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# Intelligent system for monitoring the air pollution of the city in real time

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## INTRODUCTION

In recent years, there has been a lot of talk around the world about air pollution and how it affects our lives. Today, different measures are being taken to reduce pollution. The more people talk about it, the more we educate ourselves and this topic remains in the forefront of our lives, which means that the sooner the necessary steps will be taken.

But before you think about what can be done to solve a problem, it's important to know the basic facts about air pollution, which form the basis for a general understanding of this topic.

The air is polluted by harmful or poisonous substances that fall into it and which we then breathe. This is the most dangerous and, alas, very abundant type of environmental pollution. It occurs in the form of chemical gases, such as carbon oxides or solid particles such as soot (Polozhennya pro Derzhavnu systemu monitorynhu dovkillya, 1998).

In most countries, six major air pollutants are monitored: $O_3$, PM2.5, PM10, $NO_2$, $SO_2$ and carbon monoxide (CO). Despite the presence of hundreds of harmful pollutants, these six pollutants were chosen for several reasons, including: the ability to efficiently and accurately measure them, their significant presence in the environment and their proven effects on human health even in the short term.

The most common source of air pollution is the burning of fossil fuels at refineries, power stations, cars and factories. It is estimated that 50% of all pollutants are the result of industrial and manufacturing activities. Other sources include the burning of household wood, the livelihoods of agricultural areas and large cities.

## CLASSIFICATION OF AIR POLLUTION MONITORING SYSTEMS

To date, there are several classifications of air pollution monitoring systems at the global level. Many factors are affected by this, in particular the number and

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types of pollutants being monitored, the place where measurements are made, funding, legislative and regulatory support.

In the most general form such systems can be divided:

- by the type of system: for work in premises (residential, working) or outdoors;
- by the type of end user: industrial, commercial (for individual use), city air quality control agencies, government agencies and research institutes;
- by work scale: local (city, enterprise), local (within one country), regional, global.

In view of the problems highlighted, consider the European approach to the issue of air quality and the parameters that need to be taken into account when designing and developing monitoring systems.

In most countries, six major air pollutants are monitored: ozone ($O_3$), finely divided particles (PM2.5), solid particles (PM10), nitrogen dioxide ($NO_2$), sulfur dioxide ($SO_2$) and carbon monoxide (CO).

Despite the presence of hundreds of harmful pollutants, these six pollutants are most often selected for several reasons, including: their significant presence in the environment, the ability to efficiently and accurately measure them and their proven effects on human health, at least in the short term.

It is no coincidence that most of them are included in CAQI (Common Air Quality Index) – the European Air Quality Index, which meets the definition of the European Environment Agency (EEA, eea.europa.eu, Kol'tsov, M. and Shevchenko, L.V., 2018).

The index is calculated for five major pollutants regulated by European law: $O_3$ (ozone), $NO_2$ (nitrogen dioxide), $SO_2$ (sulfur dioxide), PM2,5 and PM10 (weighted particles with a diameter of less than 2.5 micrometers and 10 micrometers respectively). For each pollutant, the index value varies from 1 (good) to 5 (very bad). The European air quality index is calculated for different pollutants separately according to concentrations (instantaneously or on average per day, depending on the pollutant): the higher the concentration, the higher the index. The total air quality index is represented by an integer corresponding to five concentration ranges as indicated in Table 1.

**Table 1 European Air Quality Index CAQI**

| Pollutant | Index (pollutant concentration, μg /m$^3$) | | | | |
|---|---|---|---|---|---|
| | very good | good | average | poor | very bad |
| Ozone ($O_3$) | 0-80 | 80-120 | 120-180 | 180-240 | 240-600 |
| Nitrogen dioxide ($NO_2$) | 0-40 | 40-100 | 100-200 | 200-400 | 400-1000 |
| Sulfur dioxide ($S0_2$) | 0-100 | 100-200 | 200-350 | 350-500 | 500-1250 |
| Particles smaller than 10 microns (PM10) | 0-20 | 20-35 | 35-50 | 50-100 | 100-1200 |
| Particles smaller than 2.5 microns (PM2.5) | 0-10 | 10-20 | 20-25 | 25-50 | 50-800 |

The total hourly index is defined as the highest value of five individual pollutant indices calculated at the same time. For example, if the indexes $O_3$, $NO_2$, $SO_2$, PM2.5 and PM10 are equal to 1, 3, 1, 2, 2, respectively, the average index will

be equal to three. The total daily air quality index is the highest value of the total hourly air quality index for the day. It is divided into three different indexes, which differ in time intervals:

- hourly index describes air quality based on hourly values and is updated every hour;
- the daily index is responsible for the overall air quality of the previous day based on daily values and is updated once a day;
- the annual index shows air quality throughout the year and is compared with European air quality standards; is based on the average level per year in accordance with the annual boundary values, and is updated once a year.

Since the standards provide a distinction between indicators in the long run (annual cycle) and in the short-term (hours and days), the index provides air quality information only in the short term.

Solid particles (PM – particulate matter) – a very common pollutant of atmospheric air, which include mixed solid and liquid particles. Metals, rocks of the earth's crust, biological components (allergens, microorganisms) can also be parts of the PM.

Air pollution not only threatens the health of people, but also violates the ecological balance. Sources of formation of these substances are as follows:

1. Natural sources – include methane emissions from animal manure, volcanic smoke and forest fires, volcanic ash, sulfur and particulate matter of volcanoes, dust from areas without vegetation, etc.
2. Point sources – are stationary and do not move. For example, power plants, industry, etc.
3. Mobile sources – vehicles, agricultural machinery, airplanes, etc.

Air pollutants are divided into two types – primary and secondary:

- Primary sources are directly emitted;
- Secondary are formed when the primary enter a chemical reaction, which leads to the emergence of a new component.

The main air pollutants.

Nitrogen oxides ($NO_x$) – contains two forms: nitrogen monoxide (NO) and nitrogen dioxide ($NO_2$). Nitrogen dioxide is in large quantities and is produced by as natural factors (thunderstorms) as factories and power plants.

Sulfur oxides ($SO_x$) – mainly consist of sulfur dioxide. They are byproducts of a number of industrial activities and volcanoes. Along with $NO_2$ they often lead to the formation of acid rain.

Carbon monoxide, (CO) – incomplete combustion of fossil fuels is the main source of CO. Exhaust from vehicles also contain a large amount of carbon monoxide.

Material of solid particles (PM) – dust particles, pollutants with a diameter of less than 10 microns are called solid.

Secondary air pollutants.

Ozone ($O_3$) is formed when nitrogen oxides and hydrocarbons react with sunlight. The presence of ozone in the atmosphere is important because it filters

out harmful ultraviolet rays. However, it is anxiety when it is near the surface of the Earth and inhaled. In the atmosphere above, ozone becomes the main component of photochemical smog.

Peroxyacetyl nitrate (PAN) is also a product of nitrogen oxides and volatile organic compounds that form photochemical smog.

Consequently, atmospheric air pollution can be defined as a change in air quality, which can be characterized by measurements of chemical, biological or physical pollutants in the air. Therefore, air pollution means unwanted presence of impurities or an abnormal increase in the proportion of some components of the atmosphere. In addition, it can be classified into two sections: visible and invisible air pollution.

The next feature of the classification of pollutants is the distribution region:

- local – refers to the quality of the ambient air within a radius of several kilometers;
- regional – acid rain, photochemical reactions and degradation of water quality at distances from several kilometers to thousands of kilometers;
- global – depletion of the ozone layer and global warming caused by greenhouse gas emissions, mainly carbon dioxide ($CO_2$).

Due to the presence in the atmosphere of toxic substances, which are mainly produced as a result of human activities, air pollution can sometimes be a consequence of natural phenomena such as volcanic eruptions, dust storms and forest fires.

The sources of anthropogenic air pollution are:

1. Combustion of fossil fuels (coal and oil) for the production of electricity and road transport, causing emissions of nitrogen and sulfur dioxide.
2. Emissions from industry and factories (large amounts of carbon monoxide, hydrocarbons, chemicals and organic compounds).
3. Agricultural activities (through the use of pesticides, insecticides and fertilizers that release harmful chemicals).
4. Waste of animal husbandry (formation of methane).

It is impossible to describe the full extent of the potential and actual damage caused by all forms of air pollution. But there are three main consequences.

On the environment. Air pollution has a large impact on the process of evolution of plants by preventing photosynthesis in many cases, which has serious consequences for air purification. It also contributes to the formation of acid rain, precipitation in the form of rain, frost, snow or fog after burning fossil fuels and transforming it in contact with water vapor in the atmosphere.

On Global Warming. Air pollution is a major contributor to global warming and climate change. In fact, a large amount of carbon dioxide in the air is one of the causes of the greenhouse effect. As a rule, the presence of greenhouse gases should be beneficial to the planet as they absorb infrared radiation that is produced by the surface of the earth. But the excessive concentration of these gases in the atmosphere is the cause of recent climate change.

On the health of people. Our constant impact on the concentration of air pollutants is often also responsible for the deterioration of human health and this is a really significant risk factor, causing allergies, respiratory and cardiovascular diseases, as well as lung damage (Velychko; O. and Romanchuk, V., 2001).

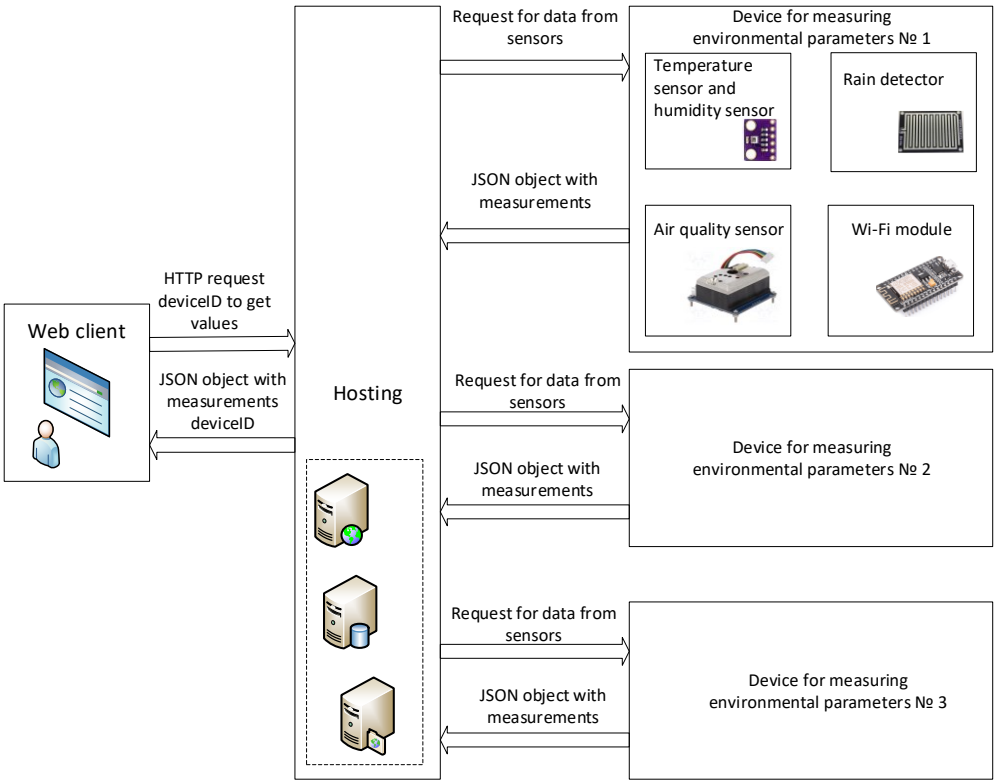


**Fig. 1 Structural scheme of work of the developed system**

## SYSTEM COMPONENTS

The main components of the projected system are:

- device for collecting and transmitting air pollution data;
- a database for storing the collected information;
- API for access to data transmitted by the device;
- Public resource APIs for access to air pollution data collected from many sources;
- a web-program for visualizing air pollution on a city map.

Let's take a closer look at each part of the system.

## CHARACTERISTICS OF THE DEVICE FOR DATA COLLECTION

As a part of the system, the device is designed to collect information on air pollution. It consists of:

- Microcontroller NodeMCU ESP8266 with built-in Wi-Fi module;
- three sensors for air analysis on the content of different gases: SNS-MQ135, DHT22 and BME280.

Sensors collect all the necessary information and using various data transfer protocols transmit it to the microcontroller, in which it is still a little bit processed. Based on pollution data, the pollution level is calculated and a json-object is

generated. It contains this indicator and some other information collected by the sensors (air temperature, humidity, pressure, altitude, and date when the data was transmitted). Then, this json is transmitted through a Wi-Fi module for hosting on the Internet for direct access by REST technology to the latest information gathered and into the database.

## API TO ACCESS THE DATA TRANSMITTED BY THE DEVICE

Data transmitted to hosting on the Internet is important not only to save, but also to get access to them for the program, which will ensure their visualization in an accessible form.

For this purpose, the Thinger.io platform is used in the project. It provides ready-to-use scalable cloud infrastructure for connecting things. Using it, manufacturers, companies, or simply developers of various equipment that transmits data over the Internet can easily control their devices via the network without worrying about the required cloud infrastructure.

The main features of the platform are:

- work with devices and interaction with the API;
- interacting with third-party services or sending messages;
- data packets for storing and exporting information;
- providing access to devices and data from other applications;
- and instrument panel for real-time data visualization.

In our case, the platform allows you to work with the NodeMCU ESP8266 microcontroller, providing the development environment and the necessary documentation for it, as well as the Server API, which allows access to a third-party application to the data transmitted by the microcontroller (our device). And the use of the GET method and the REST technology allows you to receive information about device statistics since its last connection, for example, connection time, IP address and data transmitted through the URL (Kalenchuk-Porkhanova, M., et al., 2002)

## API FOR ACCESS TO DATA FROM A PUBLIC RESOURCE

The data received by the device does not allow a qualitative assessment of air pollution, since the total pollution indicator is calculated and transmitted. Therefore, for more information, air quality data from other sources should also be displayed. In addition, it will allow them to be compared in order to obtain a more objective assessment of pollution.

API has been selected as such a resource provided by the Breezometer company, namely:

- Air Quality API (allows to request air quality information including indexes, pollutants and health recommendations for a specific place in terms of current conditions, an hourly forecast of up to four days, an hourly history of no more than 30 days);

- Weather API (weather conditions: temperature, wind speed, humidity, precipitation, etc. for a specific place in terms of current conditions, hourly forecast for up to five days, daily forecast for up to five days).

To connect to the API, you need to login to the breezometer.com website and register with an API key, which, like in the case with the Server API on the Thinger platform discussed above, will allow to identify the user and give him an access to the requested information. Getting current data is free within the 14 day trial period and up to 1000 requests per day, which is quite sufficient for the needs of this project (Devyatko, H.A. et al., 2004).

## PROGRAM FOR VISUALIZING AIR POLLUTION ON THE CITY MAP

The final component of the project and the subject of this work is a web application for visualizing all collected air condition data (from the API device and from the public APIs).

Structurally, the program consists of the following parts:

- index.html – a file with the markup of the main blocks of the web-page;
- style.css – a file for describing the appearance of a web page;
- index.js – a file that contains the main software logic;
- assets – a folder containing an image of 70 weather icons;
- markerwithlabel.js – an external library that contains additional logic that extends the functionality of the Google Maps JavaScript API, allowing to add colored markers with a label on the map;
- Functionally, the website can be divided into the following components: city maps, pollution scales, control panels, tables with data on pollution and device markers and public API tokens.

Let's consider all these components in turn.

The map of Lviv (Fig. 2) is created using the Google Maps API. The center of the map coincides with the city center. This is a map image by default, but you can drag it with a cursor, moving to other locations, and change the scale.

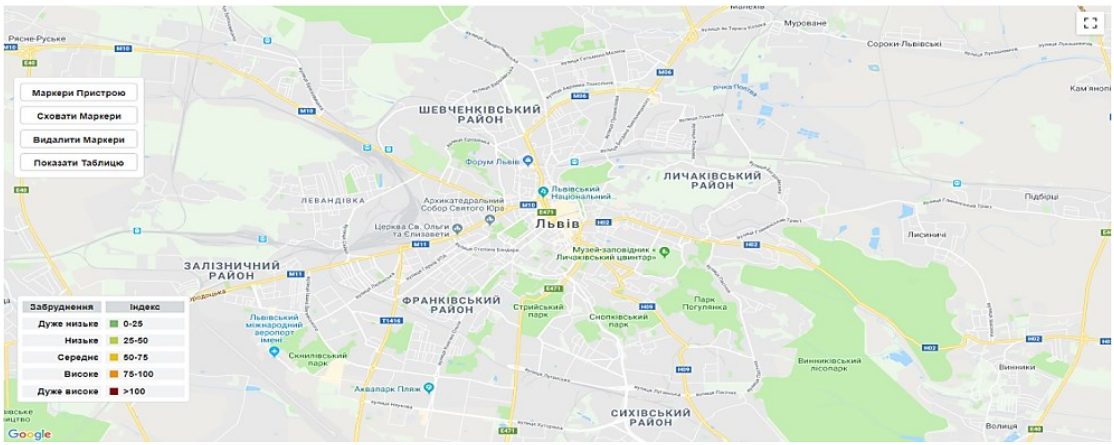


**Fig. 2 Web site appearance after the page loading**

The scale of pollution is in the lower left corner. The left column of the scale shows the levels of air pollution, and on the right – the corresponding numerical

values of the pollution index. Each level of pollution is indicated by the corresponding color (Fig. 2).

The top left corner of the site has a control panel that consists of a set of buttons:

- The "Device Markers" button shows the markers containing the information collected by the device on the map;
- "Hide Markers/Show Markers" button hides and displays all the markers that appear on the map;
- "Delete Markers" button erases all the markers from the map, updating the status of the map to the original one;
- The "Show Table/Hide Table" button hides and displays a table with detailed information about the pollutants for each marker.

There are two types of markers on the map:

- device markers that appear all at the same time after pressing the "Device Markers" button, Fig. 3;

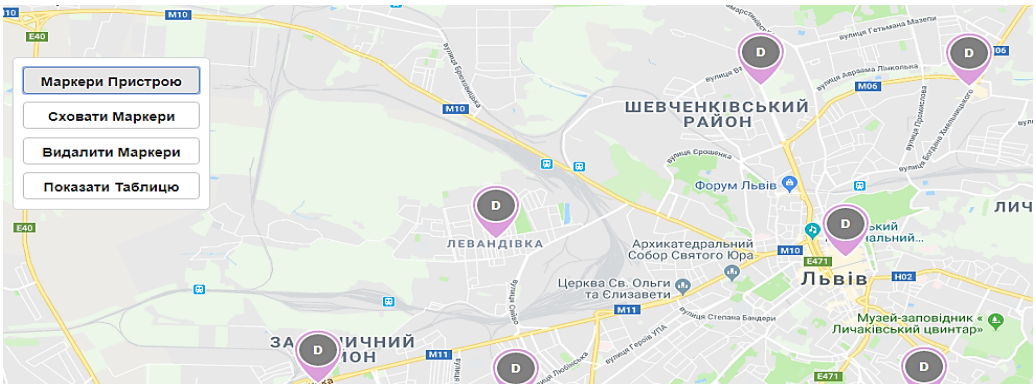


**Fig. 3 Device markers**

- data markers provided by the Breezometer API company appear on the map consistently at the click of a mouse, Fig. 4.

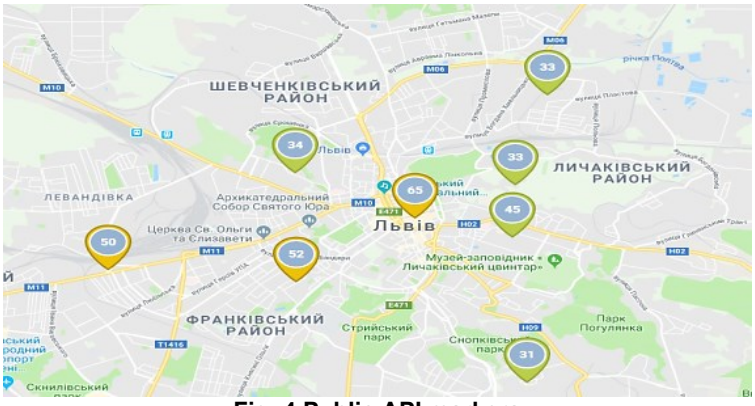


**Fig. 4 Public API markers**

When clicking on each marker, an information window with the data on air pollution and weather conditions at the indicated address appears on top of it (Fig. 5). Since all information from the requests to the Breezometer API company does not fit in the info window of the corresponding token, the rest of the information is placed in the table with the data on the pollution.

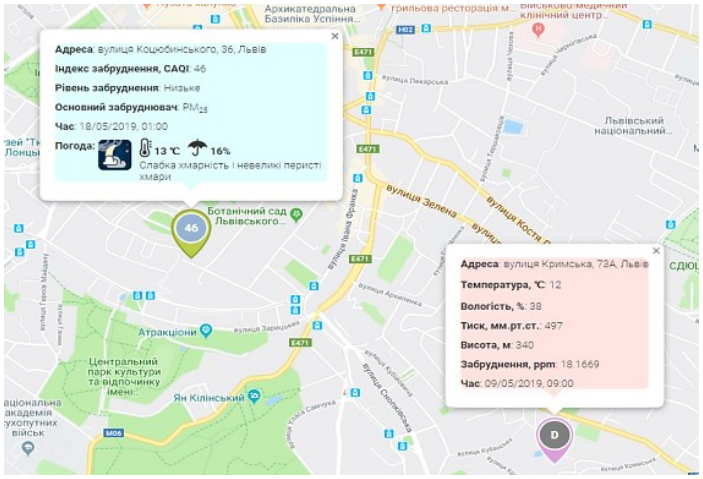


**Fig. 5 Information windows of two types of markers**

## CONCLUSION

To create the structure, style and logic of the site such tools as HTML, CSS and Javascript are used, respectively. The presentation of the site components was carried out using drawings and a description of their functional purpose.

In order to insert a city map into a page and interact with it, the Google Maps platform, including the required software interfaces, is applied.

The data to be displayed on a page is obtained from two sources:

- a device that collects through three sensors and processes information on air pollution;
- API with data on various air pollutants and weather conditions provided by the Breezometer company.

The data from the device and API provided by the air quality analysis company is received using REST technology, which significantly reduces the time to develop and helps to correctly structure the code that is responsible for the logic of the program.

Air pollution data will be stored in the database, which will allow to get information about the previous time intervals, and for a sufficient amount of data - to make statistics and even forecasts for pollution in the future period. A non-relational database is the best solution in our case.

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**Abstract.**
The article reveals the theoretical foundations, types of pollutants, classification of monitoring and visualization systems of air pollution. A description of the design of the structure of the system is described, its components are described in detail, and the justification of the selected technologies is given. In general, the system consists of two parts: a device for collecting air pollution data and a site that displays these data in user-friendly form. Graphic images that display the appearance of a software product are also added.

**Keywords:** API – application programming interface, CAQI – Common Air Quality Index, EEA – European Environment Agency