Web Application for Air Quality Monitoring

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Abstract: **Web application for air quality control as part of ecological monitoring system presented in this paper. It is proposed the database architecture and modules for data processing and visualising. Proposed application enables to monitor air pollutions from motor transport not only in measurement points, but in different points of city using mathematical models.**

Keywords: **monitoring system, air quality control, vehicular pollution, web application.**

I. Introduction

One of the biggest environmental pollutants in large cities is motor transport. During the fuel combustion the emissions such as sulfur dioxide (SO_2), particulate matter (PM_{10}), fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3) and others are polluting the air. For pollution assessing the measurement scale is using based on Air Quality Index (AQI), which determe whether a harmful substances are under permissible level. For example, the lowest level of harmful substances called "Very low", next are "Low", "Medium", "High", "Very high". Different countries have their own measurement scales. The Common Air Quality Index (CAQI) is an air quality index used in Europe since 2006. In November 2017, the European Environment Agency announced the European Air Quality Index (EAQI) and started encouraging its use on websites and for other ways of informing the public about air quality. [1] The sample of CAQI are given in Table 1.

TABLE 1. Common air quality index (CAQI)

Qualitative name	Index or sub-index	Pollutant (hourly) density in µg/m^3			
		NO_2	PM_{10}	O_3	$PM_{2.5}$
Very low	0–25	0–50	0–25	0–60	0–15
Low	25–50	50–100	25–50	60–120	15–30
Medium	50–75	100–200	50–90	120–180	30–55
High	75–100	200–400	90–180	180–240	55–110
Very high	>100	>400	>180	>240	>110

The level of these pollutants in the air affects the well-being and health of the city's population. At high levels of pollution, it is recommended to reduce or completely abandon the activity and exercises in the open air. This is especially true for children, the elderly and people with heart or respiratory diseases. In this regard, the population should be provided with quick and easy access to relevant data on the air pollution in the city regions.

II. Task Statement

To date, there are organizations in Ukraine that have means for periodic measurement of harmful emissions from vehicles. However, such approach does not provide an operational monitoring of the dynamics of these emissions. In the field of mathematical modeling, a series of diffusion mathematical models have been developed that describe the processes of harmful emissions diffusion into the atmosphere [2-5]. At the same time, the results of the application of these models are poorly correlated with actual measurement data. As a result, it is impossible to detect and react in a timely manner to raising the pollution level.

It is necessary to use modern technologies and devices that will make monitoring of air pollution in the cities more accurate and continuous. Establish on the city territory of the sensors for measurement different substances and control of traffic flows. In order for the whole area of the city to be covered, not only certain areas, it is necessary to create mathematical models and software that will show the spatial distribution of harmful substances. Access to all data should be provided via the Internet. Every resident should be able to find out what the current state of the air in the city is. Viewing the measurements should be simple, understandable, using conditional labels and images on the map. It should be possible to know the measurements for certain periods or only for certain parameters. Additional opportunities are also needed, such as informing the public, publishing news, announcements, photo materials, conducting discussions, exchanging ideas and suggestions. For a better understanding of the problem, it is necessary analyzing already existing systems of the same purpose and creating its own, which will be useful both for ordinary residents of the city and for specialized workers in the field of ecology. This will be a good step towards improving the environment and human health. The purpose of research is to plan the overall structure of the system for improving the quality and speed of air pollution monitoring by road, and to facilitate the obtaining of this information for the population of cities through the web-resource.

III. System Requirements and Architecture Design

In order to automate the air pollution monitoring, it was decided to create a system consisting of the three components described below.

1) Hardware including sensors that measure the different parameters, such as pollutant concentration, traffic flow, humidity, temperature. They will be located in different parts of the city, mainly in central parts and in places where there is a large crowd of vehicles, such as a crossroads. Data from such sensors will be transmitted using mobile communication - GSM-modules. To ensure the proper level of storage, all devices will be placed in specially designed containers or in

existing ones, for example, in places where traffic control cameras are located, and must be agreed with local authorities.

2) Software, based on mathematical models, calculations and measurements from sensors, will simulate the spatial distribution of pollution on a city map. This will allow to see the results of measurements not only in the places where they are conducted, but also to predict the level of pollution at each point of the map. The papers [6,7] show the method of solving the task of identifying mathematical models for environmental monitoring of air pollution by motor vehicles based on the use of fireflies algorithm or the bee colony algorithm. It is this research that underpins the development of a mathematical model that will be used in our system.

3) Web application that is designed to conveniently visualize the resulting measurements.

The web application must flexibly interact with other parts of the system and with any other sensors or datasets that will be available for use. The air quality level can be depicted on a city map in the form of points where the sensors are located, or as a result of mathematical modelling the spatial distribution of pollution.

As a result of the analysis of existing alternative solutions the number of functional and non-functional system requirements were listed, namely: possibility of showing the sensor measurements and simulation results on city map; ability to choose a period for showing measurements; ability to view detailed information at the selected point of the map; ability to take information through the API from various sources: sensors, other software systems, Excel files; working with different indicators and possibility of combining them on the map; development of administrative profile with ability to adjust the map showing and indicators, edit news and other materials; development of news page, including the latest news on the main page; possibility to place announcements on the main page; development of the blog; possibility to leave comments under every material; showing the contact data and feedback form; development of the forum; development of the photo gallery; provide a system design that will allow viewing site data in various browsers and devices (PC, tablet, phone).

Taking into account defined requirements to the system, a database was designed. The structure and relations of tables for working with maps and measurements showed in Fig. 1.

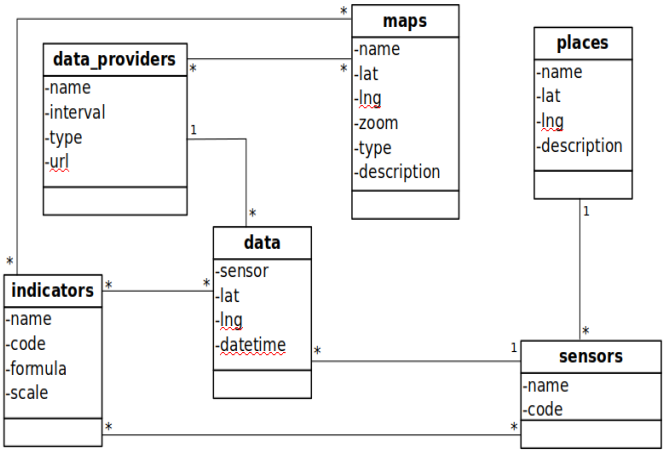

Fig. 1. Database structure

IV. Web Application Implementation

Web application as one of the components of the system for monitoring atmospheric pollution from vehicles, is designed to visualize the results of measurement and modeling the spatial distribution of pollution (fields of concentration of harmful emissions). As a result of research, a web-based system project was developed and implemented in PHP programming language. As a database, MySQL was used. CSS Media Queries, Bootstrap, were used to design a convenient and compatible site with various devices. For fast work due to AJAX interaction and dynamic interfaces, the JavaScript library for jQuery is used.

As geographic maps the Google Maps was used with additional data such as the traffic flow rate. The Google Maps APIs [8] allow to flexibly customize viewing and map interaction, add graphic objects, and various data types that are well suited for pollutions visualization. There are currently two maps on the website. The first depicts the points with the actual measurements coming from the sensors (Fig. 2). Each of the points has own color and number corresponding to the AQI scale, which is under the map.

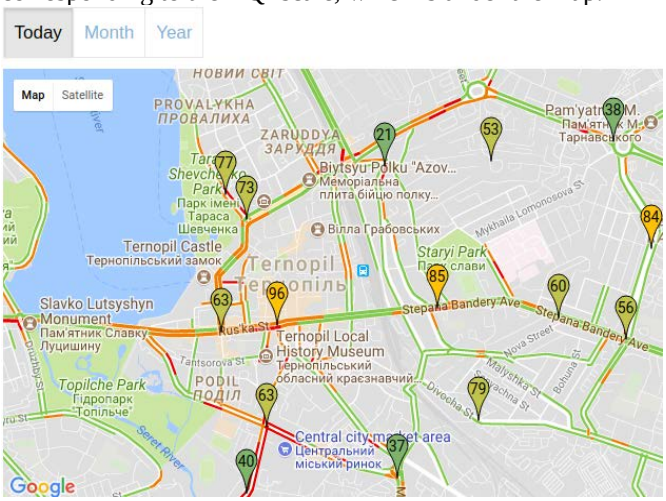

Fig. 2. Map with sensor indicators

On the second map are the simulated results calculated on mathematical model, in which one can observe the spatial distribution of pollution (Fig. 3).

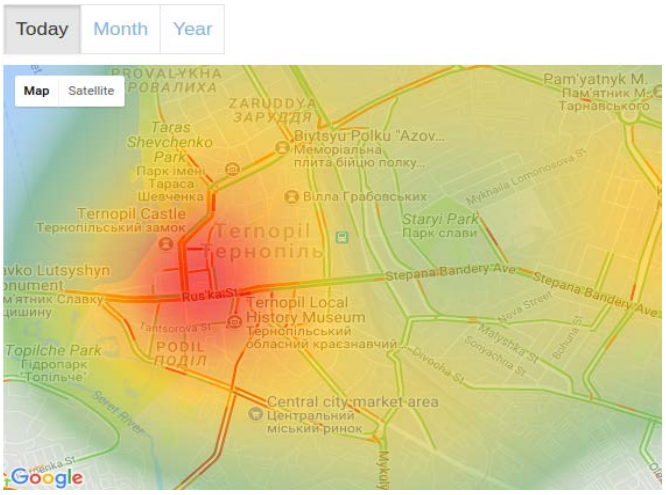

Fig. 3. Map with spatial distribution

There is at the top of each map a switch where it is possible to specify the period for which measure to be displayed: today, month, or year. Also, site users can view detailed information by clicking on a specific point on the map. Fig. 4 shows an example of an auxiliary information window, which, in addition to the indicators shown on the map, also contains additional ones such as humidity and air temperature. The content and method of displaying items in this window are configured from the administrative part.

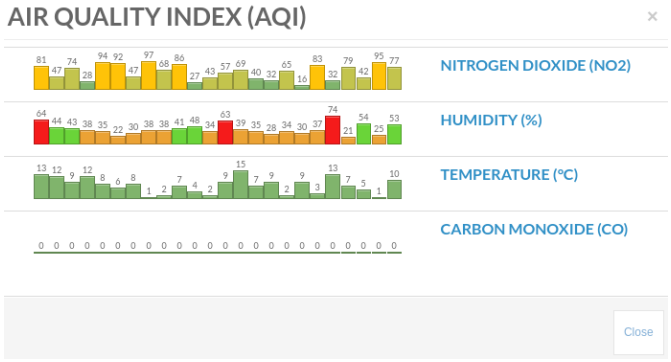

Fig. 4. Information screen

In addition to viewing maps, the website has pages with a wealth of useful information, news and blogs with possibility to add the interesting articles. In order for site users to ask questions or to offer an idea, there is a page with contact information and a feedback form. Also on the site is a forum that allows to discuss topics related to air pollution and how to improve the situation with the environment.

The administrative profile allows to create new admins and give them only certain permissions. It is possible to conveniently edit the content of the site, create news, write articles. The specialized section of the administrative profile is the control of the display of information on air pollution.

The system is called "Our city" and contains the following administrative sections: maps, providers, indicators, placement, sensors. The main menu view is shown in Fig. 5.

Fig. 5. Administrative menu

"Maps". In this section the list of all geographic maps that will be available for viewing on the site is shown. When creating a new map, it can be flexibly customized depending on the needs and the data it should display. So, when creating it is necessary to specify the name, latitude and longitude, the level of convergence, the type of relief, if necessary, a description (Fig. 6). Also it is necessary to specify one or more data providers to choose which data to display.

Each provider can provide a large amount of information and indicators, but which of them should be displayed, in what form, as well as where - on the map or in the detailed view window at the selected point - it is configured in the Indicators sub-tab (Fig. 7). Here can be selected any indicator and specify its appearance on the map (distribution chart or point of a certain color with the number), and a detailed view (diagram, graph, etc).

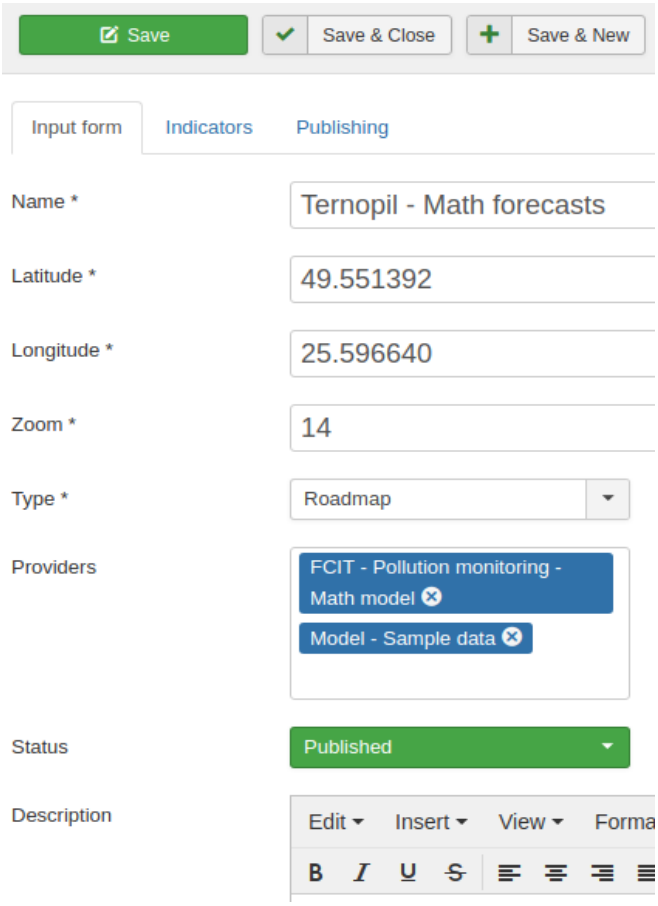

Fig. 6. Form for map editing

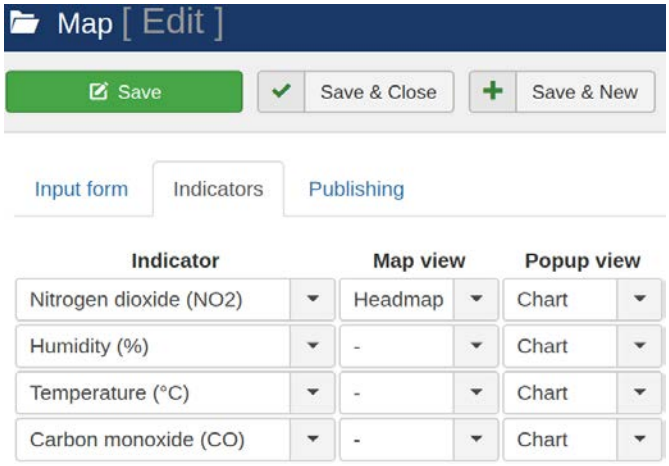

Fig. 7. Form for map indicators editing

"Providers". This section contains a list of all data sources from which the site may receive information. Connection can take place via HTTP or FTP protocol. Thus, it is possible to obtain data not only from other parts of the monitoring system - sensors and programs with implemented mathematical models, but also to third-party companies that carry their own measurements or have their equipment to sanitary stations. Also, here it is indicated, with what interval should apply for the updated data.

"Indicators". This section contains a list of all parameters, and metrics that the system works with. For each indicator, it is possible to specify the name, code and scale of measurements, where for each level is given the color and numbers min and max (Fig. 8). It is also possible to specify a formula for converting values or complex calculations. For example, one indicator shows actual values from the sensor, named NO2, and an additional indicator, named NO2-AQI, will display measurements of nitrogen dioxide translated into the air quality index. Or it was created a common indicator AQI, which in its calculations will use several different sensors measurement.

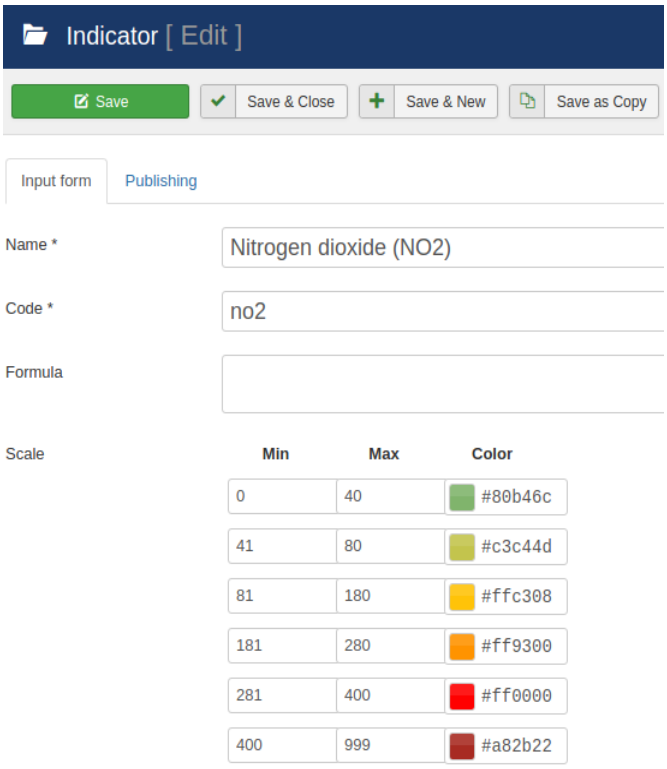

Fig. 8. Form for indicator editing

"Placing". This list lists all the locations in which the system receives measurements. When editing it is necessary to specify a name, latitude, longitude, description.

This section is intended for grouping sensors, because there can be a lot of them in one place.

"Sensors". In this section it can view the list of all sensors that the system uses. When connecting a new sensor, it need to add it to this list by specifying its name, code, list of measurements it passes on (indicators) and indicate its location. With this information the system will automatically detect sensor or communication problems, responding to the lack of measurements or their inaccuracy.

This structure makes the system flexible, allowing it to create new maps without software changes, to connect different data sources, to work with various indicators, even if in the future it will be necessary to measure, say, water or soil. Also, there is no hard bind to other components of the system, the application will be able to work correctly even at the time of their modification, and in turn will not affect the work of other components, such as sensors, when work on the site itself.

V. Conclusion

The processes of air pollution by motor transport are one of the most important problems of large cities. To solve this problem it is necessary to ensure operational monitoring of the dynamics of harmful emissions. The development of new models based on real monitoring data will increase the accuracy of both reflection and prediction of the dynamics of atmospheric pollution, depending on the intensity of traffic flows, and the creation of an appropriate software system for their implementation, as well as a web resource to visualizing the current situation of atmospheric pollution, will serve as an active tool for municipal services that deal with traffic flow management, environmental protection, and for the city's population.

Within this research the general structure of the system was described and a web application was developed.

Acknowledgment

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References

[1] "Impact assessment on the Air Quality Package (summary)", SWD/2013/0532 final, EC, 2013.

[2] M. A. Sutton, C. M. Howard, J. W. Erisman. *The European Nitrogen Assessment: Sources, Effects and Policy Perspectives*, Cambridge University Press, 2011.

[3] Outdoor air pollution a leading environmental cause of cancer deaths, Press Release No 221, International Agency for Research on Cancer, World Health Organization, Lyon, France, 17 October 2013.

[4] "Global Road Safety Facility", The World Bank and Institute for Health Metrics and Evaluation, Transport for Health: The Global Burden of Disease From Motorized Road Transport, IHME; the World Bank, Seattle, WA; Washington, DC, 2014.

[5] "Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles", OJ L 140, EU, 2009, pp. 1–15.

[6] I. Voytyuk, N. Porplytsya, A. Pukas, T. Dyvak. "Identification the interval difference operators based on artificial bee colony algorithm in task of modeling the air pollution from vehicular traffic", in *Proceedings of 14th International Conference: The Experience of Designing and Application of CAD Systems in Microelectronics*, 2017, pp. 58-62.

[7] I. F. Voytyuk, S. R. Tryshkaliuk, Ye. S. Kedrin. "Investigation of fireflies algorithm for identification of mathematical model in the task of monitoring pollution by motor transport," in *Proceedings of Conference: Advanced Computer Information Technologies*, Ternopil, 2017, pp. 235-238.

[8] Google Maps APIs. Available: https://developers.google.com/maps/web/