Analyzing the state of mining towns in the Ural region

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Abstract. The article concentrates on the analysis of the current state of settlements at the territory of the Ural region. The Ural region is shown to be an industrial and highly urbanized area. There are some settlements at the territory of the Ural region where the mining complex is the city-forming enterprise, they are mining towns. It has been revealed that the negative environmental impact never vanishes with the termination of mining but causes some new social, economic and ecological problems. With the purpose of reducing the negative impact of mining effect, a number of measures have been proposed aimed to renovate the mining complex facilities which remained after liquidation and to rehabilitate the industrial areas which remained after mineral deposit development termination.

1 Introduction

Economic activity of subsoil use includes not only the exploitation of mineral deposits (MD) but also the construction of workers settlements in the immediate vicinity of workplaces. Such settlements may be temporary (for the period of MD exploitation), but also may become permanent and stationary. Within a lapse of 350 years of the Urals development, a lot of towns and settlements connected with the mining industry have appeared. Within this period the Urals has developed from a low population area into a highly industrial and highly urbanized region.

Modern cities at the territory of Middle and Western Urals were established as follows. Originally, “the main form of organization in the mining industry was a steelworks with mines and commercial lands, factory dachas, attached to it. Dams with reservoirs, heaps of gangue and slag, and ponds of other mining waste were an integral part of the factory dachas. A group of such dachas, owned by one landlord, made up a particular economic unit interconnected by some intra-factory links, a factory district” [1]. Near the dachas, human settlements appeared, where workers and their families made their homes. Outstanding scientists of our age, Latyshev P.M. and Dementiev I.V., describe the origin of modern mining towns: “One historical phenomenon of Ural mining enterprises is their city-forming part: together with and from the factory a city develops, and the connection between the two organisms is unbreakable. This connection showed in the past and has become especially apparent since the end of the 1950s... the towns of Asbest, Volchansk,

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Gay, Karpinsk, Kachkanar, Sibay, Uchaly, VerkhnyUfaley, Korkino, Severouralsk, et al.” [2].

All the settlements above are small and medium-sized single-industry towns, the economy of which is mainly dominated by one sector, mining and processing industry.

The first problem of such towns resides in the fact that the development of MD is of a long-term but temporary character. With the termination of mining and city-forming company business, towns and settlements, which appeared as part of them, stop their development. There are two prospects for them: degradation and extinction or development by means of economy restructuring, i.e. redeployment of manpower to another field of human and business activity (Volchansk, Degtyarsk, Kizel, Kopeysk, et al).

The second problem is that the termination of mining does not stop the impact of the mining complex (MC) on the environment, especially, on the territories of human settlements. The pits, dumps, cavings, etc. not only shape mining landscapes, but also have a negative impact on the state of soil, air and water basin, and therefore on the health of population.

Ecological state of the region is traditionally determined by a negative impact of anthropogenic (technogenic) objects on the environment. In mining regions, where the objects of MC are main technogenic objects, it is manifested in the Earth's surface disturbance, industrial waste dumping, degradation, and soil contamination [1, 3, 4]. A particular impact is made by harmful substances created in the process of mineral extraction and primary processing.

2 Materials and methods

Main research methods in the given field are analytical, geographic and cartographic methods as well as statistical, design, correlation, etc.

The territory under consideration, the Ural region (UR), is situated on the border between Europe and Asia and occupies: the Urals, the East European Plain, and the West Siberian Plain. The total area of the region is 270421.7 thousand ha or 16.1% of the total territory of the Russian Federation (RF).

UR includes three republics: the Republic of Bashkortostan, the Komi Republic, and the Udmurt Republic; Perm region with the Komi-Perm Autonomous District; five regions: the Kurgan region, the Orenburg region, the Tuymen region, the Sverdlovsk region, and the Chelyabinsk region; two autonomous districts: the Khanty-Mansiysk Autonomous District – Yugra and the Yamal-Nenets Autonomous District (fig. 1) [2].

Geographical features of the Republics of Bashkortostan, Komi, Udmurtia, Perm Krai and the Orenburg region reside in the fact that they are situated partially in the Urals and partially in the East European Plain. The remaining subjects of RF as part of UR are situated both in the Urals and in the West Siberian Plain.

They are administratively included into different federal districts, and economically – into different economic regions (table 1). Geography and demographic profile of the subjects of RF as part of UR are shown in table 1.

The Ural region land resources distribution by the subjects of RF is shown at fig. 2 and corresponds to report statistics for Russia.

Table 1.The description of the subjects of RF within the Ural region.

Subject of the Russian Federation	Area,km²	Federal district	Economic region	Population,thousand people (2016)	Capital, administrative center	Number of towns
the Komi Republic	416774	Northwestern	Northern	856.8	Syktyvkar	10
the Udmurt Republic	42061	Volga	Ural	1517.2	Izhevsk	6
Perm Krai	160236			2634.4	Perm	25
the Orenburg region	123702			1994.8	Orenburg	12
the Republic of Bashkortostan	142947	4071.1		Ufa	21	
the Sverdlovsk region	194307	4330.0		Yekaterinburg	44	
the Chelyabinsk region	88529	3500.7		Chelyabinsk	30	
the Kurgan region	71488	861.9		Kurgan	9	
the Tuymen region (without KhMAD and YaNAD)	160122	Ural	West Siberian	1455.7	Tuymen	5
the Khanty-Mansiysk Autonomous District – Yugra (KhMAD - Yugra)	534801			1685.5	Khanty-Mansijsk	16
the Yamal-Nenets Autonomous District (YaNAD)	769250			534.3	Salekhard	8
Total	2704217			23442.4		186

Fig. 1. Administrative division of the Ural region territory.

Fig. 2.The Ural region land resources distribution by the subjects of RF.

The analysis of land resources distribution at the territory of UR has shown that:

- in three subjects of RF (Orenburg, Sverdlovsk, and Chelyabinsk regions) the area percentage of industry land and land of other special designation more than 2 times exceeds this figure for the Russian Federation (table 2);
- in eight subjects of RF (the Republic of Bashkortostan, the Udmurt Republic, Perm regions, the Kurgan, Orenburg, Tuymen, Sverdlovsk, and Chelyabinsk regions) the percentage of built-up area is higher than that for Russia, exceeding it more than 3.5 times in 5 RF subjects (table 2).

The total area of settlement lands in UR is 3861.1 thousand ha (20% of the total area of settlement lands in Russia).

Table 2.Comparative analysis of areas for the Ural region, %.

Land category	The Russian Federation	the Republic of Bashkortostan	the Udmurt Republic	Perm region	the Kurgan region	the Orenburg region	the Tuymen region	the Sverdlovsk region	the Chelyabinsk region
Industry land and land of other special designation	1.0	0.8	0.9	0.6	0.8	2.1	0.4	2.3	2.9
Built-up land	1.2	4.3	4.7	2.7	7.9	3.3	1.3	3.8	4.4

Settlements with mining enterprises being city-forming, according to the authors' classification of towns, are proposed to be called mining [5]. They are the towns and settlements of urban and rural type. The number of such settlements at the territory of UR is great. In the Chelyabinsk region, 23-25 (38-40%) out of 60 settlements are connected with MC. In the Sverdlovsk region, 46-50 (about 35%) out of 145 settlements may be called mining, including the ones developing MD by the underground method – 23 (49%), opencast – 27 (51%).

The number of mining towns varies from 11.1% (the Kurgan region) to 58.3% (the Orenburg region). In the subjects of RF where mostly oil and gas are produced, the

percentage of mining towns is as high as 84.6% (the Khanty-Mansiysk Autonomous District – Yugra) [6].

The number of mining towns having MC in their immediate vicinity or within their boundaries is 66 (60.6%) and is classified as follows: with opencast development – 34 (31.2%); with MD mined underground – 32 (29.4%). The number of settlements interrelated with MC, including oil and gas production, by the subjects of RF, is shown at fig. 3.

Within the period from the 18th century to the 20th century, great number of mining enterprises was established, functioned, and were liquidated at the territory of the mining Urals. Analysis has shown that 1673 mining enterprises were closed, where 1002 were placers, 566 were mines and shafts, and 105 were open pits. Currently in operation are more than 40 placers, 48 mines and shafts, 100 open pits, including about 40 large ones and a significant number of middle-sized and small open pits [6] (fig. 4), apart from common commercial minerals mining enterprises, the number of which make up about 200.

As a result of coal industry restructuring (since 1994) [7, 8], the following coal companies have been liquidated at the territory of UR: OAO Kizelugol (the Perm region towns of Aleksandrovsk, Gremyachinsk, Gubakha, Kizel), OAO Vakhrushevugol (the Sverdlovsk region towns of Karpinsk, Volchansk, Artyomovsky, and Bulanash), OAO Bashkirugol (Kumertau), and OAO Chelyabinskugol (the Chelyabinsk region towns of Yemanzhelinsk, Kopeysk, and Korkino). Unprofitable shafts and pits of OAO Vorkutaugol (Vorkuta town) and OAO Intaugol (Inta town) in Republic of Komi were closed down. In total, 40 shafts and open pits were liquidated or temporarily closed down, including 17 shafts of OAO Kizelugol, 10 shafts and 1 pit of OAO Chelyabinskugol, 8 shafts of OAO Vorkutaugol, 3 shafts of OAO Intaugol, 2 shafts and 3 pits of OAO Vakhrushevugol, and 1 pit of OAO Bashkirugol. In total, from 1994 to 2012, 188 shafts (mines) and 15 quarries (pits) were liquidated at the territory of the Ural region.

Fig. 3. The number of settlements in the Ural region which are connected with MC: diameter indicates the total amount of towns connected with mining complexes.

Fig. 4. The presence of currently operating and liquidated MC in the subjects of RF in the Ural region: 1 mm indicates 100 enterprises.

3 Results

The results of the data obtained in the course of research indicate a high level of urbanization of the UR territory. Great number of industrial enterprises is concentrated there, including the liquidated enterprises occupying vast territories, and a large number of settlements the majority of which are industrial towns and villages.

The result of the present research basically consists in revealing the main problems of the region and its densely populated areas, including industrial towns and villages

Social and economic problems are caused by the fact that a lot of towns in UR are monotowns [9] with mining industry being the only city-forming sector [6].

It is sometimes recorded that mining enterprises of various profiles share the territory – steelworks or dressing mills during MD development. The territories of Verkhny Ufaley factories or territories presently occupied by Krasnoturyinsk and Karpinsk towns may serve as examples.

Cutbacks in mining and liquidation of the city-forming enterprises of MC have led to economic, social and territorial stagnation in many industrial towns. The city-forming population has become unemployed, social and housing problems are not being solved. As a result, population declines from 5 to 20%, and in some settlements – 2 times (from 49498 people in 1959 to 26249 people in 2019 in Karpinsk town) and even 4.3 times (from 60687 people in 1959 to 14162 people in 2019 in Kizel town).

Complex social-economic state of the mining towns is confirmed by the fact that they have been distinguished by RF Government as monotowns [9]. According to the Index [9], at the territory of the Ural region, 12 towns are ascribed to monotowns of the first category (with the most complex social and economic situation), 15 towns are ascribed to the second

category (with some risks of social and economic deterioration), and only 7 towns are ascribed to the third category (with stable social and economic structure), which is shown at fig. 5.

Fig. 5. The distribution of mining mono towns in the Ural region according to the quality of urban living.

Social and ecological problems are caused by the fact that MC adversely affects the environment even after the termination of mining. The effect of their impact on the state of ground, soil, reservoirs, flora and fauna last for a long time:

- the process of land disturbance continues, including the probability of undermined land caving [10];

- the process of air, water bodies and soil contamination continues.

Contamination of soil, air, and water bodies.

Man-induced impact caused by the effect of MC in mining settlements leads to heavy metals MAC exceedance in soil.

For instance, in the area of Plast town, where soil and environment are mainly polluted by slime pits of AO Uzhuralzoloto and the calcination plant (Obzhigovyizavod), at a radial distance of 500 m from 1250-hectare slime pits the content of arsenic in soil varies within 10-150 MAC, zinc – 3-30 MAC, copper – 2-4 MAC; at the territories around OAO KMK and OAO SUMZ significant copper and zinc MAC exceedance in soil is also recorded [11].

Magnitogorsk (founded in 1929), iron ore producing and processing city, has been granted the status of an environmentally critical area. Total emissions of PJSC MMK into the atmosphere make up 99,3% of total emissions in Magnitogorsk.

Karabash town (founded in 1822) is one of the oldest mining centers. Active mining and processing industry for more than 180 years has led to a significant amount of industrial waste cumulated within the boundaries of the town in the form of cinder banks, slime and tailings storage facilities, pyrite tailings (fig. 6), and sedimentation ponds. They occupy the area of 2.5 km² and more with 30 million tons of the piled mined rock. Contamination of urban territories and the neighborhood with copper, zinc, lead, cadmium, arsenic, and mercury tens of times exceeds MAC. As of the physical state, humus level, soil biota, technogenic pollution of soil with toxic metals, the territory of Karabash was classified as a zone of ecological catastrophe in 1994 (fig. 7).

Fig. 6. Copper mine pyrite tailings bank at the territory of Karabash town (Chelyabinsk region).

Fig. 7. Changed landscape near the copper mine (Karabash, Chelyabinsk region).

In general, in the most urbanized Chelyabinsk region, 52% of the territory is polluted with industrial waste, the share of mining waste being quite considerable. On average, from 200 to 2000 kg of harmful substances per one resident precipitates from the atmosphere every year. In Karabash this indicator sometimes reaches 25 kg per day. Wastewater discharge into the suburban ponds reaches 900 million m³ per year. In the rivers Miass, Ai, Ural, Techa, the accumulation of nitrates, phosphates, ammonia, mineral oil and metals is recorded. It caused increased mineralization and iron content of subsoil waters in some parts of the region [12].

Such cities as Magnitogorsk and Nizhny Tagil, ascribed to the third category, are included in the list of Russian cities with the highest levels of air pollution [13]. Moreover, Magnitogorsk is in Top-10 most polluted cities in Russia. The list does not include Solikamsk and Berezniki of the Perm region and Karabash of the Chelyabinsk region, which have been ascribed to the cities with bad ecology as well.

Total area of disturbed, polluted, degraded and cluttered lands occupied by the facilities of the liquidated mining enterprises is currently hard to determine.

Disturbance of land (Earth's surface).

When considering technogenic disturbances of the Earth's surface caused by mining, it is advisable to distinguish the disturbances which develop under opencast mining and underground and downhole mining.

In the first instance, land disturbances manifest in the shape of rockslides, rockfalls, screes and mud slides which develop due to the vaults on the Earth's surface. Almost all

quarries and pits of the Ural region are subject to these deformations, but the size of landslide deformations of pit edges may reach 300-400 m in length, up to 40 thousand m² in the occupied area on the Earth's surface in the marginal part of a pit, and up to 4 million m³ in the volume of deformed masses (Gaisky, Sibaisky, and Novo-Bakalsky quarries; Korkinsky and Veselovsky open pits). Such deformation result in pit walls cutback, sometimes associated with the liquidation of buildings and structures, including residential ones within the deformation area (the towns of Bakal, Korkino, Karpinsk, Volchansk, et al).

In the second instance, land disturbances manifest in the shape of cavings, cracks, and subsidence as a result of rock movements which create so-called “undermined” territories. Caving dimensions may reach 200-300 m in length and width, area– up to 100 thousand m², depth – up to 30-50 m [14] (towns of Nizhny Tagil, Krasnoturyinsk, Berezovsky, Berezniki, villages of Karpushikha, Levikha et al). Such deformations of the Earth's surface are distinguished by their abruptness and uncertainty as far as time and location are concerned.

The undermined territories of settlements are the most hazardous as soon as such territories threaten the normal life of the population. The brightest examples in the Sverdlovsk region are the centers of Berezovsky and Krasnoturyinsk towns (fig. 8) where residence buildings and community facilities happened to be in the zone of mining effect.

LEGENDS OF MAPS

Apartment houses	Public service facilities
Land plots for individual houses	Land plots under gardens
Land plots under industrial facilities	Land plots for communal facilities
Mines and pits	Underground mine workings the levels
Underground mine workings the levels from 10 to 20 m	Underground mine workings the levels
Underground mine workings the levels of more than 30 m	Influence zones of underground mi
Mining boundary	

Fig. 8. Current use of a mine territory of the former Vasilievsky mine in Krasnoturyinsk town.

Settlements in UR, the territories of which are undermined, are shown at fig. 9.

Fig. 9. UR settlements with the undermined territories.

Negative impact of mining effect leads to some limitations on business activity at the territory of mining towns together with a particular legal regime of land use. For example, within the zones of mine hazardous effect it is proposed to set:

- prohibitions and (or) limitations on construction of buildings and structures, including permanent “heavy” buildings and structures;
- restrictions to land leasehold.

When analyzing the ecological state of settlements in the Ural region, not only the effect of currently operating industrial (mining) enterprises should be taken into consideration, but also the effects from the business activity of the previous 330-years period of mining in the Urals [1, 7, 15, 16, 17, 18].

In that regard the authors propose to distinguish the two periods of mining town state estimation:

- modern one, reflecting business activity of currently operating mining enterprises;
- post-mining – a period, dating from the beginning of mining (the 18th century) to the present time for mining enterprises which went out of business (business activity was stopped, and it is necessary to carry out the remaining facilities renovation or the remaining mining land rehabilitation).

In case buildings and structures are situated at the undermined territories, land state monitoring should be set [19]; observation results may be used when making decisions on land resources and building fund management in the corresponding settlements.

4 Discussion

As a result it should be noted that a high level of pollution is of a local character and is immediately associated with the sites of pollution sources, in particular, to the territories of MC location, including the territories of settlements.

Thus, the analysis of mining (mining industry) history in the Urals leads to the following conclusions:

- termination of MD development is associated with the liquidation of a mining enterprise as a legal entity, and consequently, with the liquidation of a part of MC facilities;

it may cause some new problems in future connected with the negative impact of mining effect on the environment;

- at the territory of mining towns, the influence of mining takes a heavy toll on the state of the undermined territories, and consequently, on the normal life of population; it requires special measures (actions and activities) to protect the population.

There is a problem regarding the minimization of the negative impact of mining on the environment.

At the territories where MD development was terminated, in order to rehabilitate the deformed territories of settlements (disturbed, degraded and polluted), the authors proposed to practice the following sequence of steps:

- estimate the deformed territories using the method of estimating the previous ecological damage accumulated at the location of mining enterprises, with the account of proposals made by the authors;

- consider the variants of territory rehabilitation, consisting in making decisions about land reclamation or the remaining MC facilities renovation, or mining waste reclamation, economic justification for each variant is required;

- make a decision and implement the decision by means of the local authority budget.

At the territories where MD development is in progress, the current MC should be entrusted with all the measures concerning the reduction of mining negative impact on the environment.

5 Summary

The analysis made by the authors has shown that 30-50% of settlements in the Urals are connected with mining. A number of social-ecological and social-economic problems appear as a result of mining termination in mining towns and settlements.

At the territories of such settlements, negative impact of a mining complex (after MD mining) manifests in the shape of the Earth's surface disturbance, together with air, soil and water bodies pollution, etc., which leads to some economic costs of disturbed, degraded and polluted lands reclamation. In order to reduce the negative impact of mining effect, the authors proposed a number of measures aimed at the renovation of MC facilities remained after liquidation or at the reclamation of industrial land developed after MD mining termination.

Social-economic and population problems connected with population decline as a result of mining enterprise business termination should be solved at the country (regional and federal) level.

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