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Research Article

Characteristics of environmental degradation in mining areas (A case study of the Southern Trans-Urals)

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Abstract

The areas affected by mining operations are characterized by extremely complex environmental changes that affect all components of the natural complexes. In several cases, radical negative changes (transformations) take place, which cause the formation of the habitat, characterized by changes in characteristics of all components of the natural environment, including geological structure, soil cover, surface and groundwater and atmospheric air, respectively, flora and fauna. This generally leads to a sharp deterioration of ecological conditions, including living conditions of living organisms and human habitation, causing stressful situations, inconveniences, as well as characteristic diseases due to the influence of factors of excessive pollution of components of the natural environment. As one of the objects of the study, the impact zone of mining enterprises within the town of Sibai and its surroundings in the Republic of Bashkortostan was chosen. It is typical for the assessment of occurring changes and other industrial centers and districts located within the vast strip of the Southern Urals. It has been revealed that the greatest damage is inflicted on ecosystems of small rivers, which is caused by both direct and indirect entry of pollutants into them as a result of dissolution, leaching and entry from rock dumps, emissions into the atmosphere, and settling on the surface of soil and snow cover; direct discharge of wastewater into them, etc. It is shown that with the lingering impact of the regional response to global climate change, environmental problems are exacerbated. This calls for urgent measures to restore favorable environmental conditions and address a wide range of economic and social problems.

Introduction

The regularities reflecting the changes that have occurred in the state of the environment have been identified based on a synthesis of materials obtained by us during a series of research works carried out in the late twentieth century and also in 2010 -2020. They covered the areas of location and activity of mining and processing plants, non-ferrous metal ore mining sites within a vast space stretching over the Southern Trans-Urals, including the impact zones of industrial enterprises in the cities of Karabash in the Chelyabinsk Region, Uchaly, Sibay, Buribay - in the Republic of Bashkortostan and Mednogorsk - in the Orenburg Region (Figure 1). A characteristic feature is that for each of the settlements shown in Figure 1 and their surroundings, approximately the same structural changes are observed. It is indicative that during the long-term exploitation of non-ferrous metal ore deposits and mining and processing plants, technogenic-disturbed and degraded territories have formed, including quarries, mines, rock dumps, wastewater accumulators, etc., which have similar specific physical, chemical and other impacts on the environment. Given the limited number of observations and analysis of changes in most of them, those sites for which full-scale studies are available are of great interest, making it possible to identify characteristic patterns reflecting changes in the quantitative and qualitative characteristics of the natural environment components. The characteristics of their impact on the general environmental conditions of the territories, as well as the morbidity of the population, are also indicative.

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Figure 1: Locations of mining and processing plants within the Southern Trans-Urals.

The structure and characteristics of the changes that have occurred are reflected in more detail in this article on the example of the zone of influence of enterprises located within the urban district of Sibai city. That, materials of comprehensive studies conducted in 2020 have been taken into account as the basis [1]. The materials obtained make it possible to assess the changes taking place in other areas of influence of the mining industry facilities and to substantiate the necessary environmental protection measures.

Materials and Methods

The validity and representativeness of the materials used are based on the analysis of extensive baseline information obtained in the course of a large number of studies conducted under the scientific leadership of Prof. A.M. Gareev over many decades. They included studies of the hydrological regime, water-resource indicators of water bodies, spatial and temporal variability of hydrometeorological conditions and climate, as well as characteristics and scales of formation of negative processes in the natural environment depending on the predominant impact of mining facilities.

Comprehensive geochemical studies to assess the state of the environment at several polymetallic, copper-pyrite, rare-metal and other deposits show that the most intensive pollution of the environment is associated with the following migration chains:

- Dust emissions from open-pit mining, pollute atmospheric air, forming contrasting and significant geochemical anomalies in soils;
- Deflation and scouring of tailings ponds forming intense dispersion fluxes in aquatic systems and relatively localized dispersion halos in soils;
- Run-off from underground mine workings and quarries, which form intense and extensive dispersion fluxes in aquatic systems;
- Effluents from enrichment plants after treatment plants which contaminate water systems;
- Dispersion of ore material during transportation, polluting soils;
- Organised and unorganized emissions to air from beneficiation processes;
- Natural geochemical anomalies - secondary dispersion halos in soils, dispersion fluxes in surface water courses, hydrogeochemical anomalies in groundwater, etc. [2-5].

In the course of the study of the main regularities reflecting the changes that have occurred within the base site – the zone of influence of industrial enterprises of Sibai city – field surveys and observations were carried out. They were accompanied by water and bottom sediment sampling from surface water bodies (Karagaily and Khudolaz rivers), soil samples in the watershed, as well as assessment of the degree of variability of species composition of hydrobionts (including ichthyofauna), indicators of degradation of plant communities, etc. The types and concentrations of pollutants directly affecting the environmental conditions in the watercourses in question, as well as natural and anthropogenic systems and their components, were determined under laboratory conditions for the components of the natural environment. At present, one of the additional tools widely used in assessing the state of the environment and predicting further changes is geoinformation analysis. The following geoinformation data were used to study the territory of Sibai Urban District: Landsat satellite images (date of survey 26.04.2020), Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global (date of survey 11.02.2000, resolution 30 m). Based on the application of information, reflecting locations of negatively influenced objects, indicators and level of pollution of environmental components, as well as generalization of statistical materials, characteristic features of changes in environmental conditions within particular territories were subsequently identified and population morbidity indicators were assessed. A schematic map of the study area is shown in Figure 2.

As can be seen from the mentioned figure, the territory adjacent to Sibai is characterized by an extreme density of polluted, littered and other disturbed areas, which is the consequence of prolonged extensive mining, without paying appropriate attention to solving environmental and social problems. The Sibai quarry and waste dumps are located in the southwestern part of the city, bordering residential settlements (Gorny and Zoloto settlements) to the north and west. The

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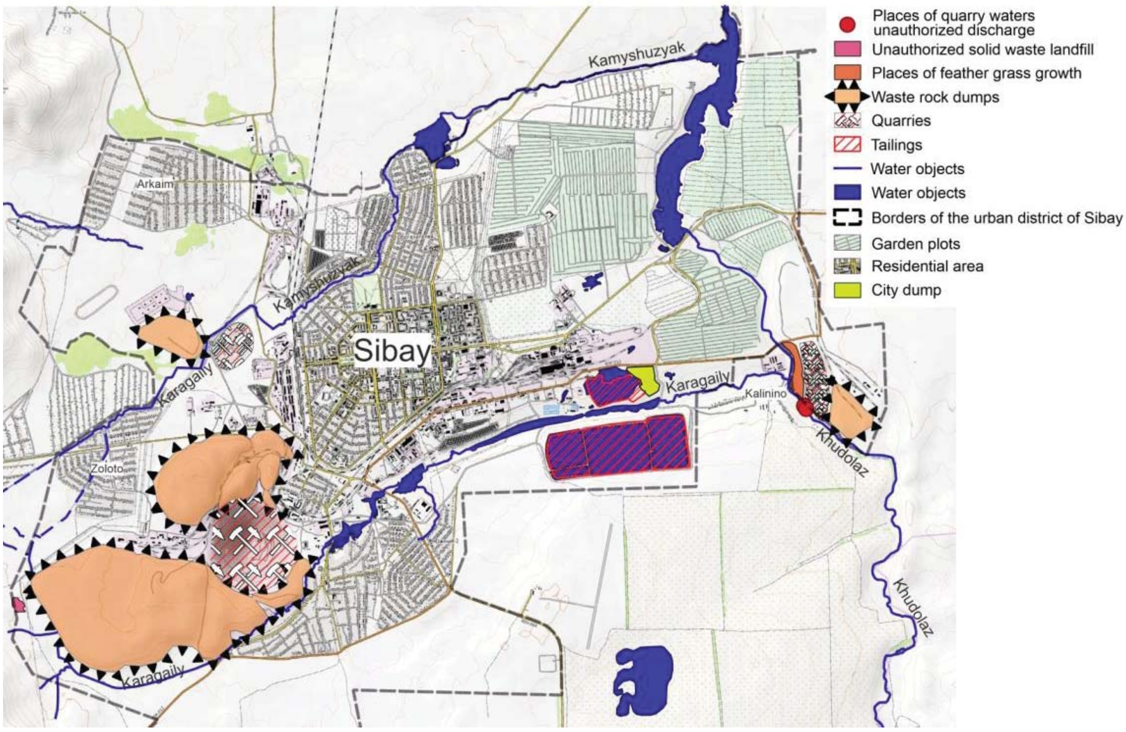

Figure 2: Schematic map of the study area.

dumps are composed of spilites, rhyolites, quartz rhyolites, tuffs and tufobreccias of spilites and quartz-rich rhyolites, chlorite-sericite-quartz, sericite-quartz and chlorite-quartz metasomatites, clays. The rocks contain impurities of sulfide minerals: pyrite, sphalerite, chalcopyrite, etc. Waste dumps are complex geochemical filters, including successively acting evaporative, cryogenic, redox, acid-alkaline and temperature geochemical barriers [3,4]. They are practically not isolated from water systems, which determines the entry of chemical elements into watercourses.

Underground water from the northern waste dumps at the Sibaysky mine until 2020 was pumped to the surface and discharged to the Karagaily River via a collector. To this day, the effluent from the southern dumps is also discharged untreated into the Karagaily River. Underground waters are highly mineralized - up to 515 g/l, pH 2.1-2.6, sulfate ion concentration reaches 29500 mg/l, copper content - from 330 to 645 mg/l, zinc - 718-890 mg/l, iron - 188-731 mg/l, magnesium - 190 mg/l, increased concentration of manganese, nickel, cobalt, cadmium, mercury, etc. [2,4]. Thus, rock dumps are a source of the formation of aggressive acidic waters containing high concentrations of chalcophile elements with high toxicity. Low volatility and low freezing temperatures cause their high mobility during all seasons. As a result of their influence, intensive, complex in composition and extended along the channel technogenic geochemical anomalies are formed. In the bottom sediments of the Khudolaz Karagaily and Kamysh-Uzyak rivers, flowing in a direct zone of influence of economic objects, the maintenance of heavy metals in tens and hundreds of times exceeds background concentration - Cu 20 - 125 MPC (75 - 500 backgrounds), Zn 30 - 59 MPC (100 - 200 backgrounds), As 50 - 90 MPC (18 - 60 backgrounds), Cd 4 - 30 MPC (40 - 300 backgrounds), Sb 4 MPC (20 backgrounds), Hq 2 - 3 MPC (25 backgrounds). Pb 1 - 3 MAC (3 - 10 background), Co 2 – 7 - background, Mo 2 - 4 background.

The highest pollution was found in the Karagaily river and Khudolaz river downstream the Karagaily river [1-4]. It was found that high values of concentrations of pollutants in drinking water were supplied to households in the village Kalinino, located in the southeastern part of the study area - a short distance from the old and new wastewater treatment plant and the city landfill.

In general, the scale of the negative impact of industrial enterprises and disturbed areas on the components of the natural environment and human health can be expressed in the form of accumulated environmental and economic damage over a multi-year period. Their parameters for many territories covered by mining activities in the Southern Trans-Urals have not been studied. Given the above, in the course of the study conducted in 2020, we paid much attention to the performance of calculations and estimations of accumulated damage from the destruction of soil invertebrates; damage caused to soils, natural vegetation, ichthyofauna, as well as damage caused by environmentally caused morbidity of Sibai population.

It is necessary to pay attention to the fact that at present there is no unified methodology for the evaluation of economic damage, caused by ecologically conditioned morbidity of the population. At the same time, it can be emphasized that the methodology of determining economic damage from environmental pollution can be represented by the following logical chain: emission (discharge) of a pollutant into the environment - change in the environment (increase in the

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concentration of pollutants) - natural damage - economic damage [6-17].

There are three instrumental methods for the assessment of natural damage:

- empirical relationships - it is based on analysis and statistical processing of empirical data about the influence of different factors on the recipient's condition;
- factor elimination - based on the selection of a control area and comparison of the recipient's condition in it with the contaminated area;
- combined - allows detailing the results of the factor elimination method using statistical processing of empirical data on the impact of individual factors on recipients.

Some authors combine the listed methods into direct counting methods and additionally distinguish the indirect method, which is based on the principle of transferring general regularities to a specific object and assumes the use of a system of normative indicators (for example, MACs). Exactly this type of method belongs to the Temporary Typical Methodology... [9] and the Methodology of Determination of the Prevented Environmental Damage [12].

In today's environmentally tense situation, to form an effective environmental policy it is necessary to have a comprehensive multilateral methodology for assessing the economic damage from the population morbidity, caused by environmental pollution, which will reflect both personal and public losses. Only then can a realistic understanding of the necessary costs for restoring health and planning measures of a socio-environmental nature be obtained. From this point of view, the approaches to damage assessment proposed by T. Anopchenko [18] and G. Denisov [19] are closest to the proposed ideal. A similar estimation of economic damage from the population morbidity caused by environmental pollution was developed and carried out for the subjects of the Russian Federation in the Privolzhsky federal district. As well the mentioned works, it takes into account both personal and public losses.

The empirical material in the course of this study was formed based on data on the general morbidity of the population, which allowed it to cover all its age groups. The difference of the proposed approach is that the personal expenses of the population were taken into account based on the share of health care expenses per capita and specifically, on the treatment of environmentally dependent diseases [20-22]. On the whole, the proposed approach to damage assessment is less detailed, but it does not require the collection of a large amount of data while maintaining the order of the damage value, which allows it to be used as an indicative indicator of the region's environmental policy.

Stooping to the methodology of calculation of the economic damage, caused by the ecologically conditioned morbidity of the population, we should note that it can consist of two components (groups): 1) damage to society as a whole; 2) personal damage to citizens.

The damage to society as a whole covers:

1. The state's expenditures in the system of compulsory health insurance for the treatment of the population.
2. The payment of sick pay.
3. The loss of a share of tax revenues to the budget due to reduced profits due to temporary and permanent disability of workers.
4. Loss of a share in the gross regional product (GRP).

Personal losses to citizens include:

1. The cost of preventive medicine.
2. The cost of medicines for the treatment of chronic and acute diseases.
3. Costs of emergency treatment (ambulance, intensive care).
4. Costs of inpatient treatment (nursing and outpatient services).
5. Cost of treatment at home.
6. Cost of rehabilitation.
7. Cost of sanatorium treatment.
8. Loss of well-being (e.g. suffering due to death or illness).
9. Property loss in earnings due to temporary incapacity for work.
10. Decrease in occupational level and loss of qualifications due to temporary incapacity for work.
11. The psychological discomfort caused by the loss of qualifications and professional qualifications.
12. Deterioration of psychological well-being caused by an unaesthetic visual environment.

Both these and other losses are equally important, so a full economic evaluation of the damage caused by public illness must include both public and personal losses to citizens. However, not all of the forms of damage represented can be objectively assessed. For example, there are no methodologies capable of providing an economic assessment of the damage caused by psychological discomfort. The personal damage in the majority of cases is estimated on expenses on out-patient and sanatorium treatment. Therefore, to obtain the closest to real data on the economic damage from environmentally caused morbidity promptly, the following variants of its estimation are proposed.

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Assessment of societal damage. Detailed data on the number of sick leave days taken or reductions in tax payments are difficult to find when making economic damage assessments. A more accessible and convenient indicator for damage assessment is the Gross Regional Product (GRP) per capita. Losses related to GRP will constitute the largest percentage of the real value of the damage, i.e. the data obtained allows us to determine the order of the damage.

We assessed the damage based on GRP per capita since the main damage to the economy of the RF subject is caused by the increase in person-days of disability (in this case we mean the underproduced GRP during the above-mentioned period). Knowing GRP per capita, as well as population morbidity, the average duration of illness and the share of cases of diseases caused by environmental factors, we can calculate the corresponding damage for the study area as a whole [14,23].

The calculation is carried out according to the formula (1):

$$Y_0 = \sum_{i=1} n_i * t * \frac{GRP_{\partial}}{365} \quad (1)$$

Where Y_o - social damage from the morbidity of the population from the *i-th* group of diseases, caused by environmental pollution, rub./year; n_i - number of people affected by an *i-th* group of diseases, caused by environmental pollution, people; t - average duration of disability, day/year; GRP_{∂} - gross regional product per capita, rub./person/year.

An important point in assessing the damage from the morbidity of the population caused by the negative impact of environmental factors is the determination of the percentage of those who fall ill from the specified cause. But it is difficult to determine the exact number of sick people, therefore, in this work, we used the method of control areas to determine the number of sick people.

Personal damage estimation. It is difficult to determine the cost to the population of treating individual diseases. An optimal statistical indicator that combines the cost of preventive medicine, the cost of medicines for chronic and acute diseases, the cost of emergency treatment (emergency care, intensive care), the cost of inpatient treatment (nursing care and outpatient services), the cost of home care, the cost of rehabilitation, the cost of sanatorium treatment are indicators of health care costs per capita, in our opinion. With this in mind, we used per capita expenditure and the percentage of health care expenditure.

However, not all types of healthcare expenditure are associated with environmentally-dependent morbidity. For example, there is currently no reliable evidence that dental prosthetics are an environmentally relevant disease. To exclude dental prosthetics costs in the calculations, we have calculated their share in the total expenditure on health services. The percentage for Ufa is 18.32%. We assumed that the same percentage of costs for dental prosthetics makes up the health care costs, so we excluded 18.32% going to this type of service in the calculations. The calculation was done using the following formula:

$$Y_1 = \sum n_i * \left(LR_d - \left(LR_d * 0.1832\right)\right) \quad (2)$$

Where: Y_1 - personal damage from the incidence of the population of the *i-th* group of diseases caused by environmental pollution, $/year; n_i - the number of people affected by the *i-th* group of diseases caused by environmental pollution, people; LR_d - the number of personal expenses per capita, $/year;

Based on the data from the statistical handbook Russian Health Care [24], the following items of citizens' expenditures on treatment have been highlighted:

1. Paid medical services;
2. Health resort services;
3. Expenses for purchase of medicines

Briefly dwelling on the review of methodological regulations for calculating cumulative damage by each of the studied components, it should be noted that calculation of the environmental damage caused to soil invertebrates as a result of the formation and functioning of open pits for copper ore mining, formation of waste rock dumps, is based on the Order of RF Ministry of Natural Resources from 28 April 2008 (№ 107). The said order approved the Methodology…[25], which contains provisions on the calculation of the amount of damage caused to wildlife listed in the Red Book of the Russian Federation, as well as other wildlife objects not related to the objects of hunting and fishing and their habitat. The damage is formed due to the destruction of soil invertebrates' habitats (soil cover of the territory) by establishing quarries, rock dumps, wastewater reservoirs, etc. on the originally sparsely disturbed territories. Their total area within the boundaries of the investigated territory was determined by GIS analysis of the map - scheme and classification of the raster image - Landsat - 8 space image, which is 11,782,520.8 m^2 or 11.783 km^2. Taking this into account, the value of ecological damage to soil invertebrates living within the boundaries of disturbed lands (Up) was determined according to the formula

$$U_p = F * Y, \quad (3)$$

Where F is - the total area of disturbed territories and Y is - the value of damage per unit of investigated territory (rub./m^2). The inflation rate in 2020 about 2008 (the year of the methodology approval) according to Rosstat's inflation calculator is 241,168%. Accordingly, the total damage figures have been recalculated taking into account this inflation rate.

Calculation of damage, caused to soils of the study area, was made based on the "Methodology for calculating the amount of damage, caused to soils as an object of environmental protection" [26]. According to it the calculation of damage caused to soils as a result of pollution with toxic ingredients was made by the formula 4:

$$USh_{zagr} = CXB * S * K_r * K_{ish} * T_x \quad (4)$$

Where: USh_{zagr} - the amount of damage (rub.); CXB - degree

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of chemical pollution, which is calculated following paragraph 6 of the mentioned methodology; S – an area of contaminated soil (m^2); K_r – index, reflecting the depth of chemical pollution (deterioration) of soil, which is calculated following paragraph 7 of the mentioned methodology; K_{ish} – index determined depending on the category of land and designated purpose where the contaminated plot is located (calculated following paragraph 8 of the mentioned methodology); T_x – tax for calculation of the amount of damage caused to soils as an object of environment. In the case of chemical pollution of soils, it is determined according to appendix 1 to the methodology (rub./m^2) [27].

ARS – the degree of chemical pollution is the ratio (C) of the actual content of the *i-th* chemical substance in the soil to the standard of environmental quality for soils is calculated by the following formula (5):

$$C = \sum_{i=1}^{n} \frac{X_i}{X_n} \quad (5)$$

Where: X_i is the actual content of the *i-th* chemical in the soil (mg/kg); X_n is the environmental quality standard for soils (mg/kg).

Standardized protocols for sampling plant diversity were used in assessing damage to plant communities. It was taken into account that the study area is characterized by the lasting impact of various economic activities on them. This should include, first of all, mainly unorganized pasturing, development of settlements, livestock complexes, road networks, etc. Further increase in the scale of anthropogenic load, formed as a result of the impact of mining facilities, occurred in already developed areas. This did not allow for assessing the damage caused by mining facilities directly. Following the above, the total amount of damage was assumed to be RUR 0.

Assessment of damage, caused to hydrobionts of the rivers Karagaily and Khudolaz, was carried out based on own research, observations, as well as analysis of published sources [28-31]. At the same time both indicators of complex pollution of water and bottom sediments in water bodies (rivers Khudolaz, Karagaily) and transformation of the hydrographic network as a result of the influence of man-made formations (quarries, rock dumps, etc.) were taken into account. Analysis of water and bottom sediment samples was carried out in certified laboratories. Accordingly, it was revealed that by now there has been a general degradation of the hydrographic network, hydrological regime and environmental conditions in the specified watercourses have drastically changed. This is due in part to the complete isolation of the upper Karagaily River from the Khudolaz River, which has resulted in a drastic reduction in the species composition of the ichthyofauna. Previously inhabited species have been accepted as having been destroyed during economic activity by the mining industry, reflecting the direct damage to hydrobionts (ichthyofauna). In assessing the characteristics of the destruction of fish species in degraded and polluted areas, consideration has been given to similar indicators for rivers that are currently in a more favorable condition. The Khudolaz River within the upper and middle parts of its basin was taken as such a water body (analog). Here, the river is characterized by minimal anthropogenic pressures and favorable hydrological and ecological conditions.

The damage caused to ichthyofauna in the above water bodies takes the form of extinction of fish species. Calculations were made by determining the value of fecundity of each fish species, including pike, roach, sprat, ide, chub, minnow, gudgeon, redeye, silver carp, carp, tench and burbot [30]. Calculation of material damage – the value of dead and lost bioresources was carried out according to the "Methodology..." [31]. The value of aquatic bioresources (fish), was determined following the rates, approved by the resolution of the Government of the Russian Federation [32].

Results and Discussion

It is known that the extraction of mineral resources is accompanied by a large number of types and scales of negative impacts on the natural environment. Production activities are associated with the alienation of vast territories for mining in the form of open pits, rock dumps, storage (settling) tanks of liquid fractions formed at the stage of enrichment of extracted elements, as well as the direct discharge of wastewater into water bodies and wind dispersion of substances from the surface of technogenic-disturbed territories. Thus, under conditions of prolonged operation of industrial facilities, as well as direct and indirect impact of disturbed areas, natural complexes and their components undergo quantitative and qualitative changes. As it is known, from the point of view of the assessment of changes in the condition of plant communities and fauna, as well as public health, the indicators of excess pollutant concentrations over their maximum permissible values in sanitary-hygienic and fishery indicators can be accepted with the highest correlation. At the same time, for example, in contrast to hydrobionts, in the course of human life, pollutants can enter the human body in different ways: as part of drinking water, food, as a result of breathing, etc. Accordingly, under conditions of significant contamination of components of the natural environment, including surface and ground waters, soil cover, atmospheric air, plant communities and fauna and consumption of food obtained from the contaminated environment, processes may occur that reflect the cumulative impact of negative factors, increasing as substances pass through the food chain. Typically, in these contexts, foci or ranges of characteristic diseases occur, due to the nature of the influence of external and internal factors.

To study the formation of characteristic diseases in the population and assess the ecological and economic damage within the study area, we chose the method of experimental and control areas. As shown in papers [4,5,33,34], this method usually selects pilot areas, where the negative impact of environmental factors is high, as well as control areas, conventionally assumed to be environmentally friendly. Then a comparison is made of the parameter under study, in this case, the morbidity of the population. The resulting difference indicates the number of people who fell ill as a result of the negative impact of environmental factors. In the case of the Sibai City District, the morbidity rate of the population of the

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Republic of Bashkortostan was taken as a reference. The latter is explained by the fact that districts close in socio-economic characteristics (Kumertau, Beloretsk, Tuimazy) differ in natural conditions and vice versa, districts close in natural conditions (Abzelilovsky district) differ in socio-economic terms.

Data on groups and levels of morbidity were obtained from data presented in the state reports of the Federal Service for Surveillance on Consumer Rights Protection and Human Welfare in the Republic of Bashkortostan (Rospotrebnadzor) for 2015 - 2019. The year 2020 was not included in the calculations for two reasons: 1) statistical data for this year have not yet been generated and 2) the spread of the coronavirus infection epidemic (COVID-19) has changed the morbidity pattern very significantly, which is typical not only for the territory under study but also for the whole world.

The period analyzed in the calculations is chosen to be 5 years (2015-2019). The latter is due to the established socio-economic situation in the Russian Federation after the 2014 crisis. The analysis was conducted for the following age groups: adults (18 years and older), adolescents (15-17 years), children (up to and including 14 years) and children in the first year of life.

Drawing attention to the prevalence of diseases such as high blood pressure, gastritis and duodenitis, anemia, chronic bronchitis, blood and circulatory diseases and digestive diseases, it should be pointed out that due to the lack of reliable information, indicators of hormonal defects are not accounted for.

Based on the data on the population of Sibai, the number of cases of environmentally caused morbidity in different age groups was subsequently determined.

To assess the economic damage from environmentally caused morbidity indicators of the gross regional product (GRP, Table 1) and the average duration of disability (Table 2) were used [24].

Based on the data presented above, as well as on formula 1, the societal damage from environmentally-caused morbidity of the population has been calculated. Thus, it was determined that the total amount of public economic damage is more than 454, 453 million rubles. In addition, the total amount of personal damage to citizens from environmentally conditioned diseases in Sibai city for the period of 2015-2019 was 73, 366 million rubles. In total, the total damage from environmentally caused diseases in the population is estimated the amount 527, 819 million rubles.

Table 1: Gross regional product per capita in the Republic of Bashkortostan in 2015-2019, rubles (according to Bashkortostanstat, 2019).

Year	GRP per capita, roubles
2015	323367,4
2016	328820,7
2017	346902,2
2018	41530,0
2019	419338,4

Table 2: The average duration of incapacity for work by different groups of environmentally-related diseases, days per year.

Disease name	Time off work, days
High blood pressure	17
Gastritis and duodenitis	9
Urinary stone disease	13
Anaemia	13
Insulin-dependent diabetes mellitus	30
Asthma	13
Chronic bronchitis	13
Certain conditions occurring in the perinatal period	13
Diseases of the blood and the circulatory organs	13
Diseases of the digestive organs	13

Calculations made to assess the damage caused to hydrobionts (ichthyofauna) by the Khudolaz and Karagaily rivers showed that it is estimated at 113, 862 million rubles. Methodological provisions for making calculations have been shown earlier.

It has been also defined that the total amount of damage caused to the soil invertebrates is 6 251, 447 million RUR; the damage to the soils is 22, 320 million RUR/ha.

In general, the data obtained by calculation allowed for estimating the total amount of accumulated economic damage, caused by the adverse effects of altered environmental conditions within the zone of influence of industrial facilities of Sibay city. It was more than 113 billion rubles at the level of 2020. This amount does not include the indicators of those damages that reflect the characteristics of degradation of the Khudolaz and Karagaily rivers channels, changes in their hydrological regime, and deterioration of water use conditions. They, as shown in [35] and according to our observations in recent years under the influence of global climate change are becoming critical. Namely, in the summer of 2020, the mentioned rivers in the zone of influence of the objects of the mining industry dried up. Consequently, all species of higher hydrobionts have died in the dried riverbeds. It was also found that large areas of the vegetation communities on the slopes of the river valleys had dried up. This causes additional ecological and social damage to both natural complexes in general and public health.

Similar changes are observed in other areas affected by the long-term impact of mining facilities. For example, in the zone of influence of the Karabash mine the waters of the Sak-Elga River have remained extremely polluted for many years, the Uchalinsky mine - of the Buida and Kidysh Rivers, Buribaysky mine - of the Tanalyk River, Mednogorsky mine - of the Blyava River, etc. The specificity and scale of influence of technogenic disturbed territories (quarries, rock dumps, waste accumulators, etc.) are approximately similar. This is reflected in the formation of the corresponding environmental and economic damage (in terms of specific indicators) to the environment and public health. It should be noted that a characteristic feature in all areas of influence of disturbed territories is the lack of necessary treatment systems for mine

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and tailing wastewater, which, as was shown earlier, is the main source of pollutants in the river systems. The existing experience of treating small volumes of such wastewater using electrodialysis in the impact area of the Uchaly facilities has not been further developed, although, it is the most promising for solving environmental problems both at present and in the future.

Municipalities do not have the necessary funds to eliminate the violations. In general, the solution to the accumulated environmental problems, including the restoration of the morphometric characteristics of river channels and their water protection zones, as well as the landscape-ecological improvement of the disturbed areas and the improvement of living conditions of people requires the attraction of huge financial and material resources. This can be allowed only based on the targeted involvement of federal, republican and municipal funds

Conclusion

It should be emphasized that the previously listed industrial centers and hubs located within the Southern Trans-Urals (Figure 1) have much in common in terms of their impact on the state of the natural environment and public health. However, for most of them, no serious calculations on the assessment of the accumulated environmental and economic damage have been carried out so far. There is also a lack of information about the targeted clinical research on the level of morbidity of the population. At the same time, the complex research, conducted by us to study changes in ecological conditions in natural-territorial and natural-aquatic complexes, experiencing an excessive and prolonged impact by mining facilities, located in Sibai city, allowed us to estimate indicators of economic damage, caused to the natural environment and public health. Methodological provisions on their calculation with high reliability can be adopted for other, previously listed industrial centers, characterized by similar features of their impact on the state of the environment and public health. The main provisions aimed at the restoration of favorable environmental conditions in the river basins exposed to the negative impact of mining facilities are as follows.

1. Within a zone of influence of economic objects of Sibay city the natural complexes located in the lower part of basins of the rivers Karagaily and Khudolaz are characterized by an extremely high degree of degradation, and also high indexes of accumulation of polluting substances. Here large areas of formerly fertile land and water bodies are allocated for quarries, rock dumps, accumulation of industrial effluents, urban landfills, etc. Radical changes have also taken place in the beds of small rivers themselves, manifested in their deformations, as well as a sharp deterioration in their hydrological and ecological conditions. This requires full-scale implementation of reclamation and environmental protection measures.

2. As a result of the long-term operation of mining facilities, huge environmental and economic damage has been caused to the natural environment and the local population. In the zone of influence of objects confined to Sibai town, the total amount of the caused economic damage is estimated at 113 billion rubles. However, there are no such calculations in the context of other territories covered by the impact of mining facilities. This requires adequate fundraising for the elimination (minimization) of committed violations in the context of all degraded and contaminated territories. The methodological provisions and results of the calculations and assessments made on the example of the zone of influence of Sibai city district reflect the necessity of urgently carrying out similar complex investigations on the zones of influence in other mining districts of the Eastern Trans-Ural Region. Their locations have been shown in Figure 1. Accordingly, necessary nature protection actions should be substantiated and carried out.

3. With the formation of a low-water phase of rivers and increasing aridity of the climate since the early 2000s, environmental and economic problems have become more acute. Municipalities of the cities do not have the necessary funds for the elimination of the violations. In general, the solution to the accumulated problems, including the restoration of the morphometric characteristics of river channels and their water protection zones, as well as the landscape-ecological improvement of disturbed areas requires the need to attract huge financial and material resources. This can only be resolved through the targeted involvement of federal, republican and municipal funds.

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