class in this time. We suppose that the models results are for this stability class in good accordance with the measured value. Therefore, we restricted our proceeding for this case.

The long-term (yearly) average concentration is less important. Either it is much less sensitive to the building structure than often assumed or either the amount of maximum short-term concentration event from the road traffic is less important within a year.

The concentration of pollutant was calculated for the averaging time of 30 minutes, neutral atmospheric stability class of 4(D) and all wind speed categories. By running the model at wind angle increments around the compass, for this example, 10 degrees increments will be used. In practice may be used as small increments as 1, but the running times largely grow with negligible effects to the accuracy. The wind speed is implicit at the standard height from the weather station on the location so that a surface roughness of 3 cm is assumed.

Our model was confirmed by the valuation of the impact of road traffic to the air quality in Košice. The model output is presented in the form of contour plots and concentration information at key receptor sites within the urban area.

Two variants for CO and NO_x have been computed to assist the user in understanding the MODIM5 model' s capabilities. The first variant was running without the surface roughness length and the second one was running with the surface roughness length. A comparison of each model's result demonstrates significant responsibilities of the roughness length for the short-term concentration calculation.

The model calculates the maximum short-term concentration as a function of the traffic rate, geometry of road, dispersion condition and the surface roughness.

Pollutant concentration was accounted in the exact approach manner at the selected points (receptors). The height of the receptor point of 1,5 m above the pavement, and distances from the receptor point to the road axis of between 10 and 50 m. Modelling results for this points of the NOx and CO are shown in Tab. 2.

Modelling results for contour plots were calculated in the approximate approach manner for the city area 3500 m x 5500 m, overlapping by the grid with the element interval 50 m. The result does not include the contribution from another types of sources and the background concentration. Model results of NO_x and CO for the area of Košice in the basin of river Hornád are imaged at the attached Fig. 2 to 5.

Tab. 2. The maximum short-term concentrations of pollutant at the selected points calculated in conditions without a specific roughness length and with a specific roughness length.

Receptor labeling	Receptor location		Maximum short-term (30 min.) concentration in [μg.m^{-3}]				Roughness length
	Co-ordinates		CO	NO_x	CO	NO_x	
	x[m]	y[m]	Without z_0		with z_0		z_0 [m]
R1 OPTIMA	819	403	342,4	49,6	794,2	96,8	0,12
R2 Južná trieda	3012	100	394,0	53,6	1081,0	128,9	0,54
R3 Carrefoure	2025	974	634,1	86,5	814,9	109,2	0,12
R4 Moldavská /SNP	1315	1416	876,1	125,5	1233,0	163,2	0,81
R5 Jantárova –juh	2702	1444	763,7	108,3	1351,0	190,3	0,67
R6. Idanská	1579	1897	512,1	69,7	1218,0	156,4	0,67
R7. Nemocnica	2340	1915	815,9	103,6	1714,0	211,0	0,81
R8. Jantárova – západ	2945	1960	922,3	128,9	1586,0	219,2	0,67
R9. Mestská radnica	773	2413	734,8	81,9	1362,0	153,1	0,81
R10 Zimný štadion	1642	2400	676,7	87,1	1340,0	171,3	1,22
R11 Dom dôchodcov	2665	2439	310,7	39,3	815,6	98,9	0,81
R12 Fitnesscentrum	2166	2632	1520,0	200,2	3130,0	408,4	1,22
R13 McDonald	2988	2892	1423,0	205,3	2596,0	365,3	0,81
R14 Hotel Slovan	2625	2747	721,6	101,6	1297,0	181,3	1,08
R15Fakultná nemocnica	797	3245	778,4	84,9	1496,0	162,9	1,08
R16 Detská nemocnica	1980	3139	880,2	104,2	1960,0	228,3	1,22
R17 Amfiteater	1082	3763	575,0	62,6	1190,0	128,6	1,08
R18 Radnica	1874	3690	1509,0	179,3	3204,0	375,6	1,08
R19 Strojárenská	1960	3749	598,5	71,5	1393,0	163,4	1,08
R20 SAV	1051	4546	516,9	73,0	1135,0	153,5	1,08
R21 Národne nám.	2074	4338	837,4	141,6	1614,0	261,5	0,81
R22 nám.Mieru	1889	5029	1088,0	169,3	2265,0	340,5	0,81

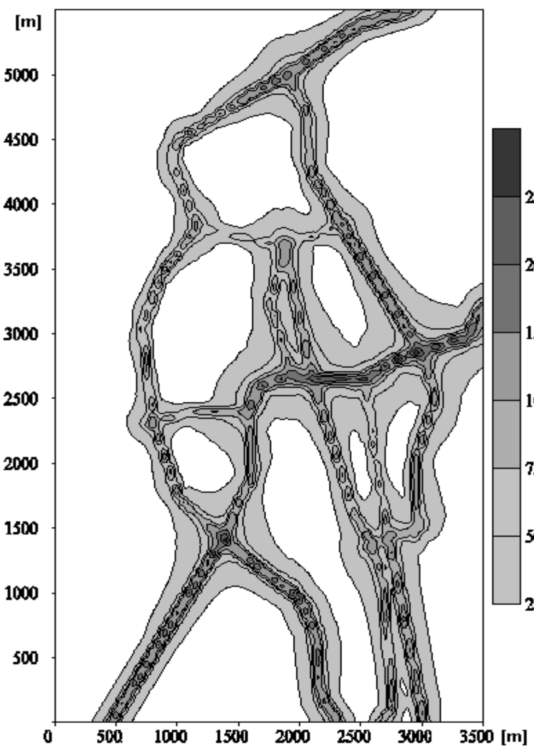

Fig. 2. Short-term concentration fields of NO_x from line sources calculated in conditions without specific roughness length for the area of the city Košice - level of the scale in μg.m^{-3}

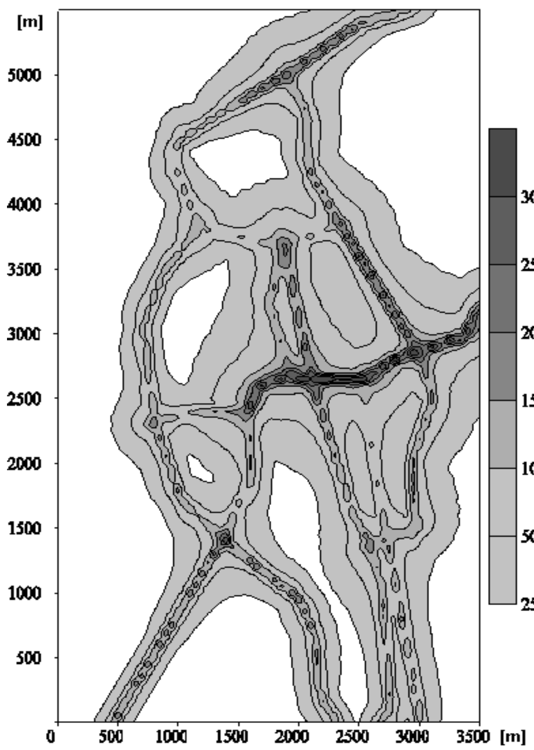

Fig. 3. Short-term concentration fields of NO_x from line sources calculated in conditions with specific roughness length for the area of the city Košice - level of the scale in μg.m^{-3}

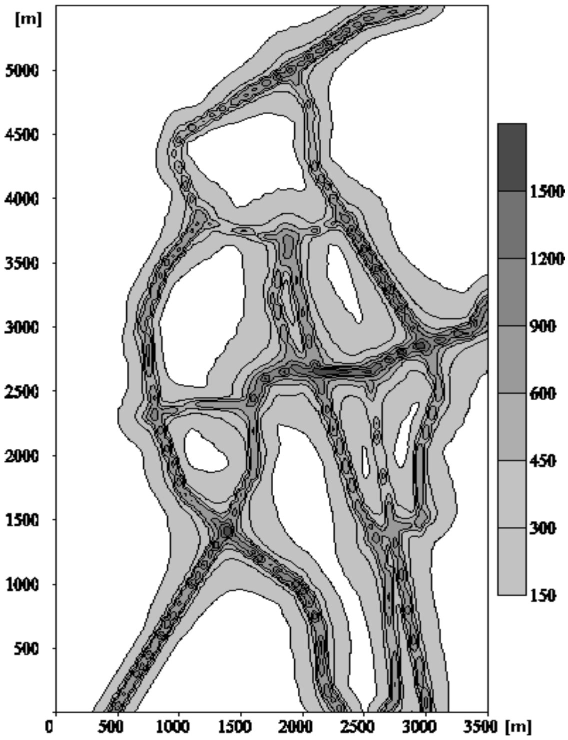

Fig. 4. Short-term concentration fields of CO from line sources calculated in conditions without specific roughness length for the area of the city Košice - level of the scale in $\mu g.m^{-3}$

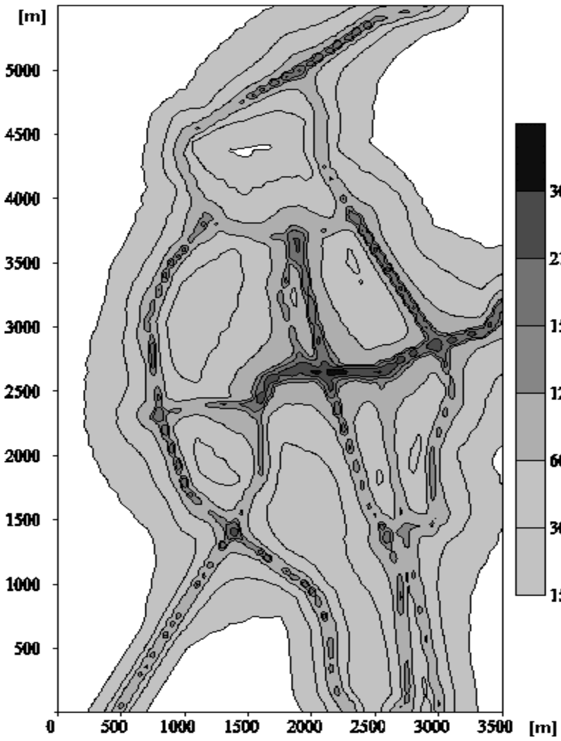

Fig. 5. Short-term concentration fields of CO from line sources calculated in conditions with specific roughness length for the area of the city Košice - level of the scale in $\mu g.m^{-3}$

As expected, the modelling results acquired by the running model without a specification of the roughness length gives underestimated values. Mainly, the most important fact is a flatness of the impact from the road traffic within the city area; i.e. the well-known built-up effect is missing. This is evident by comparing (Tab. 2.) the results of running. The model running with a specified roughness length gives results that correspond with the measured values and theoretical consideration. A comparison of the calculated and measured annual (1997) short-term concentration of nitrogen oxides is in the Tab. 3.

Tab. 3. Comparison of the calculated and measured (1997) short-term concentrations of nitrogen oxides [$\mu g.m^{-3}$].

Air quality monitoring stations	Station location coordinates		Calculated maximum concentrations*	percentil from measured short-term concentrations	
	x[m]	**y**[m]		95	98
1. Hotel Slovan	2625	2747	181,3	157	180
2. Strojarenská	1960	3749	163,4	121	142

** without city ambient and background concentration*

Summary and perspectives

The model becomes a primary tool for the analysis in the air quality assessment. It provides an information on the spatial distribution of pollutants. To assess future trends in the ambient air quality, the development of emissions must be known. The relation between emissions and ambient air concentrations can be modeled explicity. Especially, the impact of changes in emissions on the ambient air quality can be estimated. As soon as emission projections are available, they can be used as an input for models to estimate the future ambient air concentrations.

The enhancements of the model MODIM5 allowed to estimate air pollution from the line source. The model was effused according to the methodology recommended by US EPA – ISC and CALINE. The recent item stored in the model calculates the dispersion from the line source by means of specifying the surface roughness length for each in like manner side within area of the city.

The applicability of the model was attested for the area of the city Košice. As a first comparison, the results are rather good. Problems for the calculation arose in the definition of input data and city ambient concentrations. Other models, of course, are also sensitive the accuracy of these input data. The model MODIM5 can be used for a quick survey of city street air quality. Also, it is valuable tool for judging the effects of traffic management plans and for scenario studies. The interpretation of the model results requires a great knowledge and should be done by a specialist.

The paper contains some partial results of an project VEGA 2/7061/20 and 1/7311/20.

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