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THE CONCEPTION OF DECISION SUPPORT SYSTEM FOR ASSESSMENT AND MANAGEMENT OF AMBIENT AIR QUALITY

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Assessment and management of ambient air quality is carried out in Poland at local, regional and national level. A variety of informatics tools is increasingly being used in various areas of this issue. The paper presents the preliminary conception of an integrated system for supporting decisions undertaken by various institutions. It presents the legal, organizational and technical conditions governing this type of processes in Poland and potential users of the system, its functions, anticipated sources of the processed data and information. It has an indication of the possible technological solutions, including the potential tools and modules included in the proposed system.

Keywords: Decision Support Systems, Air Quality Assessment, Environmental Management, Air Pollution Control

1. Introduction

Decision Support System (DSS) can be defined as an interactive, conversational, flexible, and adaptive computer system that helps decision makers in solving problems related to the decision-making process. This process consists of several interdependent phases [1]:

- analysis - identification of the problem, data collection, gathering knowledge from experts to clarify the issue in order to further its definition and, if possible, to determine its structure,
- project - exploration or modeling problems, their analysis, the accumulation of knowledge about the possible solutions,
- selection - selection of solutions from the set of alternatives,
- implementation - implementation of the selected plan.

Advanced informatics tools, including Decision Support Systems, are increasingly often used in environmental protection, including air quality area. Process of designing such systems should contain integration of the various scientific tools for analysis of information, which support planning and management processes in the field of air quality. An important feature to consider is a relatively large and diverse group of people involved in these processes. Developed DSS are based on the integration of air quality modeling subsystems within the system for supporting various activities, such as control of emission sources, monitoring of ambient air quality and controlling of compliance with existing standards, assessment the impact of pollution on human health and the environment. Issues to be considered include:

- variety of sources of information (data collected from the multi-annual results to automated systems for the pollution monitoring),
- a wide range of spatial scales, from street canyons to the whole country,
- a wide range of time scales, from short-term episodes to annual and long-term trend analysis,
- dispersed and mobile sources of emissions with various types of periodic variations,
- various factors regulating emissions and its variability, such as direct legal conditions or complex human reactions and behaviors [2].

In Poland, there are systems for air quality monitoring, operated within the State Environmental Monitoring and supervised at regional level by the Voivodship Inspectorates for Environmental Protection (VIEP). Some of them also use mathematical modeling systems for air quality assessment and GIS (Geographic Information System) tools, primarily for illustrating results of measurements, modeling or information on emission sources. The main goal of the paper is presentation the possibilities (conception) of new tools that, using modern information technologies, would allow for more efficient and more reliable analysis and interpretation of data obtained from measurement systems and other sources. The use of this type of system could support different types of decision-making related to the operation of measurement systems, performance assessment of air quality and air quality management. The possible development and implementation of the proposed solutions could broaden the analytical capabilities of the teams involved in the assessment and management of air quality.

2. Main air quality problems in Poland

Good health and well-being require a clean and harmonious environment where physical, psychological, social and aesthetic factors are all given their due importance. The environment is thus not only important for its own sake, but as a resource for better living conditions and well-being [3]. Thanks to epidemiological studies throughout the world confirmed the association between human health and quality of ambient air, knowledge about this issues has significantly increased recently [4, 5, 6], but in some areas some pollutants still cause risk. In Poland the problem of air quality concerns mainly big cities but also in smaller towns and non-urban areas there are recorded concentrations exceeding the defined standards. Sources of pollution are industrial facilities (point sources), but also car transport (line sources) and, to a large extent, a source of municipal and household sector (surface emission). The problem here are emissions from combustion in heating systems, both in residential houses and public buildings. They result often in high values of concentrations of selected standardized pollutants, e.g. particulate matter *PM10* and *PM2.5* (smaller than 10 and 2.5 micrometers respectively), and polycyclic aromatic hydrocarbons, from which benzo(a)pyrene *B(a)P* has got established standard. There are the most serious problem in ambient air quality in Poland with those substances. Analyzing the results of measurements from the year 2010, it should be noted that in the case of these pollutants in a substantial part of the measuring stations were limit values exceeded [7]. For *PM10* annual average value is treated as the standard (limit value is 40 μg/m3). It was exceeded on 34 percent of measurement stations. Even less favorable situation is in case of the other evaluated parameter, which is the daily average concentration. Permitted is 35 days in year with the concentration higher than 50 $\mu g/m^3$, which is assessed using the percentile indicator P90.4 of the annual series of daily concentrations. In 2010 there were exceedances of the limit value specified for the daily *PM10* concentrations at about 75 percent of measuring stations for which it was possible to calculate the percentile P90.4 (possibly due to the sufficient completeness of data). Often these were results several times higher than the limit value.

Generally, it should be noted that the highest concentrations occur in the southern Polish in regions: Malopolskie, Silesia and Lower Silesia. However, high values of *PM10* and *B(a)P* is recorded in other parts of the country. According to the rules, air quality assessment is performed in Poland, as in other countries of the

European Union, in the Zones. The Polish law defines zones as: agglomeration above 250 000 of inhabitants, cities with 100 000 and more residents and the rest of voivodship. This gives currently 46 zones in Poland. When assessing the compliance with the standards, the Zone is assigned to the corresponding class: A - when on the area of the zone there were no exceedances at any of the measuring points, or C - the exceedance occurred in at least at one point. In 2010, for *PM10*, only four zones (one agglomeration and three cities) have been classified as A. The remaining 44 zones obtained class C [8]. This shows the seriousness of the problem of non-fulfillment of Air Quality Standards in Poland.

As for the other air pollutants for which there are standards, exceedances are listed for ozone O_3, affecting both human health and vegetation. In relation to other substances there are exceedances at individual stations in the country, such as nitrogen dioxide in the centers of agglomerations, nearby streets with heavy traffic.

Very important issue is the presence of episodes of very high concentrations of some pollutants, occurred in specific weather conditions, and increased emissions. Although they tend to be short-term (from a few hours to several days), they may result in serious health consequences, especially for vulnerable population groups (e.g. children, elderly people or suffering from diseases of the respiratory system).

When analyzing changes in air quality during last ten years, it can be concluded that the concentrations of *PM10* and ozone are clearly correlated with meteorological conditions in a given year (mainly the occurrence of days with extremely low or high temperatures). In recent years, adverse conditions, and higher levels of concentrations at the majority of Polish stations can be seen in the years 2003 and 2006 [9].

Various types of information systems gain an increasing role in the processing and analysis of information on air quality, both in the process of the annual assessments (assessment compliance with the standards) and the analysis and forecasting of the causes and effects of short-term episodes. They can be used at any stage of work of the measurement network and assessment systems but also for the management of ambient air quality: design, implementation and monitoring of actions to reduce the levels of pollutants in the air and reduce their negative health effects. Many decision-making processes, taken at different levels of government or local authorities can be supported through the use of information systems. The article tries to present the initial concept of this type of system, which, through the integration of different sources of information and the use of different currently available technologies, would help different users in obtaining appropriate, consistent conclusions and make effective decisions.

3. Legal basis and organization of air quality assessment and management in Poland

Main legal acts, which regulate the rules of air quality assessment and management at the European Union level are as the following: Directive 2008/50/EC, so called *CAFÉ Directive* [10] and Directive 2004/107/EC [11]. In addition, various regulations were published dealing with these issues, for example, the reciprocal exchange of information and reporting on ambient air quality.

Polish regulations in the described area are contained in the Act of April 27, 2001 - Environmental Protection Law in Section II (Articles 85-96) [12]. Detailed implementing rules, which, among other things, transposed European regulations, were issued in the form of relevant orders of the Minister of the Environment. They define, among other things, the zones in which air quality assessment and management is conducted, methods and rules for the implementation of the assessment, limit, target and alarm levels of pollutants in ambient air and the scope of information that should be reported to the national level or public.

The basic method of assessment is measurement of concentrations of pollutants in air using automatic or laboratory methods. Additionally, as supplementary, mathematical modeling or methods of objective estimation can be used. Measurements in Poland are conducted under the State Environmental Monitoring, supervised at the national level by the Chief Inspectorate for Environmental Protection (CIEP). Voivodship Inspector for Environmental Protection is responsible for carrying out assessment, including measurements, at regional level. He performs it in its region with Voivodship Inspectorate of Environment Protection (VIEP), which is headed by him. In some cases measuring stations included in the regional monitoring network, which is supervised by VIEP, are owned by other entities - industrial, research institutions, foundations or local government.

According to the current Environmental Law, VIEP forwards the results of the assessment and classification of zones to the Management Board of the voivodship. The Board is developing an air quality action plans for zones in exceedance of air quality standards. The plans are adopted by the Regional Council and implemented by local self-governments in designated zones.

If there is risk of exceedance of alarm, target or limit levels, the short-term action plan should be developed and implemented for the area. It aims to reduce the risk of such exceedances and limiting their possible consequences and duration.

Air quality assessment and management in Poland is conducted at three levels, at which appropriate Decision Support Systems can be used:

- national - including the assessment of air quality and health risks in the country, the development of national forecasts and action programs, monitor their implementation and effectiveness;
- regional (provincial) - including main assessment of air quality in the zones, conducting monitoring networks, identification of areas, exposure levels and causes of exceedances, execution, implementation and monitoring action plans, public information;
- local (city, municipal) - including local monitoring, analysis of investments impact on air quality, deal with the episodes of high concentrations, implementing local actions and information to the public, etc.

4. Systems used for ambient air quality assessment

Variety of informatics systems are currently used to carry out tasks such as: collection, processing, visualization and transmission of various types of data and information. In automatic station with measurements concentrations of pollutants, the results are collected and processed already in the station, in the so-called DAS systems (Data Acquisition Systems). Hence they are transmitted to database of so-called CAS systems (Central Acquisition Systems), located in the most common cases at the premises of VIEPs. These systems are used for collection, but also processing, analysis and visualization of information. They support, for example, verification and validation of the data. Popular office applications are often used for the purposes of data analysis, calculation of statistical parameters and the reports' preparation. Special modules have been designed and implemented to make data available to the public via the Internet network. These systems present information about air quality (e.g. sojp.wios.warszawa.pl), and serve for fulfilling the obligation to share public data from measurement stations. Some of these systems have also features of presentation of the modeling and forecasting results. However they do not give the possibility to do more advanced analysis using different types of information, such as related air pollution sources or health threats.

Special software, which implements the mathematical models of the transport and transformation of pollutants in the atmosphere, are used to determine the spatial distribution of concentration in the past and forecasted. In some institutions GIS software is used for the purposes of visualization modeling and the results of measurements, in order to, for example, determining areas of exceedances. It is rather rarely used to perform complex spatial analysis, including those based on the relationships between sources of emissions and the results recorded in the monitoring networks.

The results of measurements and modeling, as well as results of zone's classification, are collected and processed at the regional level in VIEPs. Then they are transferred to the national level, to systems managed by the CIEP. After the relevant processes, the data sets are reported to the European level. Currently a new national system for collecting and processing information about the air quality is being developed. It is a part of *EKOINFONET* - the system of Inspection for Environmental Protection. It has been implemented using relational database management system, J2EE technology and Business Intelligence software.

Different systems often operate in a manner unrelated to each other, with no mutual exchange of information. The integration of data flows in one or different institutions, combined with the use of new tools and technologies for their analysis, would allow ensuring greater consistency of information and more effective decision-making in a variety of specific issues of air quality assessment and management at various levels. This can be one of the purposes of the proposed system.

5. Potential sources of information

Various types of information should be processed in the frame of the proposed system, depending on the problem being solved and the level of work. Some of the data is relatively stable, such as type of land use or location and characteristics of emission sources. Others by their nature are variable and depend on the conditions at the time. The set of potential types and sources of information is given in the Table 1.

6. Potential users and functions of the system

Potential users of proposed system can be found first of all in the institutions responsible for the assessment and management of air quality at various levels: Voivodship Inspectorates for Environmental Protection, Chief Inspectorate. It could be important also for decision-makers from Voivodship Boards and Councils or municipal offices. Other group of users would be research institutes or companies and offices engaged in processes of developing scenarios or projects connected with air quality. If the function of information dissemination via Internet will be implemented, the group of potential users will contain the publicity, especially residents of the area covered by the system or persons professionally interested in this type of information, such as medical services.

Tables 2a, 2b provide a set of potential functions of Decision Support System, and later a description of the functionality for health risk assessment is presented. Proposed functions are often closely connected with each other.

Table 1. Potential groups and types of information processed in Decision Support System

Group of information	Type of information
Monitoring networks	Location of monitoring station, characteristic of installed equipment, spatial representativeness and methods of measurements.
Measurement results	Long-term (e.g. annual or multi-annual) validated data series: results of measurements obtained with automatic, laboratory and indicative methods.
	Sets of statistical parameters calculated from measurement's results.
	Provisional data: results transmitted from automatic monitoring stations in near real time mode (NRT Data).
Air quality assessments	Results of air quality assessments conducted in previous years (classification of zones), areas of exceedances.
	Results of objective estimation performed in previous years for the specific area.
Meteorological information	Meteorological conditions (historical, current and forecasted).
Modeled air quality	Spatial distribution of air pollution concentrations (historical, current and forecasted), e.g. from the external systems of mathematical modeling.
Land use and emission sources	Land cover and land use (various thematic layers), 3D terrain models etc. – GIS data
	Location and characteristics of the sources of air pollutants emission (linear - communication, point – industry and surface - individual and municipal heating systems etc.)
	Emission data sets –values of emission of pollutants from individual sources or selected type of sources from defined area.
	Results of automatic monitoring of emission.
Traffic	Communication system - characteristics and location of the road networks
	Traffic information (volume and structure of traffic, temporal and spatial variability) – from measurements (including the supplied up to date from automatic measurements) or traffic models.
	Results from the systems of traffic noise monitoring.
Scenarios, plans	Information on completed or planned investments, such as air pollution mitigation measures (e.g., air quality plans and programs for the region or zone).
	Plans of spatial development for the area.
	Plans of the investments, e.g. introduction of new emission sources or changes in current structure of sources, traffic scenarios.
Population	Distribution and structure of the population, including information about sensitive groups.
Other sources of information	Orhtophotomaps, aerial photographs, satellite data.
	Other…

Table 2a. Potential functions provided by the Decision Support System

Group of function	Function
Measurement data	Support for analysis of data series, including their statistical treatment. The set of available data analysis may include, among others: basic statistics, comparison of stations and parameters, correlation tests, time variations analysis.
	Support for the verification and validation of measurement results, including correlation analysis and search of dubious values.
	Searching of potential errors of current operation of the monitoring system, by searching a series of measurement irregularities on the basis of implemented patterns, including statistical functions for analyzing of the time variability and the correlation of internal measurements at the station and between stations.
Emission data and sources	Analysis of information gathered in emission inventories.
	Support for analysis of the impact of individual sources of pollution emissions to the air quality in a given area (including the projected impact), e.g. impact of industry or traffic lines (including road works).
	Analysis of current impact of sources with use of e.g. emission monitoring, traffic monitoring, weather condition measurements and automatic air quality monitoring.
Monitoring Network management	Analysis and decision support in the design and operation of the measuring system for air pollution monitoring (e.g., supporting within the process of station's localization, analysis of representative areas of measuring stations, the impact of emission sources).
	Analysis of the network structure - assessment of the quality of work (e.g. with use of geostatistical methods).
Air quality assessment	Support for regional assessment procedures: checking compliance with air quality standards.
	Identification and characterization of the occurrence of concentrations above certain standards, determining exceeding areas and population exposed.
Local air quality management	Support for cities and counties in the assessment of compliance with the relevant EU and Polish regulations.
	Analysis of near real-time description of the environment (air quality and noise) and the state of traffic in urban areas.
	Support for local decision makers in formulating policies and guidelines related to e.g. transport activities.
Episodes	Analysis of high pollution concentration episodes: sources, extent and exposures.

Table 2b. Potential functions provided by the Decision Support System (cont.)

Group of function	Function
Modeling of air quality	Analysis of the spatial distributions of air pollutant's concentrations - historical, current and forecasted.
	Use of geostatistical tools and methods (Krigging, etc.), modeling with use of geographically weighted (land use) regression. Use of prediction tools (like neural networks).
	Presentation of the external mathematical dispersion models' results.
	Support for monitoring and verifying of the models – comparison with the results of the measurements, statistical analysis, etc.
	Modeling of the current situation (called nowcast) - performed automatically every hour, using delivered real-time meteorological information. Using of measurement data for the needs of different data assimilation schemes in real-time air quality forecasts.
Plans and Scenarios analyses	Support for planning, designing and evaluation of strategies and actions to control emissions and air quality management (investments or organizational activities - for example: reduction of car traffic in a given area). Monitoring the implementation and effectiveness.
	Scenario analysis and forecasting (regular or done if needed), to evaluate the effectiveness and costs of emission reductions actions.
	Analysis of short-term action plans, evaluation of its implementation, and monitoring of effectiveness.
	Perform scenario analysis for determination of the effectiveness of environmental effects of the transport management systems. Post-implementation assessment - the impact on quality, keeping standards and public exposure.
Reporting	Reporting and providing information to policy makers and the public, e.g. using Internet network and geospatial services (WMS, WFS). Providing current and forecasted situation.
Health Impact Assessment	Analysis and assessment of health risks caused by air pollution.

The communication of the complex relationship between air pollutant exposure and ill health in a manner that is both simple and accurate is an important aspect of created air pollution information systems, especially in the areas not covered by the studies. Based on accessible air quality data available through Decision Support System with implemented Health Impact Assessment (HIA) methods decision makers can provide estimates of the expected change in the number of cases (e.g. premature mortality, hospital admission, urgent care visits, work loss and restrictions in activity) that might be expected from a specific change in air pollution. HIA defined as a combination of procedures, methods and tools by which a policy, program or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population [13], mainly intended to provide political decision-makers with quantitative and qualitative information and evidence about how any activities may affect the health of people. In respect of the health consequences of air pollution levels, HIA aims to elucidate current effects or, stated differently, the improvement in health that might be expected through reductions in air pollution [4]. To analyze quantitatively the impact on health of ambient air pollution in a chosen area (city, region or country), except of air pollution concentrations and exposure gathered in dedicated DSS's, is needed also the exposed population (very often with division into age and gender groups or sensitive groups such as asthmatics, children or elderly), background health data (incidence of mortality and morbidity classified in common rules, e.g. based on International Statistical Classification of Diseases and Related Health Problems - ICD) and dose–response functions (based on epidemiological results elaborated function describing statistical relationship relates ambient air pollution to a selected health effect).

Assessment of health benefits can be one of the important tool in decision-making. DSS with implemented HIA procedure allows link in quantifying the expected health effects associated with changes in air pollution (especially during pollutants episodes) and also based on broad estimate results, enables the public to increase awareness of the public health implications of air pollution. In this case, the information can usefully be put towards providing cost-effective improvements in public health. Furthermore, the assessment can identify threats and indicate new areas for research or monitoring. Quantitative estimates of the impacts of changes in air pollution can be used to help prioritize the actions and policies, such as improve traffic management, setting of specific ambient air standards or control strategies (e.g. to encourage a reduction in activities that contribute to air pollution). That kind of data can help decision-maker with providing more explicit and comprehensible information for the public. Presenting data on air quality, e.g. using Internet network may play an important role in the strategy of the institutions responsible for research and analysis of issues related to air pollution. At the same time can perform the tasks of education, by disseminating knowledge on pollutants, their sources and effects, as well as promoting specific behaviors aimed at reducing emissions. The role of information systems may be important in the process of air quality management, such as the implementation of a variety of preventive and corrective actions and monitoring their effects [14]. What is more, if economic values are assigned to the health impacts, economic benefits can be determined for alternative air pollution reduction strategies [4].

The system should integrate various informatics tools, technologies and data from various sources into desired format. It can be implemented as independent, *tailor made* application, which also uses possibilities of other software packages, such as commercial GIS products with its extensions, and also open source GIS software. Some of functions can be realized with help of advanced external tools, like statistical packages or modeling software. It has to be remembered that interface of the system should be user-friendly and easy-to-use, what is one of the conditions for its potential use, often by users without a lot of experience with IT technologies.

7. Summary

It is planned to carry out further research in presented range of functions and perform partial implementation and demonstration of selected elements of the System. Such a system should be modular, allowing for its adaptation to the needs of different user groups and enabling the development and including of new components. It is possible to include elements also related to the assessment of other environmental hazards that may have a common source with air pollution, like traffic noise. Such solutions can be found in some already implemented Decision Support Systems at the local (municipal) level (such as HEAVEN DSS [15]). Other systems operating in selected areas of Europe, related to management of air quality, that perform certain functions from the list of proposed in the described system include AirWare, AirQUIS [16] and ARIA. Designing and developing of the system presented in this paper will need close cooperation with people engaged in air quality assessment and management at various levels.

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