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Assessment of the possibility of using CityAir air monitoring station in environmental engineering

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Abstract. On the basis of the definition of the term "engineering" in accordance with GOST R 57306-2016 and the requirements of environmental legislation of the Russian Federation the task of "environmental engineering" is justified, which is to implement environmental control (monitoring) of the concentration of particulate matter in the air during the construction and operation of industrial or other economic activity. The possibility of CityAir air monitoring station application for this task is analyzed. It is established that the readings of the sensor of the concentration of particulate matter should be corrected with respect to the measurement results obtained at stationary observation posts (operating under the license of Roshydromet). After this adjustment, CityAir stations can be used in environmental engineering.

1. Introduction

In the scientific and technical literature, the concept of the term "engineering" is constantly expanding, including areas that are more and more distant from classical engineering activity [1-4].

In the normative documents of Russia, the definition of the term "engineering" was first formulated in the GOST R57306-2016 national standard. This standard was enacted on September 1, 2017 (Order of the Federal Agency for Technical Regulation and Metrology of November 30, 2016 No 1907-c). In accordance with GOST R57306-2016: "engineering: engineering and consulting activities, the content of which is the solution of engineering problems associated with the creation or improvement of products, systems and (or) processes. Note: the subject of engineering is not the product (the final result of production), not the design and production of products, and the intelligent process of solving creative (engineering) tasks related to the design and organization of production processes (performance of work, provision of services)."

In 2018, the national standard of the Russian Federation GOST R58179-2018 "Engineering in construction. Terms and definitions" with the date of the enactment of September 1, 2018 has been approved. This standard formulates the concept of the term "engineering in construction", which is defined as engineering consulting services in investment and construction activities carried out by consulting engineers in construction and/or engineering organizations under contracts with customers and having the ultimate goal of obtaining the best results from capital investments or other costs associated with the implementation of investment and construction projects.



Currently, the term "environmental engineering" is not defined in any regulatory documents of Russia. The term and objectives of "environmental engineering" are described in various interpretations in scientific and technical articles [5, 6].

The authors of this article formulated one of the tasks of "environmental engineering" on the basis of the definition of the term "engineering" and the requirements of the environmental legislation of the Russian Federation: Federal Law No. 7-FL of January 10, 2002 (as amended on 07.29.2018) "On Environmental Protection", Federal of the Law of 04.05.1999 No 96-FL (as amended on 07.29.2018) "On the Protection of Atmospheric Air", Resolution of the Government of the Russian Federation of February 16, 2008 No 87 (as amended of 04.21.2018) "On the Composition of Project Documentation and their content". The task is to carry out environmental control (monitoring) of the concentration of particulate matter in the atmospheric air during the construction and operation of an industrial or other object of economic activity.

2. Measurement of air pollution by particulate matter

Air pollution by particulate matter less than 2.5 microns ($PM_{2.5}$) adversely affects human health [7]. Large-scale and continuous monitoring of particulate matter in the air is carried out in most industrialized countries. However, such control is not carried out in Russia at the state level. Only in several subjects of the Russian Federation (including in the Krasnoyarsk Territory) monitoring of the $PM_{2.5}$ concentration is carried out [8]. Thus, the problem of monitoring (environmental control) of the concentration of particulate matter in the air is relevant on the scale of the Russian Federation.

Equipment for measuring the concentration of $PM_{2.5}$, used at stationary observation posts, operates under certain temperature conditions (different from climatic parameters) and requires, as a rule, monthly maintenance. The use of such devices for environmental control (monitoring) causes some difficulties during the construction and operation of the facility.

Analysis of the market of devices for measuring the concentration of $PM_{2.5}$ showed that the CityAir air monitoring station for technical and operational characteristics (indicated by the manufacturer) meets the requirements of environmental control (monitoring), including in the climatic conditions of Siberia.

The purpose of the study was to verify the parameters measured by the CityAir station, with similar parameters determined at the stationary posts of the Regional State Budgetary Institution "Center for the Implementation of Environmental Management and Environmental Protection of the Krasnoyarsk Region" (RSBI "CIEMandEPKR").

The measurements were performed in the period from December 1, 2018 to February 28, 2019.

The geographic locations of stationary posts observation "Krasnoyarsk-Vetluzhanka" and "Krasnoyarsk-Pokrovka" are presented on the official website (<http://krasecology.ru/>). CityAir air monitoring stations were installed on the roof of each stationary post.

CityAir air monitoring station (UNCL.421451.1000-01 factory code) is designed to collect data on the state of the surrounding air (mass concentration of aerosol particles, temperature, humidity and atmospheric pressure) and transmit them to the server via a wireless communication channel.

Operating conditions of CityAir station:

- Temperature of surrounding air from minus 40 to plus 50 °C;
- Relative humidity of the surrounding air at a temperature of 25°C up to 100%;
- Atmospheric pressure of the surrounding air from 84.0 to 106.7 kPa.
- The station's sensors allow for:
 - Measuring the $PM_{2.5}$ and PM_{10} particle content in the range of 0 to 1.6 mg/m³. Maximum permissible relative error ±20%;
 - Measuring ambient air temperature in the range of -40 to +50°C. Maximum permissible absolute error ±1°C;
 - Measuring relative humidity in the range of 0 to 100%. Maximum permissible relative error ±3%;

- Measuring atmospheric pressure in the range of 600 to 850 mm Hg. Maximum permissible absolute error ± 1 mm Hg;
- Establishing the station's position in the GPS and GLONASS systems. Permissible positioning error: 2.5 m CEP.

Additional features of the CityAir station are as follows.

1. Measurement frequency is user-configurable: from 1 measurement per day to 1 measurement per minute.
2. The obtained data is transferred to the server. GSM GPRS modem is the main data transmission channel.
3. A built-in Wi-Fi module serves as an additional data transmission channel.
4. Remote control of the station is available.
5. The station can perform self-diagnostics, in automatic mode or upon remote request.
6. Autonomous fully functional operation with maximum measurement frequency is enabled by a built-in storage unit for at least 24 hours under normal weather conditions (when the temperature is below 0°C , the heater turns on and quickly exhausts the battery).
7. Turnaround period (before filter replacement and replacement/calibration of sensors) is 12 months.

Characteristics of the equipment and methods for measuring of meteorological parameters and $\text{PM}_{2.5}$ concentration at stationary posts of RSBI "CIEMandEPKR" are presented on the official website (<http://www.krasecology.ru/>).

3. Results and discussion

The topographic features of the territory of Krasnoyarsk and the non-freezing Yenisei river adversely affect the dispersion of particulate matter emitted from stationary and mobile sources [9]. Adverse meteorological conditions contribute to an increase in the concentration of $\text{PM}_{2.5}$ in the surface layer of the atmosphere to $500 \mu\text{g}/\text{m}^3$ (<http://krasecology.ru/>). This level of air pollution allowed the testing of CityAir stations of air monitoring in a wide range of particulate matter (figure 1 and figure 2).

The scatter of points relative to the regression line in figure 1 is less than in figure 2. The coefficient of determination (R^2) for the data obtained at the "Krasnoyarsk-Vetluzhanka" post is 0.8941. The value of R^2 for the data obtained at the "Krasnoyarsk-Pokrovka" post is smaller and equals 0.8475. Dependencies with a coefficient of determination above 0.8 are considered good enough.

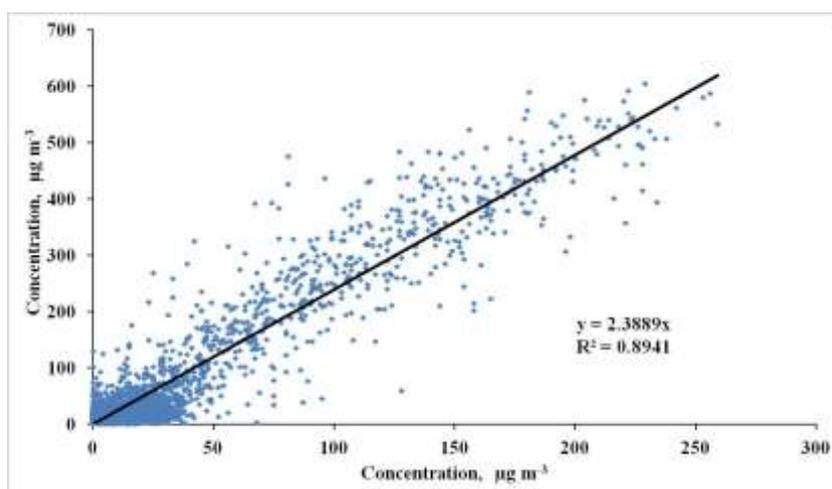


Figure 1. Correlation of $\text{PM}_{2.5}$ concentration between the readings of the stationary observation post "Krasnoyarsk-Vetluzhanka" (abscissa axis) and the readings of the CityAir station (ordinate axis), located on the roof of this post.

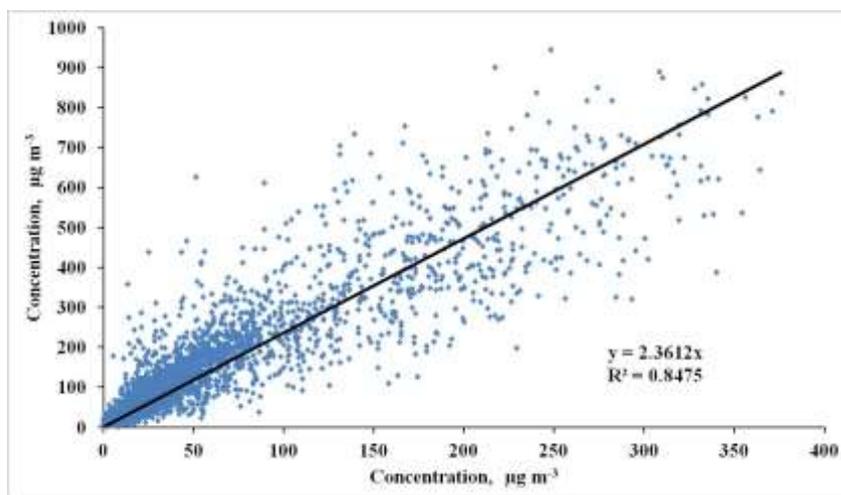


Figure 2. Correlation of $PM_{2.5}$ concentration between the readings of the stationary observation post "Krasnoyarsk-Pokrovka" (abscissa axis) and the readings of the CityAir station (ordinate axis) located on the roof of this post.

The equation of linear regression for the data obtained on the "Krasnoyarsk-Vetluzhanka", "Krasnoyarsk-Pokrovka" posts slightly differ in magnitude of the coefficient under variable value: $y=2.3889x$ and $y=2.3615x$, respectively.

The value of the coefficient in the regression equation indicates that the concentrations of $PM_{2.5}$, determined by the sensor of CityAir station is almost 2.4 times higher than similar values determined by the devices of stationary observation posts.

RSBI "CIEMandEPKR" uses at its stationary posts dust analyzers of the BAM-1020 model (produced by "Met One Instruments Inc.", USA) to measure the concentration of $PM_{2.5}$ in the atmospheric air. The principle of measurement of these devices is based on the weakening of beta radiation by solid particles deposited on the filter tape. The principle of measurement of $PM_{2.5}$ concentrations of the sensor installed at the CityAir station is based on the dispersion of the luminous flux.

Method of measuring $PM_{2.5}$ concentrations with BAM series instruments is considered a reference throughout the world. Therefore, the results of measuring the concentration of $PM_{2.5}$ using CityAir stations need to be corrected.

Testing of CityAir stations of air monitoring confirmed that the measurement of $PM_{2.5}$ concentration perhaps in winter conditions of Siberia. During the research period the temperature of the surrounding air at the "Krasnoyarsk-Vetluzhanka" post dropped to minus $40^{\circ}C$, at the "Krasnoyarsk-Pokrovka" post dropped to minus $35^{\circ}C$ (figure 3). Under such temperature conditions $PM_{2.5}$ concentration data were transmitted from CityAir stations to the cloud network server steadily and without interruption.

Thus, the use of CityAir stations for monitoring (environmental control) of the concentration of particulate matter in the atmospheric air is possible under the condition of calibration of the sensor for measuring of the concentration of $PM_{2.5}$.

The CityAir station of air monitoring is equipped with sensors that allow to measure meteorological parameters. Correlation of temperature, humidity and pressure with the same parameters defined at fixed stations RSBI "CIEMandEPKR" shown in figure 3, figure 4, figure 5, respectively.

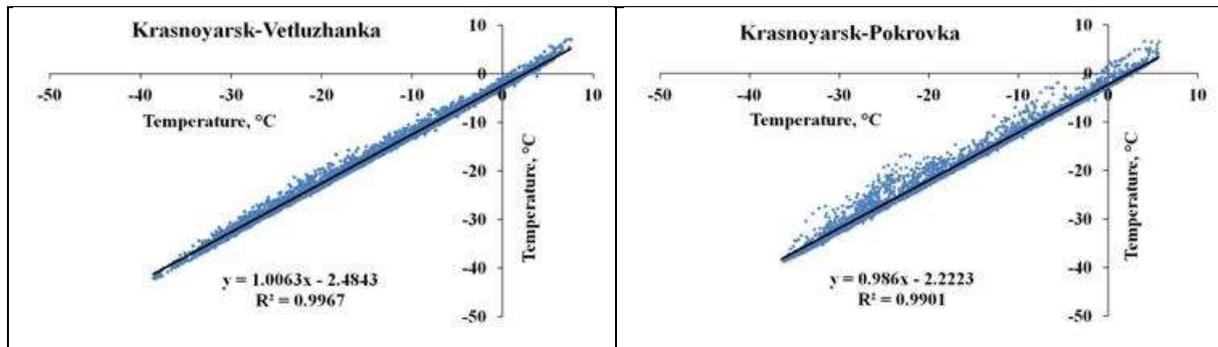


Figure 3. Temperature correlation (°C) between the readings of device of the stationary post of observation (abscissa axis) and the readings of the CityAir station (ordinate axis) located on the roof of the stationary post.

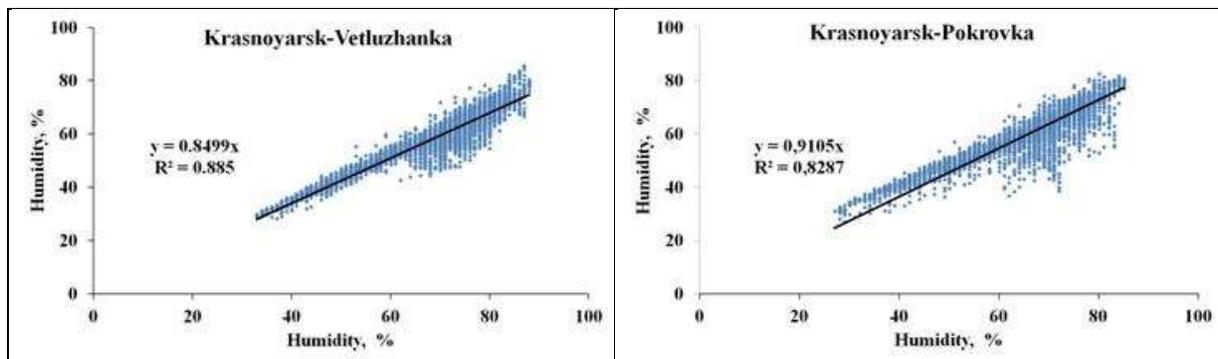


Figure 4. Correlation of humidity (%) between the readings of device of the stationary post of observation (abscissa axis) and the readings of the CityAir station (ordinate axis) located on the roof of the stationary post.

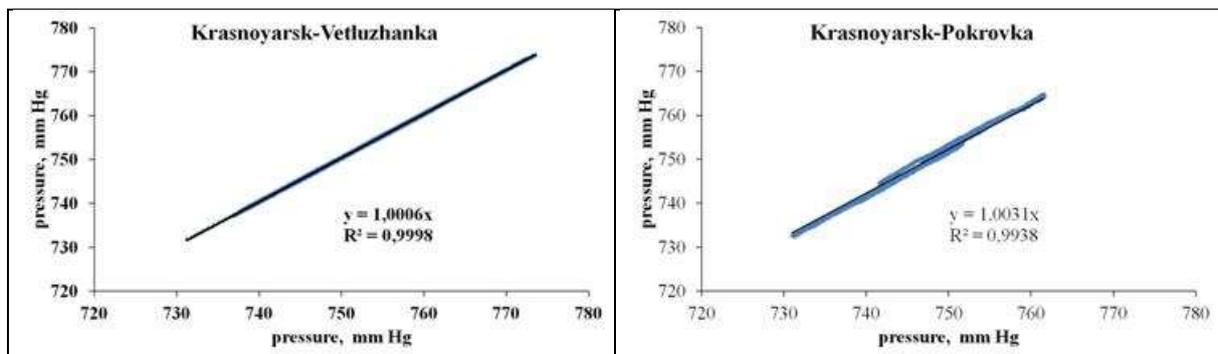


Figure 5. Correlation of humidity (mm Hg) between the readings of device of the stationary post of observation (abscissa axis) and the readings of the CityAir station (ordinate axis) located on the roof of the stationary post.

The following linear regression equations were obtained:

- a) for temperature: $y = 1.0063x + 2.4843$, $R^2 = 0.9967$, (1);
 $y = 0.9860x + 2.2223$, $R^2 = 0.9901$, (2);
 b) for humidity: $y = 0.8499x$, $R^2 = 0.8850$, (3);
 $y = 0.9105x$, $R^2 = 0.8287$, (4);
 c) for pressure: $y = 1.0060x$, $R^2 = 0.9998$, (5);
 $y = 1.0031x$, $R^2 = 0.9938$, (6).

Equations 1, 3, 5 are obtained on the basis of data analysis registered at the "Krasnoyarsk-Vetluzhanka" post. Equations 2, 4, 6 are obtained on the basis of data analysis registered at the "Krasnoyarsk-Pokrovka" post. Determination coefficients greater than 0.99 are obtained for temperature and pressure (equations 1, 2, 5, 6). It should be noted that the temperature sensors located on the CityAir station underestimate the readings by 2.2-2.5°C. The worst match was found for humidity (equations 3, 4). The coefficients of the variable in linear equations are 9% and 15% different from the value of 1.0.

Consequently, only one parameter (pressure) of the three meteorological parameters determined by the CityAir air monitoring station can be used for monitoring purposes.

4. Conclusions

Testing of CityAir stations of air monitoring in conditions of negative winter temperatures reaching minus 40°C allowed to establish that the readings of three of the four sensors need correction. First, the PM_{2.5} concentration sensor overestimates readings by almost 2.4 times. Secondly, the temperature sensor underestimates readings by almost 2.5 °C. Third, the humidity measurement accuracy does not correspond to the values specified in the operating manual.

The smooth operation of the PM_{2.5} concentration sensor in the winter conditions of Siberia is the advantages of the CityAir station. The corrected readings of the PM_{2.5} concentration sensor can be used in environmental engineering.

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