Social and ecological problems of a small town with a developed mining industry

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Abstract. The article presents the results of a study of the social and environmental problems of a small town with a developed mining industry. The authors have tested the methodology for assessing social and ecological tension for the city of Sibay in the Republic of Bashkortostan based on the approaches by I.A. Sosunov for the regions of Russia. The key indicators of the analysis were the data of official information on the socio-economic and ecological state, a sociological survey and a comprehensive assessment of the state of the environment. As a result, the index of social and ecological tension of the city was calculated in the context of settlements: Gorny (3.7) - Yuzhny (3.2) - city center (2.7) - Zoloto (2.6) - Vostochny (2.4) - Dom Rybaka (2.3) - Arkaim (1.6). The use of the category of social and environmental tension in the proposed interpretation allows for a comprehensive analysis of the urbanized territories of the mining region, which determine its environmental safety and sustainable development, their ranking, and also development of a set of economically justified measures to be included in the programs of the strategic development of the region.

1 Introduction

A modern city is an integrated territorial and socio-economic system, which consists of economic, cultural, social, and environmental factors. An imbalance in one of them can cause irreversible consequences and lead to the destruction of the system as a whole. The stress in the ecological situation directly negatively affects the state of life of the townspeople: the rates of morbidity and mortality of the urban population increase, the psycho-emotional and social state is disturbed. The natural and climatic conditions of the region, industrial focus, building features and the degree of landscaping have a significant impact on the socio-ecological situation in cities. A comprehensive analysis of these factors will make it possible to develop effective mechanisms for optimizing urban settlements and improve their condition [1]. Cities with a developed mining industry are

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characterized by an increased anthropogenic impact on the natural environment, which causes its change. As a result of production activities, the natural balance is disturbed, especially in open-pit mining zones, where quarries, dumps, mines, and processing plants are formed [2]. Quarries are a set of excavations on the surface of the earth, formed by a person during the open mineral extraction. After the depletion of valuable deposits, large areas become desolate. The open pit mine is flooded with water, and very often point underground mining is carried out. The stacked multi-ton dumps of rocks of different colors and sizes resemble a "lunar landscape". Some quarries get a "second life" over time: they acquire the status of attractions, function as a mining museum, sometimes become the site of a unique green landscape or botanical garden, and sometimes can cause significant environmental problems.

The southeast of the Republic of Bashkortostan, where mining has been carried out for several centuries, has many active and developed open pits, including the Sibay copper ore open pit. The mine, unique in its scale, is one of the world leaders [3]. The depth of the open-pit mine is over 500 meters, the diameter is over 2000 meters.

According to historical data, in 1913, large copper and gold processing plants operated near the deposit, but during the Civil War, exploration mines and factories were almost completely destroyed. The city of Sibay was founded on the site of the village of miners (Fig. 1, 2).

Fig. 1. A monument at the entrance to Sibay against the background of dumps

Fig. 2. The Sibay open-pit mine

Currently, Sibay is a large settlement in the Republic of Bashkortostan, which is the cultural, educational, and industrial center of the Trans-Ural zone [4]. The city has a total of more than 60 thousand inhabitants, living, in addition to the city center, in the villages (microdistricts) of Zoloto, Arkaim, Yuzhny, Gorny, Dom Rybaka, and Vostochny.

Since 1948, the city had the largest mining enterprise operating in the Soviet Union - the Bashkir Copper and Sulfur Industrial Complex (BCSIC) with an open-pit mine, a processing plant, etc. By 2004, the extraction of ore from the Sibay open-pit mine stopped, the BCSIC became a branch of the Uchalinskiy ore mining and processing plant. A new Kamagan open-pit mine was opened, which then quickly depleted. Since 2007, ore mining has been mainly carried out by the mine (underground) method.

Since October 2018, the environmental situation in the city and adjacent territories has deteriorated significantly, as the Sibay open-pit mine began to smolder and emit sulfur dioxide. The main volume of sulfur dioxide began to accumulate at the bottom of the pit bowl and, when the weather changed, spread throughout the city in the form of smog with a strong burning smell.

The tense environmental situation in the city is also caused by the presence of the Sibay Processing Plant (SPP), a tailing dump, a large thermal power plant (Zauralskaya CHP) and a drilling reagent plant (Fig. 3-5).

Environmental problems are directly related to social stability, public health, and demography, labor activity, migration, etc. In this regard, it is relevant to conduct a comprehensive assessment of the socio-ecological situation in the mining region.

Fig. 3. The city shrouded in smog

Fig. 4. Drains around the SPP used tailing dump

Fig. 5. Zauralskaya CHP

The objective of the research, the results of which are presented in this article, was to study the most significant factors characterizing the ecological and economic burden of the city with mining production.

2 Materials and Methods

To collect primary sociological information about the opinion of the residents of the city of Sibay on the state, problems, and priorities of the city's development, an individual questionnaire survey of the population was conducted from July 15 to September 15, 2019. The survey involved 429 people. The selection of respondents was randomized. Sex, age, type of housing were used as quota indicators. In addition to the above, the survey recorded several more socio-demographic indicators: education, main occupation, number the family members, the level of well-being of the city, including its self-estimate. The scale of public concern is given according to V.A. Prokhod [5].

The pollution of facilities as well as the level of excess of permissible concentrations of sulfur dioxide in the atmospheric air of Sibay from January to March 2019 was analyzed according to the data of the annual reports of the Territorial Committees of the Ministry of Ecology of the Republic of Bashkortostan. Averaged data from three laboratories were used: the laboratory of the supply service civil protection measures, the laboratory of the state analytical control department, and a mobile laboratory of the Sibay branch of the Uchaly mining and processing plant, available in the open media. The assessment of the chemical composition of snow as an indicator of air pollution in January-February 2019 was carried out in accordance with the requirements of generally accepted regulatory and methodological documents. The concentration of sulfates was measured by a photometric method (KFK-2 photometer); to determine the pH, a HI 2211 HANNA pH meter was used. The study of the state of water quality in the city rivers was carried out in compliance with the requirements of GOST R 51592-2000, GOST 17.1.5.04-81. For a comprehensive assessment of the quality of surface water and drinking water, the corresponding pollution indices (WPI) were calculated, considering the most common pollutants [6]. The selection, storage, and transportation of soil samples taken for HM analysis were carried out in accordance with GOST 17.4.4.02-84. The collected material of soil and liquid samples was analyzed for the content of heavy metals (HM) by atomic absorption spectrophotometry (Contr AA spectrophotometer, Analytik Jena) in an accredited laboratory. The total pollution indicator (Zc) was calculated, which is widely used as an integral indicator reflecting the total contribution of ecotoxicants to the pollution of the corresponding natural objects [7, 8]. To assess the pollution of natural objects with heavy metals, he maximum permissible concentrations (MPC) factor, adopted in the Russian Federation, was used.

To identify the situation with green spaces in the city, their area was determined using a plan of functional zones, available in the public domain on the official website of the administration of the city district, and a situational plan of the city obtained on the basis of

data from Google Maps. The area of public green spaces was calculated per resident of the city according to GOST 28329-89 [9].

All generalized indicators were evaluated using five-point scales [10]. The final indicator was the index of socio-ecological tension (IET), which was determined by dividing the sum of assessment points for all indicators under consideration by their number according to the formula:

$$I_{ET} = (P_{pc} + P_{sn} + P_w + P_{dw} + Pp_{gross} + Pp_{mob.} + P_{gs})/7, \quad (1)$$

Where: P_{pc} - public concern; P_{sn} is the total indicator of snow cover pollution; P_w - total indicator of surface water pollution; P_{dw} - total indicator of drinking water pollution; P_{so} is the total indicator of soil pollution with HM (Pp_{gross}- values of gross forms; $Pp_{mob.}$- values of mobile forms); P_{gs} - availability of green spaces.

3 Results and Discussion

The industrial infrastructure of Sibay includes more than 10 large and medium-sized industrial enterprises. As of 01.01.2018, according to the data of Bashstat, the territory of the city had 796 units of economic entities registered. The changes in industrial production in the urban district of the city is quite stable in general.

Sibay has an actively developing construction complex and a well-developed transport infrastructure. There is a railway station, an airport, and an extensive network of asphalt roads. The city is provided with resources that allow it to form a diversified economy, where, along with traditional industrial sectors, the service sector, small and medium-sized businesses should actively develop. Free energy capacities in Sibay are: - for electricity - 12 MW, - for water supply - 7.0 thousand m^3/day, - for gas supply - more than 150 million m^3/year.

The key demographic indicators in the city tend to decrease. In 2019, the population of the city amounted to 98.4% of the level of 2015; over 5 years there was a decrease equal to 1.6%. There is a tendency towards a decrease in the mortality rate of the working-age population from 671.7 per 100,000 population to 571.1. The leaders in the general mortality of the population of Sibay are cardiovascular diseases - 42.8%, the II place - tumors - 11.6%, the III place - external causes - 8.5%. The issue of reducing infant mortality remains topical. In the republic, this indicator is 6.0 per 1000 live births, while in Sibay during 2015-2018 it remains high (10.0, 9.5, and 8.7, respectively). The main causes of infant mortality are certain perinatal conditions, congenital abnormalities, respiratory and circulation diseases, trauma, infectious diseases, etc. Teregulova Z.S. et al. [11] also confirm the peculiarities of diseases of the population in the mining region.

One of the reasons for the decline in the city's population, which was revealed during a sociological survey, is migration due to environmental problems associated with man-made accidents. As of 01.01.2018, according to Bashstat, the migration loss of the population was 625 people - the number of incomers was 1943 people, the number of those who left was 2568 people. Thus, more than a third of the respondents are sure that the activities of mining facilities and man-made accidents, in particular the smoldering of pyrite in the quarry, are a significant reason for the deterioration of public health.

The sociological survey revealed a high activity of the population in relation to the environmental problems of the city. More than 80% of citizens consume crops grown on the territory of the city and use drinking water from the central water supply system. At the same time, 48% of respondents reported health problems (mainly bronchitis and allergies), 52% - their absence. 63% of the respondents believe their children have excellent and good health, 21% - poor.

According to the survey, the population's concern about the ecological situation in Sibay is quite different. The people living in the area 500m from the Sibay quarry in Gorny and Zoloto are highly concerned. The residents of the Yuzhny settlement, located 1000 m from the quarry, the city center, influenced by motor transport and the drilling reagents plant, as well as the Vostochny settlement, on the territory of which the Zauralskaya CHP and the Sibay enrichment plant operate, also have strong concerns.

As a rule, industrial enterprises are powerful sources of harmful atmospheric emissions. Daily intake of solid and gaseous substances in large quantities can have a toxic effect on a person and contribute to the deterioration of his health. As a result, various diseases (bronchitis, asthma, nausea), headaches and a feeling of weakness develop, and the ability to work decreases. The concentration of sulfur dioxide in the atmospheric air of Sibay during the crisis of sulfur smoldering exceeded in some micro-districts of the city the standard levels by 50-60 times. The highest concentrations were noted near the Sibay quarry. Through the efforts of the City Administration, restoration work carried out by the Sibay branch of the Uchalinskiy ore mining and processing plant extinguished the centers of smoldering. By the summer of 2019, the state of atmospheric air in the city has returned to normal.

Assessment of the chemical composition of snow as an air pollution indicator is also a very important indicator. The relevance of this assessment has especially increased due to the fact that our studies covered the winter period of the end of 2018 - the beginning of 2019, when an emergency ecological situation occurred in the city of Sibay caused by the processes of self-oxidation and combustion of pyrite deposits in the quarry. The presence of heavy metals (iron, manganese, copper and zinc) and sulfates was revealed in the composition of snow in the territories of the city adjacent to the quarry. The study of the degree of pollution according to the scale of the quality of snow cover (Zc) showed an acceptable level in all micro-districts. However, relatively high rates were noted in the Zoloto, Gorny, and Yuzhny settlements located close to the fire.

The river network of the city is also the main depository medium for various components of ecosystems. Many substances are deposited in bottom sediments, some migrate over long distances [12]. Discharge of treated domestic wastewater is carried out into the Karagayly river, the right tributary of the Khudolaz river. The Sibay branch of JSC Uchalinsky MPC discharges poorly treated wastewater from treatment facilities into this river as well. The Kamyshly-Uzyak river flows along the north-western side almost through the entire city. Examination of water quality in these rivers revealed high water pollution with heavy metals. In the Karagayly river, the excess of the maximum permissible concentrations for fishery purposes in terms of copper content was about 200 times, zinc - up to 1000 times, manganese - up to 400 times, iron - more than 30 times; in the Kamyshly-Uzyak river - copper - up to 44 times, and Zn - 13 times.

The quality tests of drinking water in Sibay showed high concentrations of iron, exceeding permissible concentrations [13]. This is most likely due to its increased content in underground water sources, as well as to the state of the metal structures of the water supply network, some of which are deteriorated and subject to corrosion processes. In addition, some wells have high levels of water hardness and dry residue.

Calculation of water pollution indices revealed water pollution of rivers flowing through the city, up to “extremely dirty” (Yuzhny, Gorny, city center). At the same time, the quality of drinking water varies from “very clean” (Dom Rybaka and the central part of the city, where water was taken from the central water supply system) to “polluted” (Zoloto, Yuzhny, Gorny - water from wells).

Chemical analysis of urban soils showed their contamination with copper, zinc, and cadmium. Soils of industrial and residential areas are classified as "moderately hazardous", soils of industrial zones within 1 km from pollution sources - as "hazardous". In the context

of microdistricts, the soils of Gorny and the central part of the city belong to the "highly dangerous" category.

The analysis of the provision of the city's population with green spaces showed that Arkaim, the Vostochny micro-district, and the city center correspond to the recommended standards for the green area. The rest of the settlements require more areas of green spaces.

A comprehensive analysis of the results obtained showed that the socio-ecological burden of the settlements of the city of Sibay can be presented in the following descending order: Gorny (3.7) - Yuzhny (3.2) - city center (2.7) - Zoloto (2.6) - Vostochny (2.4) - Dom Rybaka (2.3) - Arkaim (1.6). The conducted studies can serve as a methodological basis for a comprehensive analysis of indicators for monitoring urbanized territories of a mining region, which determine its environmental safety and sustainable development, rank territories, and develop a set of environmentally and economically sound measures to include them in the city's strategic development programs.

4 Conclusion

By interfering with nature, man disrupts its normal course, which affects the state of the environment and public health. Therefore, it is highly important to take care of nature, to carry out work on the reclamation of quarries, tailings, landscaping of dumps and settlements. According to our research, the local flora suits best for this purposes, which is adapted to the extreme conditions of the steppe Trans-Urals and is able to provide maximum survival rate, reduce the destructive force of water and often repeated and dry winds that dry up the soil and carry away dust particles containing toxic elements. Measures have been proposed to reduce the toxicity of contaminated soils by applying organic fertilizers and natural zeolite, using only water from the central water supply system for food purposes. Recommendations have been developed for enterprises to prevent pollution of the soil cover, surface waters, etc.

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