MODELING AND VISUALIZATION OF ENVIRONMENTAL DATA IN SPACE AND TIME USING GIS

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ABSTRACT

The article deals with the development of geoinformatics procedures accelerating and simplifying the application of the scattering model SYMOS´97 (Gaussian model), for selected pollutants in the open air to an area with a large number of sources and reference points. They are compared here with real measured concentrations of these persistent organic pollutants. One of the chapters illustrates the spatial and temporal variability of the ratios of the contributions of individual resource sectors to the total air pollution by polycyclic aromatic hydrocarbons. The interdisciplinarity of cartography and geoinformatics also lies in a wide range of scientific disciplines, for which it can be a valuable contribution in terms of effective data processing and presentation of achieved results. The next chapter article describes how to apply cartographic knowledge and procedures in the field of environmental chemistry. Thus, its focus is not only on the comparison of data obtained by measuring air pollution and calculated by the SYMOS´97 dispersion model. The main focus is on the demanding data processing for the mentioned model so that these procedures are as simple as possible, automated, and refined using geographic information systems. Because it is hardly possible to imagine manually preparing a larger amount of input data for this software without the use of GIS, automation of this process is obvious. Thanks to the automation of the preparation of the necessary documents, it is possible to achieve results that will not be affected by the subjective perception of the user, as well as a lower probability of entering errors into the processed data. The ideal conclusion of this work would, of course, be a complete agreement of the results obtained by the application of the scattering model and air sampling. However, the relative failure of this comparison is also beneficial if the main causes of this output can be identified. This means the possibility of identifying areas or types of relief in which there are significant discrepancies between the compared data. Finally, there is a warning in areas where SYMOS´97 gives worse results and a warning that in these areas there may be sources that are not part of the emission source database and could not be included in the model calculations.

Keywords: Air pollution, Dispersion model, GIS, Polycyclic aromatic hydrocarbons, Spatial interpolation

INTRODUCTION

Papers The interdisciplinarity of cartography and geoinformatics calculated in a wide range of researchers who can be accommodated in affordable tools to effectively process data and present your expected results. Information on the application for the application of cartographic applications and procedures in the field of life chemistry. Thus, its focus is not only on comparing data obtained by measuring air pollution and calculating for dispersion customers SYMOS´97. The main attention is focused on the straightened processing of data for the mentioned model so that these procedures are performed as simplified, automated, and refined as possible using geographic information systems. You find it represents and manually prepares a large amount of data for this software without the use of GIS is hardly possible, automation of this option is obvious. Thanks to the automation of editing any data that can be used for results that can affect the subjective views of the user, neglect of data processing errors may also be less likely.

The ideal conclusion of this work would, of course, be a perfect match for the results obtained by the application of the scattering model and the air sampling. However, no such work did the ideal happen. The reasons are obvious. The model is always just a simplified picture of complicated reality, and also the actual sampling and analysis are error-prone procedures. However, the relative failure of this comparison is also an advantage in the case that it is possible to identify the main causes of this output. This means, for example, the possibility to identify areas or types of relief in which there are significant discrepancies between the compared data.

The conclusion of the article, therefore, draws attention to areas where SYMOS´97 gives worse results and warns that in these areas may operate, for example, sources that are not part of the database of emission sources and could not be included in the model calculations. Regardless of the detailed form of the results of the comparison, the article proves that cartography and geoinformatics also have their place in this branch of environmental care.

1. GIS IN ENVIRONMENTAL MANAGEMENT

While modern Earth remote sensing (RS), satellite navigation (GPS) and digitization devices strongly support the efficient collection of digital spatial data, geographic information systems (GIS) are currently available in test operations, often in very complex mathematical and statistical operation. Commercial ballistic GIS programs I often offer a special palette method for editing, evaluating, and reproducing data and results. The implementation of GIS technology into environmental management is possible by the classic example, where it is often possible to solve tasks more often with standard tools of individual available technologies. The usual solution is to combine different Packages, if necessary in connection with your programming procedures. [1]

In modern environmental management, GIS helps to solve the following basic goals:

- storage, management, and reproduction of environmental spatial data,
- performing spatial and statistical analyzes with this data,
- modeling of various situations in the environment, which can be used for warning or prognostic purposes. [1]

2. AIR POLLUTION MODELS

Mathematical models are used to predict air pollution. Different classifications can be used for them, divides them into dynamic and statistical ones. Both types were originally designed to model a smaller number of resources in a limited area. [2]

Dynamic models are used, for example, to model the dispersion of pollutants in the air. They are suitable in cases where we want to monitor the influence of the dynamics of the source of pollution (changes in emissions from the source over time), for example in the case of accidental releases of pollutants or their dispersion in complex conditions (dense construction, rugged terrain). [2]

Statistical models use analytical solutions using modified diffusion equations, simplified based on practical observations. I describe the actual flow in a simplified way and are based on simplified assumptions and the following boundary conditions. [2]

Among the statistical models is, among other things, the dispersion model SYMOS´97, which is a binding method for monitoring and evaluating air quality. The SYMOS´97 dispersion model is used mainly in environmental impact assessment (EIA) in the location of new buildings or changes in technology, estimating the potential impact of a new building or technology on the environment and a comprehensive solution to the issue of the pollution on a large scale. However, extensive and detailed modeling is not possible without the application of GIS. [3]

3. SYMOS´97 PROGRAM

In the Czech Republic, the SYMOS´97 software is by far the most used application in practical calculations. It is based on the methodology of the same name. It is a commercial application designed to calculate virtually all pollution parameters defined in the methodology. It was developed and distributed by Idea-envi, whose main activities are related to building information systems in the field of the environment. The program allows you to work with large areas, a dense network of reference points, and thousands of emission sources. [4]

SYMOS´97 works with input text data files, which must be prepared before calculation. Some data, such as a network of reference points or a network of altitudes, can also be obtained with the help of GIS conversion to the required format. However, this is not a direct link between the scattering model and GIS. A more common way of obtaining the necessary data is either to manually read them from maps or to purchase them from a specialized company. The program contains tools enabling the preparation of input data for use in the computing part. The calculation module first converts the individual input text files to binary, then performs its calculation and the result is again a text data file in tabular form. Thanks to the possibility of exporting the result to the * .xls or * .dbf format, it is possible to easily convert and visualize the results in GIS. [4]

4. SOURCES OF DATA USED AND METHODS OF THEIR IMPLEMENTATION IN THE SYMOS´97 DISPERSION MODEL97

The central point of this chapter of the article is the scattering model SYMOS´97. The software program was created by Idea-envi based on the model of the same name, developed by CHMI staff. Since 1998, this methodology has been a part of the legislation of the Czech Republic, so it is binding for performing calculations in the Ministry of the Environment. To obtain relevant calculations from the SYMOS´97 model, it is necessary to collect several different types of data. These are elevation data of the monitored area, wind roses, data on sources of pollutants, characteristics of

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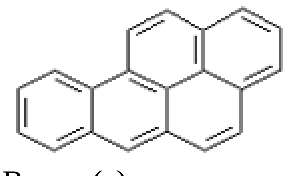
pollutants, and reference points. This article discusses the sources used for these inputs to the SYMOS´97 scattering model and the methods of their implementation. It should be noted in advance that with the volumes of data used, manually inserting individual points of elevation, pollution sources, and reference points into the model of the matter would be extremely laborious and time-consuming. Moreover, it can be said that this method of insertion would certainly be a source of many unforced errors that could affect the results of the calculations. For this reason, the software was used to prepare the vast majority of inputs to the model. [5]

5. EVALUATED POLLUTANTS

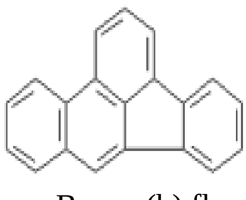
Persistent organic pollutants (POPs) are substances that remain in the environment unchanged for a long time, spreading over long distances, deposited in the adipose tissues of living organisms, and toxic to humans and animals. Although the hazards of the individual substances vary, the properties mentioned are common to all. [6]

They are used in various industries or as pesticides. Some POPs also arise as by-products of combustion and industrial processes. Because they are also caused, for example, by burning vegetation or volcanic activity, some of them are a natural part of the environment in a certain amount. Concentrations of POPs have been increasing for a long time since the industrial revolution when combustion and thermal industrial processes were developed using mainly fossil fuels, chemical and other industries as such, transport development, and increased use of pesticides during the period of industrialization. Their concentration depends on the proximity of sources, but they also occur in remote areas, where they reach by long-distance transport in the air and water environment. They contain non-polar molecules of lipophilic character, thanks to which they accumulate in adipose tissue, which leads to enrichment of organisms towards the top of food pyramids. [7]

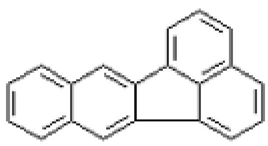
Polycyclic aromatic hydrocarbons, the occurrence of which in the air of the locality of interest is dealt with in this chapter, are benzo (a) pyrene (BaP), benzo (b) fluoranthene (BbF), benzo (k) fluoranthene (BkF) and indeno (1,2,3 -cd) pyrene (IP). In the Czech legislation, which largely coincides with the European one, according to Government Decree No. 350/2002 Coll., As amended (amendment 597/2006 Coll.), Only the limit value for Benzo (a) is stated for PAHs. pyrene. Its arithmetic average for a calendar year is 1 ng.m-3, the date by which the limit must be met. [8]



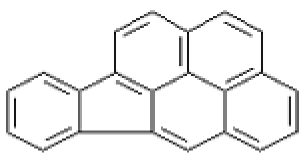
Benzo (a) pyrene



Benzo (b) fluoranthene



Benzo (k) fluoranthene



Indene (1,2,3-cd) pyrene

Figure 1 Monitored pollutants (taken from: EcoChem Analytics, 2001)

6. PASSIVE SAMPLING METHOD

The article also deals with the comparison of the results of the scattering model SYMOS´97, as a mathematical simulation of the distribution of pollutants in the air and the values measured by passive samplers. This chapter is devoted to the introduction of this sampling method, in which the principle of operation of the type of passive samplers, which are used by the RECETOX Research Center, will be explained. [9]

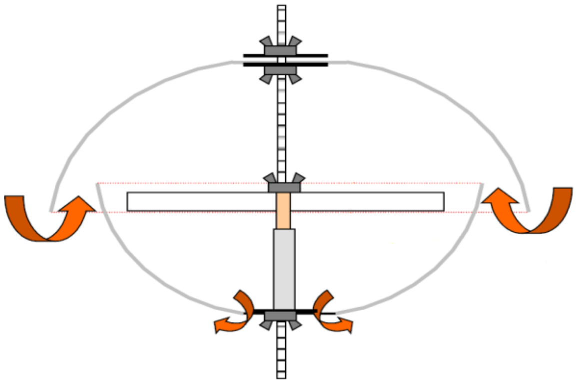


Figure 2 Principle of operation of a passive sampler (adapted according to KLANOVA ET AL., 2007).

The passive sampler forms a simple mechanism. Its body consists of two stainless steel bowls with different diameters (30 and 24 cm). These bowls are placed days apart and connected employing a common axis, also made of stainless steel, on which a filter is fixed employing a metal ring leading through its center. The sampler does not require demanding maintenance, which is limited to cleaning with water or alcohol during filter replacement. [10]

The filter itself is in the shape of a disc with a diameter of 150 mm and a thickness of 15 mm. It is made of polyurethane foam (PUF). The mentioned organizations use colorless disks with a density of 0.030 g.cm-3 type N 3038 from the manufacturer Gumotex Břeclav. Before use, the filters are leached in acetone for eight hours and in dichloromethane for eight hours. At the end of the measurement, the sampler is unscrewed and the polyurethane disc is carefully removed with the help of aluminum foil. This is then wrapped again in two layers of foil, provided with the date, place, and number of the sample and placed in an airtight bag. Additional measurement data, such as the start and end date of the measurement, the prevailing weather conditions during the measurement and the GPS coordinates of the sampling point are given in the measurement protocol. [10]

7. RESOURCES

In the case of the source, this is the most complicated input to the scattering model SYMOS´97. As there are several types of producers of monitored pollutants, it is not possible to look at them all in the same way. To capture as faithfully as possible the manner and extent that they contribute to the overall immissions, it is necessary to process the individual types of resources separately. The scattering model SYMOS´97 distinguishes three basic types of sources of a completely different nature: point, line, and area. The fourth category is then defined for the case of flue gas discharge employing cooling towers of some thermal power plants. However, this situation did

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not occur during data processing, because even in the vicinity of the area of interest, where emissions from the thermal power plant could be relevant for the result, there is no thermal power plant. [11]

Point sources

Point sources are considered to be those whose emissions come from only one point (or an area that can be considered as a point at a given scale), but not from linear and planar structures. In practice, like point sources, emission values are inserted into the model mainly from chimneys and exhausts of factories and other enterprises, as well as heating sources of larger residential buildings. The precondition for characterizing the source as a point source is its negligible size compared to the distances in which air pollution is calculated. For the most accurate simulation of emissions from these sources, which often have a decisive influence on the results of the calculation, it is necessary to know the following characteristics of the modeled sources. [12]

Line sources

These are sources that stretch significantly in one direction. In practice, road transport is most often considered to be these sources. For the scattering model SYMOS´97, the line source must be divided into a sufficient number of length elements. It is necessary to know these data for each element. [12]

Area sources

According to the Air Act 309/1991 Coll. small sources of pollution belonging to the REZZO 3 category are considered to be surface sources. This category includes stationary equipment for the combustion of fuels with a heat output of less than 0.2 MW and technological processes not falling into the category of large and medium sources. This also includes areas where work is carried out that may pollute the air, storage of fuels, raw materials, products, and waste and captured exhalate, and other structures, equipment, and activities that significantly pollute the air. [12]

Reference points

Reference points are the last type of important data entering the model. The results of the model calculations are stored in them. Usually, a regular network is formed for subsequent spatial interpolation with the help of GIS software. However, unlike elevation data, these points can also be entered in the format of an irregular network. This can be used in several cases. On the one hand, it is appropriate to thicken the network of reference points in areas where greater spatial accuracy is required when visualizing the results, which can be, for example, in residential areas, near pollution sources, etc. If necessary, know the calculated value for a specific place interpolation, it is possible to insert reference points in these places as well. [13]

8. CONCLUSION

In the total national emissions of PAHs into the open air in 2006, 66% accounted for domestic heating, 4% for transport, and the rest of the share is largely assigned to the category, which in this article includes sources from categories REZZO 1 and 2. It is a nationwide and year-round average, the situation varies in different periods and regions or areas. In the locality whose description was the subject, the decisive share of resources of category REZZO 3 was confirmed. It was approximately 90% (depending on the specific sampling locality) in the winter period and in the summer period, it was zero. In the case of emissions caused by industrial sources and transport, close share values were achieved. I illustrate the outputs with a specific example of Valašské

Meziřiči, the spatial and temporal variability of the ratios of the contributions of individual sectors to the total air pollution of PAHs.

Another benefit lies in the development of geoinformatics techniques that can significantly facilitate the processing of geographic environmental data in describing the quality of the environment. The procedure of preparation of all necessary data for their insertion into the scattering model of SYMOS´97 open-air pollutants was described in detail. A similar document describing this relatively complex process from data acquisition to the creation of map outputs for this software has probably not been created yet. In combination with the methodological manual for this model, it can be a material that will save valuable hours of working with this dispersion model. Among other things, a procedure was also developed that generates a relatively simple and fast irregular network of reference points around line sources. The applicability of this procedure is proved by map outputs. From an environmental point of view, the benefit can be seen in the comparison of data obtained in several different ways and in the reference to possible sources of air pollution in a particular area, whose activities cannot be registered. In addition to the above-mentioned findings, it is, therefore, possible to draw attention to the existence of areas in which there is a significant share of unrecorded sources of air pollution in total air pollution. Geoinformatics procedures developed within the solution will be used for the application of the SYMOS´97 scattering model for some cities. At the same time, the possibility of their application and possible modifications when working with the Lagrange scattering model KSP (Kinematic Simulation Particle Model) opens up. In the future, in cooperation with the Freie Universitat Berlin, it will also be applied to the rugged relief of the site. This procedure will make it possible to compare the two models based on different principles.

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