Ecological monitoring of air condition in smart cities according to conception of “Internet of Things”

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Abstract. The paper considers the current state of art in the ecological monitoring in the urban locality, existing problems and disadvantages of the installed monitoring systems of air conditions that are autonomous, stationary and ecological. The paper presents studies on the current state of monitoring systems in the city of St. Petersburg with a comparative analysis based on the results of field observations. Possible solutions proposed in this paper are based on the existing trend in the development of the Internet of Things and the requirements of regulatory documents.

1. Introduction
The global trend towards improving the environmental situation is still increasing every year. The air around us is directly related to the quality of life of any population, since with an unfavourable composition of the surface level of atmospheric air, people can develop respiratory and cardiovascular diseases. The issues of monitoring and assessing the air quality were raised in the works of the authors of the Mining University. To develop preventive actions in this situation, ecologists have created monitoring systems that make it possible to assess the current state of the environmental situation, that is, water, soil and air. The issue of monitoring atmospheric air and controlling emissions of harmful substances was raised only when it reached urban settlements, industrial facilities. These issues should be resolved not only by ecologists, but also by specialists in the field of metrology and instrument making, since this issue is at the intersection of these specialties.

The regulations for the organization of such systems, the requirements for them, the entire environmental component of megalopolises are regulated by the documents [15,18]. Also, in addition to the fundamental standards, clarifications are given for particular situations, depending on the controlled parameters and conditions [16,17,19]. This work is devoted to the assessment of the air condition in the city of St. Petersburg, since at the moment there are a number of excess concentrations of harmful substances in the city, especially ozone, which is classified as the first hazard class. The task of air monitoring systems is to monitor the current state of atmospheric air, but the purpose of these observations may differ, depending on the tasks.

The task in the framework of this work sounds as follows. It is the modernization of the existing automated measuring systems for environmental monitoring of atmospheric air up to intelligent ones in order to predict and identify possible sources of emissions of harmful substances. During the fourth industrial revolution, humanity began to move in the direction of smart things for the digitalization of everything around. Environmental monitoring is ideally suited for this direction in accordance with the concept of the Internet of Things, since in the works of many scientists [4-6] devoted to reviewing the
current state of affairs in the system of smart cities, one of the components of such cities is mentioned, namely "smart ecology". Intellectualization of existing systems will allow one to solve many problems, such as the reduction of imbalance at the heat source to the intellectualization of the operation of the entire combined heat and power plant [23] and agriculture [1]. The scope of this technology is so wide that it has its own name as the industrial Internet of Things. Since this area is extensive, a lot of research has been carried out on basic areas in the current state of affairs in the field of the Internet of Things, including specific examples of such cities [11-13]. As mentioned earlier, this issue is interdisciplinary, therefore, IT specialists also considered existing problems and ways to solve them [2,3,7].

At the moment, there are discrepancies among specialists in various fields in the definition of the term "smart sensor". In the course of the work, it was indicated that, in accordance with the kami, it was from the existing definitions that a plan for the modernization of automated measuring systems to intelligent ones was presented. This task has two branches, namely software and hardware. Then there are two components of this work, engineering and scientific. From an engineering point of view, it is necessary to replace the existing stationary post control unit with a device that will reduce the cost of production of such posts and increase the reliability of this module by placing the main computing power in cloud services for possible interchangeability, in the event of a module failure, without the need to reprogram a new module.

The scientific component of the work is to develop a new approach to the implementation of the function of remote calibration, or auto-calibration, which will reduce the time to restore the operating state in the event of a failure in one of the sensors. To solve this problem, it is necessary to analyze the current calibration procedure for gas analysis equipment and propose a new method. The new approach should be based on the basic principles of building cyber-physical systems to increase the share of automation of the measurement process [8-10].

2. Materials and methods

The main objective of the study is to propose a possible solution for the modernization of automated measuring systems for environmental monitoring of atmospheric air to obtain intelligent ones, based on the existing shortcomings of the current systems. To establish the relevance of this work, a number of experiments were carried out. One of them has been established in the current air pollution by two means. The first was the field observations and analysis of theoretical data presented in an open source, the result is presented in the form of maps with isolines of concentrations of harmful substances and meteorological parameters at the moment of the experiment to substantiate the need to equip the existing monitoring posts with meteorological stations. It will allow predicting the directions of the spread of emissions of harmful substances. The concentration values are presented in accordance with [20], the summation of harmful substances. Formula 1 is used for typical cases, but provided that sulfur dioxide and nitrogen oxide are present, formula 2 is applied.

\[
\frac{C_1}{MPC_1} + \frac{C_2}{MPC_2} + \frac{C_3}{MPC_3} \leq 1
\]  
(1)

\[
\frac{C_1}{MPC_1} + \frac{C_2}{MPC_2} + \frac{C_3}{MPC_3} \leq 1.6
\]  
(2)

where \(C_i\) – concentration of a harmful substance, \(MPC_i\) – maximum permissible concentration.

The analysis results are shown in Figure 1 and Figure 2.

The above images show the summation concentrations of the following substances \(NO_2 + CO + SO_2\). The analysis shows that the data have a correlation, but differ significantly. All equipment with which the field observation took place was verified and had identification documents. Obviously, it is noticeable that the presence of such meteorological parameters as the strength and direction of the wind makes it possible to understand in which direction the halos of pollution can be transformed. It will produce the opportunity for forecasting. In addition to the aforementioned analysis, an assessment of the frequency of failures in the operation of existing systems was carried out and it was revealed that a frequent situation is the failure of one of the analyzed parameters and long-term loss of
measurement information for a short time. For instance, such failure in operation and data display is shown in Figure 3.

**Figure 1.** Isolines of the concentrations of harmful substances with the indicated meteorological parameters.

**Figure 2.** Isolines of concentrations of harmful substances, based on the results of analysis of open sources

**Figure 3.** Monitoring station malfunction
Hence, the second task arises in the form of upgrading the existing measuring systems to obtain intelligent ones. For this it is necessary to be guided by a number of standards in this area [21, 22] and to focus on replacing the installed control module with an arduino unit to implement the function of remote control and response in the event of a breakdown of the post for repairable situations. In a number of works by Russian scientists, the existing technologies of the "Internet of Things" were considered, which allow modernizing the existing monitoring systems to intelligent ones, and the current role of a specialist metrologist in innovative processes was considered [14].

Modernization work will be carried out on the equipment of the mining university. The existing monitoring posts were purchased about 10 years ago; therefore the instrumental component of the existing posts is very outdated.

The first stage in the improvement process will be to restore the operational state of the entire post, since individual elements, such as the GANK gas analyzer 4 works outside the post, and the internal power systems must be replaced with updated ones due to a non-working state. There is also the possibility of power supply from a solar battery, but at the design stage of a new system, this function is not necessary.

The emphasis is on the engineering component, that is, the return of the working state of the station and the replacement of obsolete modules and also the development of the methodological and instrumental part for the implementation of the auto-calibration function. Self-diagnosis, as mentioned earlier, will be implemented by means of cloud technologies on the Amazon service.

3. Results

Based on the results of the analysis of input data on the current state of monitoring systems in the city of St. Petersburg, the necessary list of works was determined that are necessary to modernize existing systems and form a new approach to building intelligent measuring systems for monitoring the state of atmospheric air. The approach should be based on the principles of predicting the transformations of halos of harmful substances, as well as on creating a platform with a simplified system of accessibility for upgrading or returning to an operational state in a minimum period of time, in the event of failure of one of the elements of the system.

In the work, R. Taymanow raises the issue of different interpretations of the word "smart and intellectual" by specialists in various fields. During the process of approbation of works on this topic, the misunderstanding of the differences between these terms appeared, since different standards give different definitions to these terms.

For example, in GOST R 8.673-2009 it is the system for ensuring the uniformity of measurements (GSI), including intelligent sensors and intelligent measuring systems. The main terms and definitions are the following: an intelligent sensor - adaptive sensor with a metrological self-control function; an intelligent measuring system - an adaptive measuring system with a metrological self-monitoring function.

While GOST 55233-2012 is electronic gas-sensitive intelligent modules. General technical requirements and test methods give the following definition: an intelligent sensor (sensor) - an electronic sensor that has at least one of the following functions: self-diagnosis, self-calibration, the ability to adapt to changes in the external environment. Within the framework of this work, the definition of the standard for gas-sensitive summer cottages was taken as a basis, since we will be talking about gas analyzers. The structural basis in the design of the monitoring system, a detailed diagram is shown in Figure 4 [21].
Figure 4. Scheme of the post of atmospheric air monitoring

As shown in the image above, this scheme lacks a calibration module, and one of the components of intelligent systems is the ability to implement this function. The built-in microprocessor is responsible for the self-diagnosis process, the computing module of which is located in the cloud service, where the self-control functions are already implemented directly by the software algorithm. This allows real-time tracking of the deviations of the measured values in the data array. For the reliable operation of the deviation monitoring program, it is necessary to turn to machine learning so that the program recognizes random deviations and malfunctions, hence there is a need to collect and download information before starting the implementation of the intelligent measuring system itself. The diagram of the measuring installation is not presented in this work, since it is patentable information and will be presented in the following works. During the experiment, comparing two types of monitoring, namely stationary automated and field observation, the following was found.

The main disadvantage of stationary observations is the lack of information about the current meteorological parameters, namely the strength and direction of the wind. These data are necessary to predict the spread of harmful emissions in the ground level of the atmosphere and to track wind shadows. This problem is solved by equipping the existing monitoring posts with meteorological stations, which can also be powered either from their own power source or be part of the measuring system and be connected to a single centralized power supply.

The second disadvantage of stationary systems at the moment is the impossibility of an instant response to a system failure, namely, the establishment of conditions under which a failure occurred. This problem is solved by placing the Arduino module and interconnecting it with Amazon Web Services to implement permanent access to the system in real time. This module allows for two-way communication, which allows you to control the system remotely.

During the approbation of these studies, the employees responsible for the operating systems stated that at the moment in St. Petersburg, Rostelecom is implementing a unified Internet of Things system, where it is trying to link all currently available intelligent systems, including city cameras. This idea allows you to supplement the process of self-diagnosis of the system and expand it not only to instrumental, using the studied algorithm, but also to visual, so that there is an idea of the nature of the post failure, whether it is a software error or the impact of external factors.

4. Conclusion
At this moment, measuring information is obtained by means of stationary automated environmental monitoring of the state of atmospheric air used for reporting purposes. The small volume of measurement information available in the public domain complicates the task of finding and
identifying sources of emissions or pollution without additional field observations. The task of the new systems proposed in the work is to provide access to data online for the possibility of using the obtained data in real time in order to predict the spread and transformations of halos of harmful substances and develop preventive actions to prevent reaching the limit state. This goal is achievable thanks to the development of cloud technologies and the development of a new, automated auto-calibration system.

An integral part of these studies will be a full-scale experiment and comparative analysis with existing measuring systems. This is necessary to build a reliable picture of the changes obtained in the modernization process. One of the important criteria will be the assessment of the measurement uncertainty, since according to the standard it cannot be 25%. The further direction of this scientific work is aimed at developing a technical solution for the implementation of self-calibration functions in measuring systems for environmental monitoring of atmospheric air. It is necessary to assemble an intelligent measuring system with an Arduino module, while the task is to teach this module to implement the self-diagnostic function.

The scientific aspect of this work will be the development of a new method for implementing the self-calibration procedure of the gas analyzer sensors. Since now, this procedure has been carried out in several ways, the simplest of which is to supply a gas calibration mixture from a special package, but the complexity of automating this process is the need to restore such packages. This gives rise to the problem of finding a solution for the implementation of this process without human participation. Since the current trend in the intellectualization of industries and cities as a whole sets itself the goal of reducing the role of humans in measuring and diagnostic processes to optimize such systems in terms of financial indicators and energy efficient ones.

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