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Research Article

ECOLOGICAL ASSESSMENT OF THE CURRENT STATE OF ENVIRONMENTAL COMPONENTS ON THE TERRITORY OF THE IMPACT OF CEMENT PRODUCTION INDUSTRY

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ABSTRACT

The monitoring of the environmental components condition, exposed to the influence of the cement production enterprises, was the aim of the conducted research. One of the largest cement production factories in Russia, where the territory of negative impact has a total area of over 300 square kilometers, was the object of the study. The observations of the dust content in atmospheric air, as well as the determination of degradation degree of vegetation in the area of influence of the considered production facility were conducted. Chemical and granulometric composition of the cement dust, which is emitted in atmospheric air, were identified in the laboratory. Mapping model, which indicates the complex ecological welfare of the territory, exposed to the cement production industry, was compiled by the authors on the basis of the data, obtained in conducted research. The mapping model takes into account both the content of dust in near-ground atmosphere, and the extent of its deposition to soil, vegetation and surface water bodies.

Keywords: cement production industry, cement dust, environment, pollution, degradation of vegetation, NDVI index, deposition of dust.

INTRODUCTION

The current pace of growth of the urban population compels humanity to expand the territories of cities, create the industrial agglomerations and build the new buildings to ensure the comfortable existence of people. It leads to a rapid increase in the demand for construction materials, whereas increased demand leads to increased supply. Thus, currently there is a trend of increasing the volumes of production of building materials in Russia and worldwide. In turn, it increases the negative impact on the environment exerted by the enterprises engaged in the production of building materials [Strizhenok et al. 2016].

To date, the extraction and production of building materials accounts for a large sector in the Russian economy. The high price of transporting raw materials and finished products, as well as the need for a large number of workers are increasingly forcing industrial enterprises producing construction materials to place its facilities within settlements or in close proximity to them. Under these conditions, environmental control of emissions discharges and waste disposal is especially important; however, purification of wastewater, exhaust dust and gas emissions should be carried out at a high technological level [Industrial production in Russia 2016].

All enterprises producing construction materials, regardless of production technology and their specificity, release suspended solids and gases into the atmosphere, discharge polluted waste waters in natural water bodies, as well as allocate significant area for the storage of waste products. These processes lead to the formation of pollution in surface water, soil and atmospheric air. The area of polluted territories can reach tens and hundreds of square kilometers and extend far beyond the boundaries of the sanitary protection zone of industrial enterprises. The result of this intensive man-caused influence is the violation and modification of natural landscapes, decreasing soil fertility, deterioration of sanitary-hygienic indicators of the human habitat and, as a consequence, health indicators: decreased life expectancy, increased morbidity and mortality, increased risk of congenital abnormalities [Soussia 2015.].

Traditionally, one of the most common and the most environmentally hazardous industries in the branch of building materials production is the cement production industry. In Russia alone, the enterprises of cement industry annually emit over 27 million tons of inorganic dust into the environment. They account for 8% of all industrial emissions of suspended solids and about 5% of all gaseous emissions in Russia and in the world [State report 2015].

Cement dust emitted into the atmosphere poses a great threat to people, as it contains about 80 percent of suspended particles, the fineness of which does not exceed 10 microns. That is why the cement dust infiltrates into the respiratory system deep and is able to stay there for a long time, thereby causing acute bronchitis and, in rare cases, pneumoconiosis. In addition, cement dust has an irritant effect on the skin and a fibrogenic effect on lung tissue. Irritation, caused by alkaline medium of cement dust, is often accompanied by pathological changes of the respiratory tract [Health care in Russia 2015].

In addition, cement dust can have a negative impact on all components of the natural environment, and it is particularly acutely affects the biosphere. The degradation of the vegetation cover occurs as a result of atmospheric air pollution with cement dust. It is formed from direct deposition of aerosol and dust on vegetation and root uptake of the metals accumulated in the soil for extended periods of time of receipt of contamination of the atmosphere by dry gravitational deposition or washout of their precipitation [Mehraj et al. 2013].

At present, purification of the cement industry emissions and air quality monitoring on the territory of the impact of these enterprises in Russia are often carried out to an insufficient degree. As for contamination of soil and vegetation, in most cases, there is almost no control of the soil cover condition on the areas exposed to the influence of large cement production plants. In principle, the ratio of pollution for many pollutants in the soil is not fixed. For this reason, it is difficult to determine the level of pollution characterizing environmental components and to control the emissions which lead to pollution [Korobova et al. 2016].

MATERIALS AND METHODS

The main methods of research involved: system analysis of fundamental scientific works of Russian and foreign scientists on this subject; environmental monitoring of atmospheric air and vegetation cover in the form of field observations; experimental and analytical works in the laboratory with a using of modern scientific instrument base; methods of mathematical statistics, cartographic modeling and definition of the state of natural complexes affected by the anthropogenic load of the enterprises of cement industry based on the study of satellite imagery.

Particle size analysis of the cement dust was carried out in accordance with the international standard ISO 13320–1:1999 "Particle size analysis. Laser diffraction methods" [ISO 13320–1:1999]. Environmental monitoring of atmospheric air was conducted in line with GOST 17.2.3.01–86 "Nature protection. Atmosphere. Air quality control regulations for populated areas" [GOST 17.2.3.01–86].

The main method for determining the cement dust concentrations in the atmospheric air included laser nephelometry, which is used in the dust analyzers manufactured by TSI Company [Dust analyzer DustTrak 2017]. The methods of chemical analysis of dust samples were x-ray fluorescence and atomic absorption. It allowed to establish their qualitative and quantitative composition. NDVI index, which was calculated using satellite images of MODIS with a spatial resolution of 250 meters per pixel was used for determining the degree of vegetation degradation .

Cluster analysis and methods of cartographic modeling were used for the identification of areas, where the most intense impact of a cement industry on the natural environment is observed. Maximum inhibition and degradation of vegetation is observed on these territories. The data used for cluster analysis and cartographic modeling has been extracted by the authors during field observations and laboratory experiments.

The whole scientific instrumental base for carrying out field surveys, analysis of collected soil samples in laboratory, mathematical processing of the obtained results and cartographic modeling were provided by the Laboratory of Environmental Monitoring of the Saint-Petersburg Mining University [Scientific instrument base 2017].

RESULTS AND DISCUSSION

Experimental research was carried out on the example of one of the largest cement factories in Russia, located in the South-East of the European part of Russia. The considered industrial object started operation in the mid 1970-ies and the production capacity today exceeds 2.5 million tons of cement per year.

The considered cement enterprise was selected as the experimental platform because it is located 1 km North-West of the city of Novoulyanovsk with a population of about 15 thousand people. In addition, mild continental climate and low coefficient of atmospheric stratification (140) increase the range of the cement dust migration, which in turn contributes to the intensification of air pollution and degradation of the vegetation cover on the territory of the considered industrial factory, including the areas located in the immediate vicinity of the settlement.

The analysis of the archival production facility materials showed that the plant generates more than 50 thousand tons of inorganic dust per year. The efficiency of dust emissions treatment in electrostatic precipitator, installed on the enterprise, is about 95%; hence, it can be argued that the enterprise emits about 2.5 thousand tons of cement dust in the atmospheric air every year [Voronova et al. 2015].

The analysis of the chemical composition of the cement dust, carried out in the laboratory, showed that its composition includes: CaO – 66%, SiO_2 – 21%, Al_2O_3 – 6%, Fe_2O_3 – 3% and MgO – 3%. This dust composition is similar to natural stone; therefore. its impact on human health is considered harmful and can cause acute bronchitis and in rare cases, pneumoconiosis. However, this dust has no toxic effects on the human body.

The analysis of granulometric composition, carried out in the laboratory, showed that the cement dust, emitted in atmospheric air by the cement facility, contains more than 90% of particles smaller than 10 microns. The graph depicting the ratio of particle size and their content in cement dust is presented in Figure 1. The analysis of granulometric composition was performed using Horiba LA-950 laser diffraction particle size analyzer.

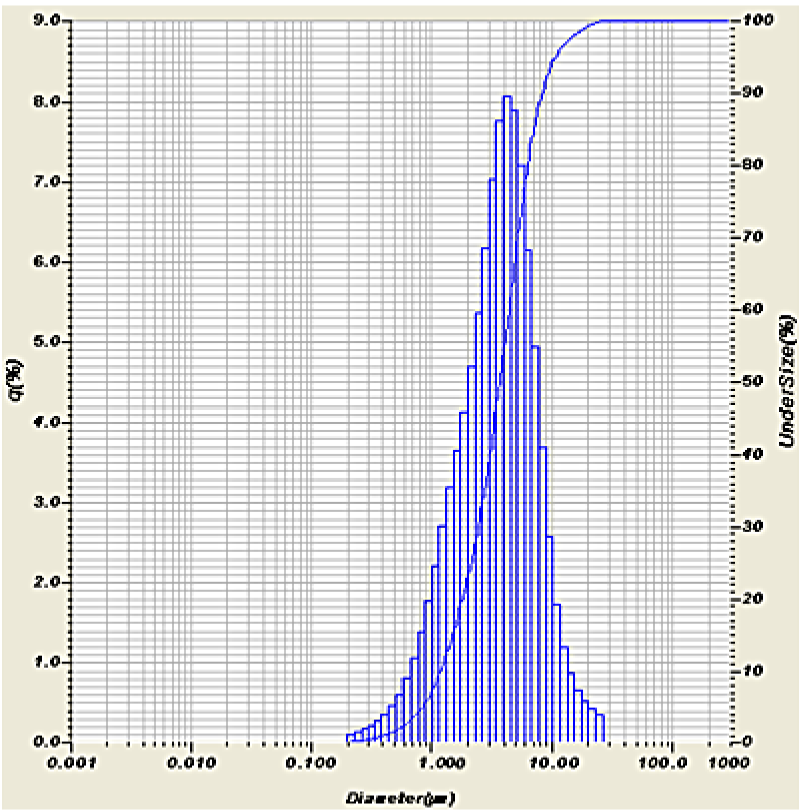

Figure 1. The graph depicting the ratio of particle size and their content in cement dust

It is known that – assuming the same meteorological parameters –the specific surface increases whereas the speed of deposition is reduced as the particle diameter increases, which leads to a greater intensity of scattering and the distance of migration of particles in near-ground atmosphere. Moreover, as the size of dust particles is being reduced, their dynamics is becoming increasingly characteristic for the dynamics of gases, that is, they are practically not exposed to dry gravitational settling and washout by atmospheric precipitation, which increases the duration of their residence in the near-ground atmosphere. Thus, in a stationary dispersion, medium particles of cement dust with a size of from 10 to 0.25 microns are deposited with a constant low speed that characterizes their long residence in the ground atmosphere in dry weather, and intensive deposition in soil in the presence of precipitation [Masloboev 2014].

Monitoring the surface atmosphere, carried out on the territory affected by the considered production enterprise, showed that at a wind speed of 3–4 m/s and humidity below 70%, the dust content of the ground atmosphere on the territory of residential development exceeds the ratio by the factor of 3–5, determined for inorganic dust with SiO_2 content from 20 to 70% in populated areas. At a wind speed of 7–8 m/s and humidity less than 70%, the concentration of inorganic, dust exceeds the norm by 1.5–2 times, at wind speeds above 8 m/s observed only in 10–15% of cases) the concentration of cement dust on the territory of the settlement is within the set standard. At humidity greater than 80%, the concentration of cement dust on the territory of the settlement is within the norm, as with this humidity the process of gravitational deposition of inorganic dust from air into surface water bodies and soil and vegetation cover is intensified.

The atmospheric deposition of cement dust during a long-term activity of the plant led to the formation of the large territory of soil pollution in a radius of 10–15 kilometers from the production facility with a total area of over 300 square kilometers. The result of this intensive man-caused influence is the removal of large areas of potentially fertile land from agricultural use, degradation of surface soil and vegetation, pollution of surface water bodies. Cement dust is not toxic, so at this stage, the process of self-recovery in contaminated soil can still progress, which is possible under the condition minimizing the technogenic loading on them. However, it is currently impossible to allocate this area for agricultural use [Strizhenok A.V. 2015].

In order to determine the degree of vegetation suppression on the territory affected by the considered production plant, the NDVI index (Normalized Difference Vegetation Index) was calculated using software and satellite images of MODIS with a spatial resolution of 250 meters per pixel. NDVI index is a simple quantitative indicator of photosynthetic active biomass. The NDVI is defined as: NDVI=(NIR-RED)/(NIR+RED), where NIR is the reflection in the near infrared region of the spectrum, RED is the reflection in the red region of the spectrum.

According to this formula, the density of vegetation (NDVI) at a certain point of the image is equal to the difference of the intensities of the reflected light in the red and infrared range, divided by the sum of their intensities [NDVI index 2017].

A mapping model of the level of degradation of natural environment components (Figure 2), graphically reflecting the environmental situation in the research area, was constructed as a result of field and experimental observations by the authors. The resulting mapping model is based on two main parameters: 1 – average concentration of cement dust in near-ground atmosphere during a calendar year, taking into account the wind speed and the atmospheric moisture content; 2 – the level of vegetation degradation in the area.

The map of the ecological welfare of the region, affected by the enterprise of the cement production (Figure 2), reflects the environmental well-being in the territory affected by the cement industry plants on a scale from 1 (the territory is not exposed to the production facility) to 5 (the territory is greatly exposed to the production facility and it is practically unsuitable for living).

CONCLUSION

1. The production of building materials is a developing and promising branch of industry which, like any other production, will have a significant adverse impact on all environmental components if no sufficient environmental and economic regulation is introduced. It may have a large negative impact on social welfare of the population living on this territory.
2. The conducted scientific research shows that the enterprises of the cement industry pose a significant ecological threat, and such industry can lead to extremely negative economic

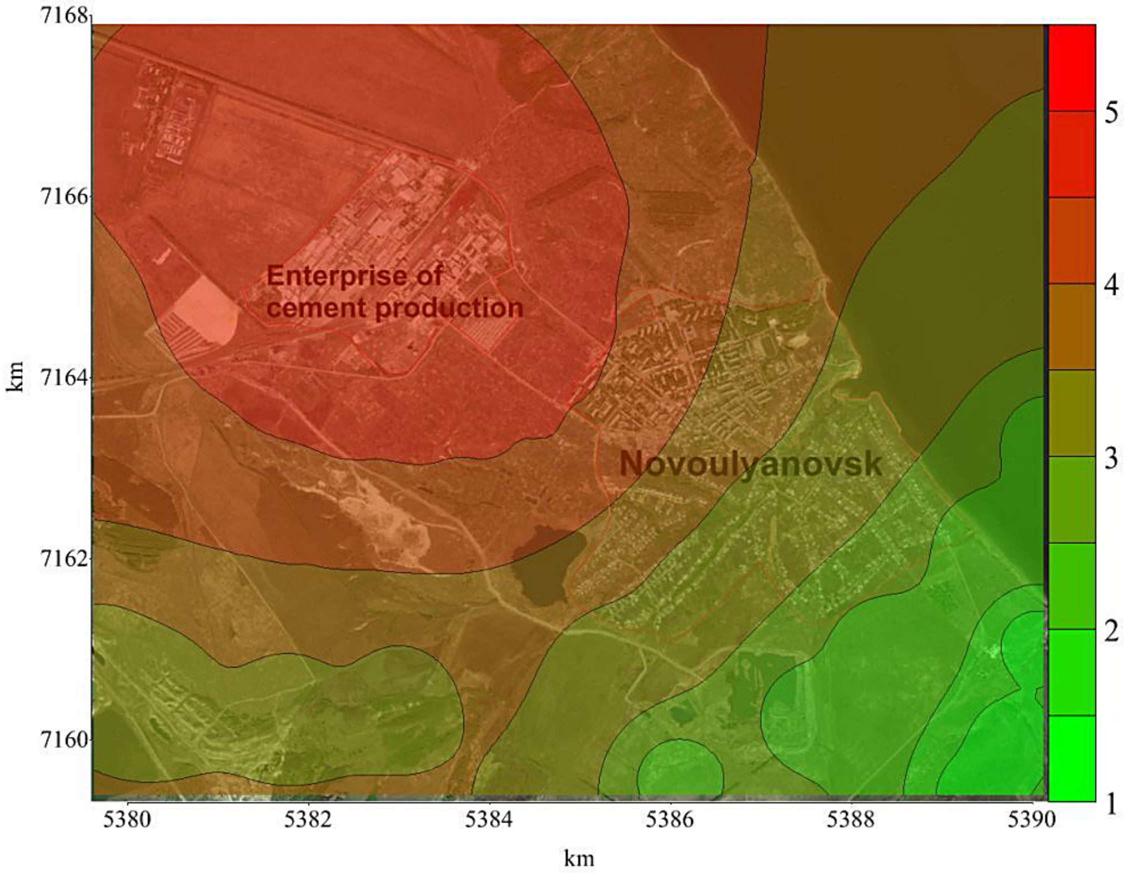

Figure 2. The map of the ecological welfare of the region, affected by the enterprise of the cement production

and social impacts on a territory of hundreds of square kilometers without its sufficient environmental assurance.

3. The authors proposed a comprehensive evaluation system of ecological well-being of the territory exposed to the adverse effects of the cement industry, based on the assessment of the level of air pollution and level of vegetation degradation in the framework of the research. The level of vegetation degradation indirectly reflects the intensity of the gravitational deposition of cement dust from the atmosphere.
4. Fundamental scientific novelty of the study is a mapping model that reflects the ecological welfare of the territory, exposed to the enterprises of cement production. This map better reflects the level of ecological well-being, as it considers not only the content of cement dust in atmospheric air, but the intensity of her deposition on water bodies, soil and vegetation cover.
5. Such map can be the basis for further research in the field of formation of operational system of production ecological monitoring of pollution of atmospheric air, as well as in the field of modernization of dust and gas cleaning equipment in the cement industry.

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