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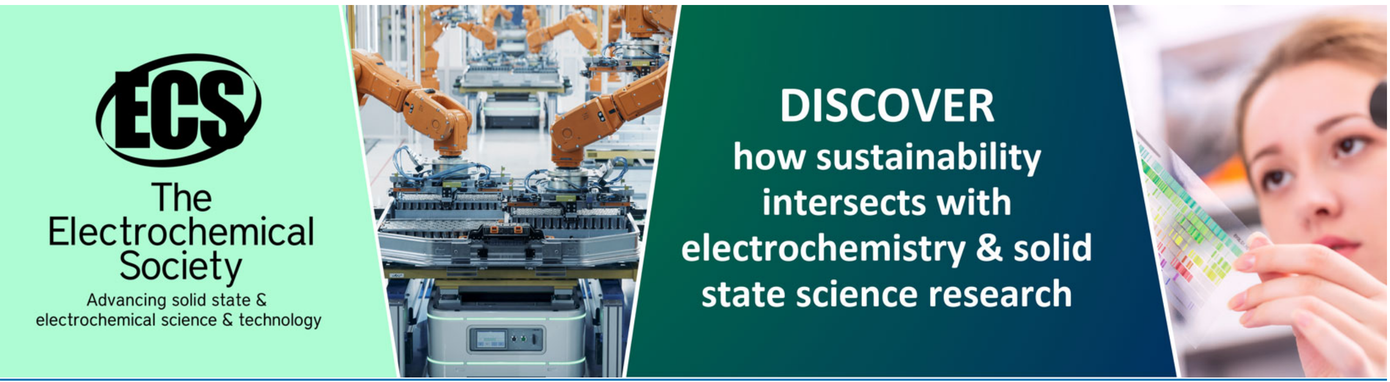

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Improvement of the system of industrial environmental monitoring of atmospheric air in the area of anthropogenic arrays impact

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Abstract. Nowadays the waste management is one of the most pressing problems in the industry of mineral resources extraction and processing. The main method of waste disposal is storage on the surface of the Earth in the form of anthropogenic arrays. Anthropogenic arrays have an integrated and long-term impact on the atmospheric air. In this regard, the need for continuous monitoring of the state of atmospheric air in order to identify the main sources of dust emission and their quick elimination acquires particular relevance. This task can be performed by automating the existing system of industrial environmental monitoring. The article touches upon the issues of the implementation of the task of continuous monitoring of the dust content of atmospheric air in the areas of the anthropogenic arrays impact. The structure of the automated system of industrial environmental monitoring for the rapid detection of sources of intense dust emission, their ranking by the degree of potential danger and the measures for their timely elimination are proposed.

1. Introduction

Currently, one of the most significant sectors of Russian economy is the mineral-raw material complex. While the enterprises of the mineral resources extraction and processing are sources of an integrated and concentrated impact on the components of the natural environment and on the health of the inhabitants. Today the area of land which is disturbed by the activities of enterprises of the mineral-raw materials complex reaches more than 15 million hectares only in Russia. At the same time, about 10% of disturbed areas are occupied by storage sites of the wastes of mineral resources extraction and processing - anthropogenic arrays [1].

Anthropogenic arrays are sources of continuous and prolonged environmental pollution through the atmosphere, lithosphere and hydrosphere. There are disturbance and alteration of natural landscapes, a decrease in the species diversity of animals and plants, deterioration of population health indicators are observed (life expectancy, morbidity and mortality, congenital abnormalities) in a territory of their impact [2].

The production facilities of JSC Apatit, and first of all the alluvial technogenic array of the second apatite-nepheline processing plant (the ANOF-2 tailing dump) were the objects of research.

The ANOF-2 tailing dump was commissioned in 1963 and today it is the largest alluvial technogenic array in Russia according to the height of the enclosing dam and the volume of waste stored in it. The tailing dump is located 8 kilometers north-west of the city of Apatity (Murmansk region), its total area is about 8 square kilometers and the height of the enclosing dam at the beginning

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of 2018 reached 76 meters. About 8 million cubic meters of apatite-nepheline ore processing waste flow from the concentrating plant to the tailing dump every year, but more than 680 million cubic meters of processing waste had been accumulated in tailing dump from the beginning of its operation [3].

The main source of negative impact on the atmospheric air, lithosphere and hydrosphere is wind dusting of open beaches and sides of the dam of tailing dump, as a result of which more than 250 tons of inorganic dust with SiO_2 content from 70 to 20% gets into the air annually. This makes up more than 30% of the total mass of suspended substances emitted by the enterprise. In addition, there is an excess of the average maximum permissible concentration by 1.5-2 times in the territory of the city of Apatity provided the southeastern direction of the wind and its velocity of 6-8 meters per second. It should be noted that, the probability of southeastern winds for this region is 27% in accordance with the average annual wind rose, but the air flow rate in the summer months reaches 25 meters per second [4].

The company has successfully used a number of environmental protection measures that can significantly reduce the intensity of dust transfer from the territory of the alluvial anthropogenic array today [3,4].

In this regard it is necessary to introduce an automated production environmental monitoring system for the improving the effectiveness of existing environmental protection measures during periods of adverse meteorological conditions. Automated monitoring system is able to quickly and efficiently identify areas of intense dust formation and rank them by the degree of potential danger in order to eliminate them rapidly.

2. Materials and methods

The structure of the automated system of industrial environmental monitoring was developed in accordance with the regulatory document SP 11-102-97 "Engineering and environmental surveys for construction". Based on this document, industrial environmental monitoring should identify the main regular occurrences of quantitative and qualitative changes in the state of the environment in space and in time. In this regard, the automated production environmental monitoring system should perform the following tasks:

- systematic registration and control of indicators of the state of the environment in the locations of potential sources of pollution and areas of its possible distribution;
- the development of environmental regular occurrences of natural and man-made nature and the forecast of possible changes in the state of the components of the environment based on the identified regular occurrences;
- development of recommendations and proposals to reduce and prevent the negative impact of industrial facilities on the environment;
- control of the use and effectiveness of the adopted recommendations to reduce the anthropogenic load on the territory at issue [5,6].

The main research methods are: system analysis of fundamental scientific works of Russian and foreign scientists on this subject; environmental hardware monitoring of the state of atmospheric air in order to determine the layout of stationary monitoring posts; methods of mathematical statistics, cartographic modeling and ranking of sources of environmental pollution according to the degree of potential danger.

Environmental monitoring of atmospheric air was conducted in line with GOST 17.2.3.01–86 “Nature protection. Atmosphere. Rules of air quality control for populated areas” [7].

The method for determining the concentration of inorganic dust in atmospheric air included laser nephelometry, which is used in dust analyzers manufactured by TSI Company [8]. In addition, a particle size analysis of enrichment wastes was performed in the framework of scientific research for the revelation of the dynamics of dust transfer. It was carried out in accordance with GOST R 8.777-2011 “State System for Ensuring the Uniformity of Measurement. The disperse composition of aerosols and suspensions. The determination of particle size by laser diffraction” [9].

Multifactor analysis and methods of cartographic modeling were used to rank the sources of air pollution by degree of danger, as well as to determine the location of posts in the system of industrial environmental monitoring [4].

The scientific instrumental base for conducting field research and for results processing was provided by the Environmental Monitoring Laboratory of St. Petersburg Mining University [10].

3. Results

The system of industrial environmental monitoring is an analytical complex, which consists of an information-measuring unit, a source data processing unit, a settlement unit and a central management unit. The automated production environmental monitoring system carries out continuous quality control of the surface atmosphere in the territory of the production facility at issue. It continuously records concentrations of inorganic dust, air humidity, wind speed and direction at stationary monitoring stations and transmits the received data to a united information resource. The united information resource collects, stores and processes these data [11,12].

The number of monitoring posts and their positioning directly depends on the dusting intensity, the distance of the dust transfer and the waste parameters stored in the anthropogenic array [13]. The dependence of the specific blowing of dust on the moisture content of the stored material and air velocity was revealed based on experimental studies. The graph of the dependency is presented in Figure 1.

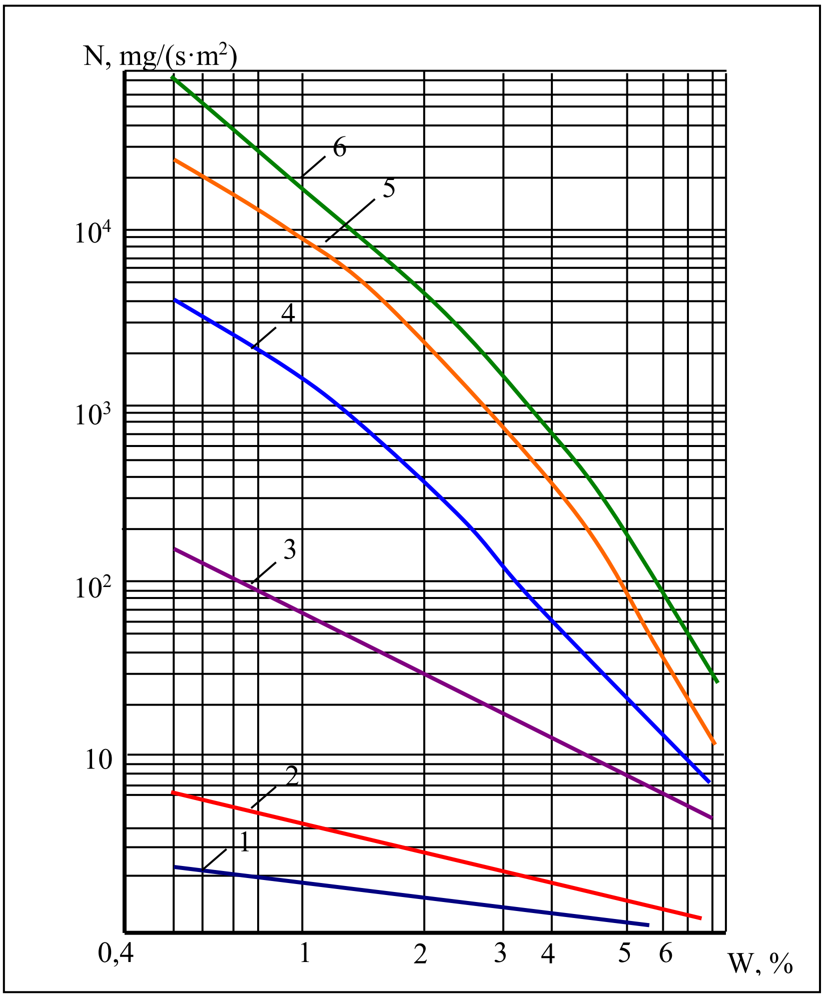

Figure 1. Graph of the dependency of the specific blowing of dust (N) on the moisture content of the stored material (W) and air velocity (V): 1 - 2 m/s; 2 – 3.5 m/s; 3 - 5 m/s; 4 – 6.5 m/s; 5 - 8 m/s; 6 – 9.5 m/s

The graph shows that when the wind speed is up to 5 meters per second, the specific blowing of dust is insignificant and its change is linear, however, with an increase in the wind speed, the specific deflection of dust increases along a parabola, but the dusting intensity increases manifold.

A network of atmospheric air monitoring posts in the production environmental monitoring system was developed on the example of the ANOF-2 tailing dump based on the established experimental dependency [14]. The network includes five stationary posts located on the territory of the alluvial beaches of the tailing dump. The monitoring posts are located taking into account the average annual wind rose (along the most frequently observed wind directions) so that, with any wind direction, the current concentration of dust is recorded in at least one monitoring station. The network of monitoring posts is designed in such a way as to control the dusting of the surface atmosphere throughout the tailing dump with minimal costs for monitoring stations equipment. Thus, five monitoring stations are the minimum number of control points required to cover the entire ANOF-2 tailing site and to create the possibility of rapid response in the event that sources of intense dust emission are formed on its territory under adverse meteorological conditions [12].

Each monitoring post is equipped with an automatic dust analyzer (for example, the DustTrak TSI-8533 dust analyzer), a digital wind speed measurement sensor (for example, WS 100) and a digital wind direction measurement sensor (for example, WD 100). Any other sensors similar in characteristics and determined parameters may be used for the equipment of the monitoring post. All devices are powered with 220 V.

The concentration of inorganic dust in the atmospheric air, wind speed and direction are updated every 20 seconds and transmitted to the central management unit as a digital signal, which eliminates the possibility of interference.

As a communication channel, it is supposed to use a channel for transmitting digital data of GSM 1800/900. This type of communication is one of the most reliable types of digital communication, ensuring high quality of the signal on the territory covered by the GSM operator. The GSM communication channel does not require significant capital expenditures, since the data channel requires only the installation of GSM signal transmitters at each monitoring station and a GSM signal-receiving sensor on the central management unit, and has relatively low operating costs. In addition, during the operation of the data channel via GSM, highly qualified specialists are not required to maintain equipment that ensures uninterrupted operation of the GSM communication channel, since the signal transmissions are carried out by repeaters of mobile operators, whose employees independently install and service their equipment. Thus, the use of a GSM communication channel eliminates the need to deploy your network of repeaters [15,16].

Any other type of communication can be used to data transfer, such as Wi-Fi, GPS, radio and others if it is impossible to use a GSM connection.

The central management unit controls the operation of the automated system of industrial environmental monitoring, including:

- a survey of sensors monitoring the quality of the surface atmosphere and meteorological parameters;
- primary processing of digital data and accumulation of measurement results on a single information resource;
- comparison of the obtained concentrations of inorganic dust with the maximum permissible concentration and the calculation of contrast ratios;
- calculation of the total dispersion of inorganic dust tailings with a particle size of less than 10 microns for various meteorological parameters;
- identification of regular occurrences of migration of inorganic dust and the development of a forecast of the state of the surface layer of the atmosphere in the residential area of the city of Apatity;
- identification of areas on the territory of the ANOF-2 tailing dump with the greatest potential danger of forming sources of intense dust emission under various meteorological conditions, taking into account the natural and technical security of the production facility;

- ensuring the dialogue between the operator and the industrial environmental monitoring system;
- change the mode of operation of the automated industrial environmental monitoring system;
- generation of messages and displaying them on the screen in a tabular and graphical (in the form of a map) form, as well as transmission of these messages, via radio channel, if it is necessary [12].

The identification of zones with the greatest potential danger of forming sources of intense dust emission is carried out using a computer program, which in its essence implements the solution of the logical function "IF ... THEN ...". That is, if the concentration of inorganic dust exceeds the value of the maximum permissible concentration at one or several monitoring stations, the tailing areas from which emission of inorganic dust could occur under certain meteorological conditions are automatically highlighted on the screen of the central management unit. Graphic information displayed on the screen of the central management unit is also necessarily duplicated by an audible signal, and an information message that contains the approximate area of the dusting territory and recommendations for its elimination, as well as a forecast of the state of the surface atmosphere in the residential area of the city of Apatity [17]. The message can be transmitted over radio channels if it is necessary.

A GIS software product, for example MapInfo Professional, ESRI ArcGis or Golden Software Surfer, carries out the processing of digital information and its conversion into graphic form automatically. The construction of the algorithm implemented by the automated system of industrial environmental monitoring is developed by the author of research and made up as a computer program [18,19]. It is set to the computer of central management unit as a basic function that the computer performs periodically as new digital data is received from atmospheric air monitoring stations.

The structure of the automated system of industrial environmental monitoring is presented in Figure 2.

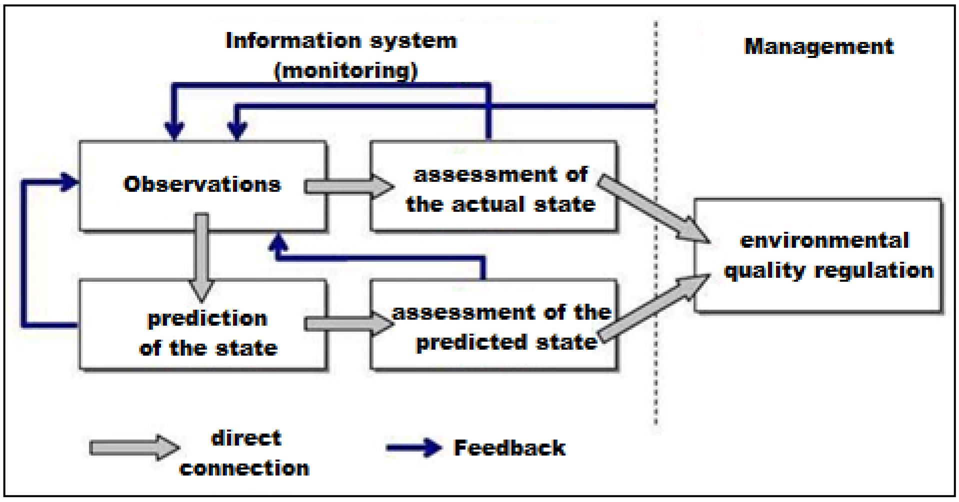

Figure 2. Structure of the automated system of industrial environmental monitoring

The information-measuring unit is a set of sources of information about the state of the surface layer of the atmosphere, the data from which are transferred to the source data processing unit via a GSM communication channel. The main sources of information are the network of automatic stationary stations for monitoring atmospheric air and stations for monitoring atmospheric air of the State Institution “Murmansk UGMS”. In addition to the monitoring data, the information-measuring unit provides access to electronic databases of maximum permissible concentrations, archives of data of long-term observations of the quality of the surface atmosphere in the region and cartographic base of the ANOF-2 tailing dump. A mobile laboratory for monitoring the quality of the surface atmosphere can also be introduced into the automated system of industrial environmental monitoring if it is necessary or if there is insufficient data from stationary monitoring stations of atmospheric air [12].

The raw data processing unit includes a single information resource that receives, preprocesses and accumulates digital data of the industrial environmental monitoring system, data of atmospheric air monitoring stations “Murmansk UGMS” and standards for maximum permissible concentrations of the pollutants being analyzed. All data is archived and stored on the server for the required period.

The processing unit also includes an information resource that receives and stores cartographic bases. Periodic updating of the cartographic base is required because the height of the alluvial dam of an anthropogenic array increases proportionally with the accumulation of enrichment waste, which leads to a change in the area of the alluvial beaches of the tailing dump. These changes must be taken into account when organizing a system of industrial environmental monitoring in the area of anthropogenic arrays impact [20].

A block of mathematical, statistical and analytical calculations is a powerful personal computer, on the basis of which the parameters characterizing the quality of atmospheric air, the identification of environmental regular occurrences and the prediction of the state of the surface atmosphere based on the calculated parameters, as well as the visualization of the established regular occurrences are made. All operations are carried out automatically using the software package for mathematical calculations (MathLab, MathCad), statistical calculations (Statistica) and for visualizing production environmental monitoring data and established patterns (MapInfo, ArcGis, Surfer). Software products with similar functionality can be interchanged, for example, one of the listed applications in this category or any other software product with similar functionality can be used as a software application for data visualization [17, 19].

The central management unit is the head center of the entire system of industrial environmental monitoring. It is a separate building located on the territory of the land allotment of the ANOF-2 tailing dump. It contains all the blocks of the automated system of industrial environmental monitoring except for the information-measuring unit, which components are situated on the territory of the considered anthropogenic array. In addition, the operator’s workplace is located in the central control center, ensuring uninterrupted operation of the entire system of industrial environmental monitoring. The operator of the central management unit can make certain management decisions and send commands via the radio link on the need to eliminate promptly the sources of intense dust emission based on the received information [12].

4. Conclusion

The automated system of industrial environmental monitoring is a modern and effective means of continuous monitoring of the quality of the surface atmosphere in the territory of intensive technogenesis. The introduction of an automated system of industrial environmental monitoring on the territory of existing anthropogenic arrays will allow obtaining timely and reliable information about the state of the surface layer of atmospheric air in the area of their impact. This information will allow a timely response to changes in the environmental situation and the rapid elimination of sources of intense dust emission. Thus, it becomes possible to manage the quality of atmospheric air in the area of impact of anthropogenic arrays and in the territory of nearby residential areas.

Acknowledgements

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