UDC 504.5:622+556.51

Impact of enterprises of Ural mineral resource complex on water resources

Z. M. Bobrova, O. Yu. Il'ina, G. A. Studenok, E. M. Tseytlin

The article discusses the negative impact of mining and metallurgical enterprises of the Middle and South Urals on water resources. Authors define characteristic pollutants for mineral resources complex, including ferrous, nonferrous metallurgy and mining enterprises of building materials. Authors also show the information about water pollution contaminants, including metals, nitrogen compounds, sulfates, manganese and other substances. The article describes main causes of pollution and measures to reduce the negative impact. The article also shows information about the excesses of the concentration of pollutants on maximum allowable concentration and quality of surface water for the Southern and Middle Urals and gives characterization for many rivers by a high degree of contamination. The article deals with measures to reduce the negative impact on the water resources of the Urals, which in 2014 planned and (or) have implemented the largest mining and metallurgical enterprises in the region, such as Magnitogorsk Metallurgical Company, Uchalinsky Mining and Processing integrated works, Uralasbest, Gayskiy Mining and Processing integrated works, Sibayskiy Mining and Processing integrated works, Nizhny Tagil Metallurgical Company. Authors provide information about the level of funding for these activities. In summary, environmental engineering on water resources which is based on culling component of value and on using current topographic features (i.e. coffins) stays as an actual problem for Ural enterprises. These questions need a timely solution for reducing negative impact on surface of the water body.

Keywords: water resources; pollutants; the negative impact of drainage water; wastewater; environmental protection measures.

Rational use of natural resources, reducing of environmental pollution by emissions, discharges and wastes are the strategic objectives in the fi ld of environmental protection and natural resource problems, according to the Federal Law № 7-F3 "On Protection of Environment" under date of 10.01.2002 and "National security strategy of the Russian Federation", approved and came into force by Presidential decree № 537 under date of 12.05.2009.

Extractive and processing production of minerals in the Middle and Southern Urals, including the mining redivision and manufacturing industries cause a high concentration of industrial enterprises of metallurgical and petrochemical orientation in the Republic of Bashkortostan, Sverdlovsk and Chelyabinsk regions.

There are development projects of increasing mining capacities of ferrous and most nonferrous metals in the Urals that will reduce dependence on raw materials import and will provide metallurgical companies with minerals. The long-term program for the period up to 2020 contemplates increasing mining of iron ore up to 320 mln tons. By 2020, a deeply buried (more than 600 m) bauxite ore output is projected at the level of 11.5 mln tons. The main enterprises, working with copper deposits in the Urals are JSC "Gayskiy mining-and-processing integrated works", JSC "Uchalinskiy mining-and-processing integrated works", JSC "Bashkirskiy copper and sulfur company", LLC "Saphyanovskiy copper – Medin". In the context of the defic t of the copper concentrate, copper molding and refini g factories of the Urals use recycled and technogenic materials. Presetting power-level maintenance of JSC "Uchalinskiy ore mining and processing enterprise", demands scheduling of some new deposits to be operational in the near future (for example, the west-lake deposit etc.). JSC "Gayskiy mining-and-processing integrated works" is one of Russia's largest mining enterprises and the main ore base of "Ural Mining and Metallurgical Company" holding. Gayskiy ore mining and processing enterprise exploits the richest Gayskiy copper deposit in the Orenburg region, reaching the plant's capacity of up to 8 mln tons per year. Deficiency of zinc raw materials by 2020, based on the projected zinc metal production, estimated need for which is more than 500 ths tons will be eliminated by the intrusion of new mining capacities, including the ones in the Bashkortostan republic. In the Sverdlovsk region, the researches assume the development of deposits on the molybdenum mining based on specialized mining enterprise JSC "Malyshevskoye Mining Group". One of central enterprises of ferrous metallurgy of Ural region is JSC "Nizhnetagilskij metallurgical industrial complex" (NTMK). The annual economic capacity of cut products (cast iron, pig iron, steel, cast billet, rolled iron, etc.) in this enterprise is about 15–20 mln tons [1].

On the mining enterprises there is continuing a tendency of deterioration of geological, mining and technological conditions of the deposit exploitation: mining at the signifi ant depth, ore transportation to ore dressing factories, and overburden to refuse heaps, waste-drainage water discharges [2, 3].

The increase of volume in mining of minerals, and, as a consequence, the increase of amount overburdens results in such objective appearance as:

– reduction of the content of desired cut in the exploiting deposits;

– need for increase of the ore-dressing volumes;

– high requirements for the quality of the raw ore, that is prepared for the metallurgical extraction etc.

One of the most important factors of impact of mining enterprises on the environment and, in particular, on water resources is the type of commercial mineral. For example, the extraction of ferrous metals can be followed by discharging into water of such pollutants as As, Sb, Pb, Hg, Cu, Zn, S, Au, Ar, Mn, Ni, Co, V, Sc, SO4, P, Cl, the extraction of copper ores – U, Cd, As, Zn, Pb, Hg, Mo, Se, Te, Sb, Zi, Fe, Cu, Zn, V, SO4, Al, Cl, the extraction of black iron ores – U, Pb, Fe, Mn, Sc, P, Cl, the extraction of industrial minerals – Rn, U, Th, a, S, Fe, Cl [4].

The impact of the dumps and emerging dump waters on the environment and the functioning of natural and industrial systems requires the development of additional measures to protect the atmosphere, land and water resources [5]. Typical for mining sector impact on water resources is the disposal of mine drainage and quarry waters into water bodies. Issues of protection of the air basin from pollution take a leading place in environmental activities, which one cannot say about the problems of influence on quality (as a result of the infiltration of toxic substances) and operation mode of the underground and surface waters [6].

Ural mining enterprises are situated on river basin watershed – Tobol, Ural, Kama, Volga and Ob'. Negative impact of mining and industrial enterprises especially affects the ecological state of headwaters. The river network of the region is unique: rivers flow here mainly with their headwaters, so they are small and shallow. The quality of the surface waters within the basins of these rivers forms under the influence of hydrochemical composition of underground waters, wastewater discharges from industrial facilities, surface run-off from agricultural areas, forests and territories of settlements, as well as the transit of pollutants from neighboring areas. There is the water basin of the river Ural in southern-east region of Chelyabinsk Region. The water-collecting area of the river Tobol in western part of Chelyabinsk Region forms by the rivers: Miass, Uy, Toguzak, Techa, Ayat, Sintashta and others.

The rivers Iset, Pyshma, Chusovaya, Hudolaz are characterized as "extremely dirty". They contain Fe, Cu, Zn, Mn, Ni, sulphates and other pollutants, concentration of which exceeds the maximum allowable concentration (MAC) multiple times [7]. The rivers Tobol, Ural, Miass, Neyva, Ay, Blyava are estimated as "very dirty" (according to the data in the Governmental report about the state of the world In Russia Federation by 2013 and 2014).

In Bashkortostan Republic during the program of monitoring of the bed silts in 2014 the waters and bed silts of the water-collecting area of river Belaya (river Belaya, Ufa, Nugushskoye reservoir), Ural (river Tanalyk, river Hudolaz) and Ob were explored twice.

Exploration of the quality of water and bed silt of river Belaya was done from its head (Makhmutovo village) to the border with Tatarstan Republic (Andreevka village).

There is the MAC overrunning at all the studied sector by Cu (up to 13 MAC), Mn (up to 8 MAC), Zn (up to 9 MAC), Fe (up to 8 MAC), and in some sections by Al, Sr, V, NH4, sulphates, nitrates, chlorides, and dry residues. On explored Ufa river stretch from Sverdlovsk Region border there is the MAC overrunning by Cu, Zn, Mn, Al, Fe, V, NH4.

Mostly inorganic compounds pollute the rivers Tanalyk and Hudolaz: heavy metals and sulphates, that is typical for mining regions. In summer, the quality of water is "moderate"; in autumn, it is "very dirty".

Water and bed silt pollution assessment of Buyda river (the water-collecting area of river Ob') near the technological pond of Uchalinskiy mining-and-processing integrated works can be characterized by the high concentration of Cu, Zn, Mn, Fe, Al, Cd, Pb and sulphates.

In surface water of the downstream of the river Suhaya Olhovka in the zone of influence of cinder dump of JSC "NTMK" the concentration of dry residue, suspended substances, chlorides, sulphates, Na, K, nitrates, nitrites, Fe, V, Cu, Cr and phenol is increasing [8].

It is significant that the typical pollutants in drainage water which concentration is overrunning the MAC are nitrogen compounds – ammonia, nitrite and nitrate nitrogens. Their existence in drainage waters is due to the usage of the blaster agent, based on ammonia nitrate, used for mucking.

The main reasons for entering of nitrogen compounds in the drainage waters of mine workings are dissolving and leaching of ammonium nitrates during the charging of watered wells and precipitation leaching of nitrogen oxides formed during explosions and sorbed by the blasted rock mass [9].

The concentration of nitrogen compounds in drainage water of open-cast "Tsentralnyi" JSC "Uralasbest" in Sverdlovsk Region is overrunning the MAC from 3 to up to 130 times[1].

Monitoring studies in some regions of Russia indicate a migration soil process of toxic substances and at the same time reveal the level of higher toxicity of the deep layer of the soil in relation to the surface layer. One can detect ways of getting of infiltration substances into underground aquifers only by carrying out the long-term observations, and qualitative and quantitative analysis with the usage of highly effective analytical techniques.

[1] Hereinafter the materials of cleansing structures working project of JSC "Uralasbest".

Table 1 | Dynamics of wastes discharge volume changes in Russian Federation during 2010–2014 years

	2010	2011	2012	2013	2014
The total volume of contaminated (untreated or inadequately treated) wastewater, billion cubic meters/year	16,5	16,0	15,7	15,2	14,8

Thus, on the anthropogenic areas adjacent to the mining complex, it is easy to see the impact of emerging dump waters on the quality of surface water bodies, leading to high content of ions of different elements in the control points of the river network of the Ural region [1, 3, 10].

According to the data in the Governmental report about the state of the world in Russian Federation by 2014 the volume of wastes discharge decreased by 10.3% (from 16.5 billion meters to 14.8 billion meters) and during the last 5 years dirty water probes percentage is about 10% (by hygiene parameter) and 17% (by chemical parameter) (Table 1).

Information about the federal subjects of the Ural region with the largest volume of wastewater discharge in 2013 is given in Table 2.

The share of polluted wastewater in the total volume of discharges in the Ural Federal District is 55%, Volga Federal District – 37.6%. As can be seen from the tables, the volume of wastewater discharge, including the one discharged without treatment, is significant.

Year after year, there remains high number of regions with a high level of water contamination, i.e. the average annual concentration of one or more pollutants exceeds the MAC by more than 10 times. The main causes of bad quality of water are: the absence of cleansing structures, the defects in mining engineering (ex. absence of high-velocity layer under the dump), discharging of dirty water from the territory of big cities, enterprises and agricultural companies, the great quantity of pollutants in bed silts, that leads to the increased pollution of surface waters.

Let us note that in addition to the previously marked high contamination of drainage waters with nitrogen compounds by mining enterprises, an important factor determining their impact on water resources is its signifi ant volume, directly proportional to the area of mining and quantity of precipitation falling on these areas.

For example, the during the period of 2004–2013 years, spillover of drainage water, which are polluted be nitrogen compounds (JSC "Uralasbest", Sverdlovsk Region) and disposed without cleansing to the Bol'shoy Reft iver was about 6 million meters a year.

In 2014, the water consumers of the region accomplished the following most signifi ant environmental water protection measures.

On the Sibayskiy branch of JSC "Uchalinskiy mining-and-processing integrated works", the pipe installation for storm water drainage to the water recycling processing factory is fin shed. On June 17, 2014, discharge of storm water to the industrial site of the processing plant of Sibay branch of OJSC "Uchalinskiy mining-and-processing integrated works" in the river Karagaily stopped. As a result the wastewater discharge reduced by about 70 000 m^3 a year. Th s environmental protection measure cost was about 0.15 million rubles. The reconstruction of sewage treatment plants of industrial wastewater of Uchalinskiy area at JSC "Uchalinskiy mining-and-processing integrated works" continues. The cumulative expenditures are at about 57.801 mln RUR.

The LLC "Bashkir copper" started the development of working documentation for the construction of sewage treatment plants of industrial waste-water. Expenses amounted to 3.7 mln RUR.

The modernization of existing sewage treatment plants for mine and underdump waters has begun for Sibay and Kamagansk quarries of Sibay branch of OJSC "Uchalinskiy mining-and-processing integrated works". The cumulative expenditures are about 1.42 mln RUR.

The cumulative expenditures of JSC "Sibayskiy mining-and-processing integrated works" for formulation of technical regulations of water drainage treatment for the Hudolazskiy deposit are about 1.55 mln RUR.

The JSC "Magnitogorsk metallurgical industrial complex" implemented the following measures:

– carrying out of hydromechanized cleaning of bottom sediments sump and sump of the left bank at the mouth of the northern industrial stormwater channel (the amount spent – 37.0 mln RUR);

– wastewater aeration system design in the sump at the mouth of the channel is made, and the left bank of the northern industrial stormwater sedimentation tank (the amount spent – 32.0 mln RUR);

– a complex of converter sludge dewatering was put into operation (the amount spent – 370.0 mln RUR);

– the construction of two drainage pumping sta-

Table 2 | The volume of wastewater discharges for the Sverdlovsk and Chelyabinsk regions and the Bashkortostan Republic for 2013 year

Federal subjects	Volume of wastewater discharges, mln m^3
Bashkortostan Republic	305,1
Chelyabinsk region	712,77
Sverdlovsk region	686,79

Table 3 | Changes in the concentrations of nitrogen compounds in the drainage water after exposure to the waste rock dump for 2014–2015 years (mg/dm³)

Year	The drainage water of open-cast, mg/dm³		The drainage water after storage in coffin, mg/dm³		The rectification efficiency, %	
	ammonium nitrogen	nitrite nitrogen	ammonium nitrogen	nitrite nitrogen	ammonium nitrogen	nitrite nitrogen
2014	7,39	3,65	0,58	0,60	92	84
2015	5,81	3,78	0,19	0,20	97	95

tions № 1 and 2 was carried out. They are returning filtration waters of the dam body to the pond sump of slime storages № 2 (the amount spent – 50.0 mln RUR).

The main pollutants discharged into water bodies as a result of production activity of JSC "Magnitogorsk metallurgical industrial complex", are iron, manganese, zinc, oil products, sulfates, fluorides and others [2, 3].

Gross discharge of pollutants (7 issues) into wa-ter bodies relative to 2013 decreased by 14.3 ths tons (14%) and amounted to 90 ths tons.

In accordance with the environmental program of JSC "Magnitogorsk metallurgical industrial complex" in 2014, 50 technical measures (10 are in progress) of varying degrees of complexity were fulfilled, aimed at reducing and preventing of negative impacts on the environment. The actual costs of the program amounted to 1,671,700,000 RUR, including:

–1.124 mln RUR. The implementation of measures for reducing of pollutant emissions into the atmosphere (including capital construction – 1.0397 bn RUR);

–345.0 mln RUR.The implementation of measures to reduce the discharge of pollutants into water bodies (including capital construction – 294.8 mln RUR);

– 202.7 mln RUR. The implementation of measures on the disposal of industrial waste and remediation (including capital construction – 185.6 mln RUR).

As can be seen, the issues of protection of water resources get 3 times less money in comparison to the protection of the atmosphere, which in part can explain the assignment of the Ural River to the "very dirty".

Currently, scientific journals publish methods, designed to meet modern standards, of protecting water bodies from pollution and then using compounds extracted from underdump, mine, wastewater of mining enterprises [1]. Promising method of cleaning of the drain water of mining enterprises from of nitrogen compounds is the biochemical method of cleansing in the presence of the natural microfl ra, for which nitrogen compounds are a nutrient medium. The experience of JSC "Uralasbest" shows that even a simple storage of water drainage in coffi leads to reducing of the concentration of ammonium nitrate and nitrite by 98% and 91% accordingly (Table 3).

Authors should also note that the objects of waste disposal mineral complex often also are technogenic mineral formations [11, 12]. Nowadays, a draft is developed at NTMK that processes slag dumps to further reduce their negative impact on the environment and at the plant "Uralasbest" waste mining production is adjusted to obtain thermal insulation materials.

The "Strategy of development of Russian metallurgical industry for the period till 2020, approved by the order of the Industry and Trade Ministry of Russia from 18.03.2009 № 150, among the areas of technical innovation policy shows a set of scientific researches, on the one hand aimed at improving the state of the environment in areas within the enterprises, on the other – recommended for implementation in the period up to 2020.

In conclusion, we can add that the most rational need is the need to develop modern, effici t methods of wastewater treatment with the extraction of valuable components for environmental management at the enterprises of the Middle and South Urals using possibility of existing of mine workings for cleaning the drainage water (e.g. waste quarries).

REFERENCES

1. Kompaniya Evraz [Evraz company]. Available at: www.evraz.com

2. Bobrova Z. M., Iljina O. Yu. 2010, Otsenka sostoyaniya vody v reke Ural [Assessment of the state of water in the river Ural]. *Teoriya i tekhnologiya metallurgicheskogo proizvodstva: mezhvuzovskiy sbornik nauchnykh trudov* [The theory and technology of steel production: Interuniversity collection of scientific papers], vol. 1, pp. 165–170.

3. Bobrova Z. M., Iljina O. Yu. 2011, Vozdeystvie predpriyatiy na sostoyanie vody reki Ural v predelakh goroda Magnitogorska [The impact on the state enterprises of the Ural River water in the city of Magnitogorsk]. *Teoriya i tekhnologiya metallurgicheskogo proizvodstva: mezhvuzovskiy sbornik nauchnykh trudov* [The theory and technology of steel production: Interuniversity collection of scientific papers], vol. 11, pp. 159–161.

4. Tseytlin E. M. 2013, *Issledovanie, otsenka i optimizatsiya urovnya ekologicheskoy bezopasnosti okruzhayushchey sredy v usloviyakh gornogo proizvodstva (na primere Srednego Urala)*: dissertatsiya kandidata geologo-mineralogicheskikh nauk [Study, evaluation and optimization of ecological safety of the environment in

terms of mining production (On the example of the Middle Urals): the dissertation of geology and mineral sciences candidate], 194 p.
5. Khokhryakov A.V., Fadeichev A. F., Tseytlin E. M. 2014, Description of environmental issues of mining enterprises basing on environmental hazard index. *Inzynieria Mineralna,* vol. 15, no. 1, pp. 283–287.
6. Medyanik N. L. 2012, *Teoreticheskoe obosnovanie i razrabotka resursovosproizvodyashchikh tekhnologiy kompleksnoy pererabotki tekhnogennykh vod medno-tsinkovykh gornykh predpriyatiy*: avtoreferat dissertatsii doktora tekhnicheskikh nauk [Theoretical substantiation and working resurce reproducing technology of complex processing of industrial waste waters copper-zinc mining enterprises: the synopsis of dissertation of doctor of technical sciences], 450 p.
7. Revvo A. V. 2015, Vozdeystvie predpriyatiy gorno-metallurgicheskogo kompleksa na dinamiku zagryazneniya reki Chusovoy [The impact of mining and metallurgical complex dynamics of pollution of the river Chusovaya]. *Izvestiya vysshikh uchebnykh zavedenii. Gornyi zhurnal – News of the Higher Institutions. Mining journal*, no. 2, pp. 67–73.
8. Zakharov A. V. 2014, Ekologicheskoe sostoyanie okruzhayushchey sredy otvalov chernoy metallurgii (po rezul'tatam monitoringa shlakovogo otvala NTMK) [The ecological state of the environment dumps of ferrous metallurgy (as a result of monitoring of the slag dump of Nizhnetagilskij metallurgical industrial complex)]. *Izvestiya Ural'skogo Gosudarstvennogo Gornogo Universiteta – News of the Ural State Mining University*, no. 3, pp. 51–56.
9. Studenok A. G., Studenok G. A., Revvo A. V. 2013, Otsenka metodov ochistki stochnykh vod ot soedineniy azota dlya drenazhnykh vod gornykh predpriyatiy [Evaluation methods of wastewater from nitrogen compounds in drainage waters of mining enterprises]. *Izvestiya Ural'skogo Gosudarstvennogo Gornogo Universiteta – News of the Ural State Mining University*, no. 2, pp. 26–30.
10. Antoninova N. Yu. 2012, Geoekologicheskaya otsenka zemle- i vodopol'zovaniya v rayonakh osvoeniya prirodnogo i tekhnogennogo syr'ya Urala [Geoecological assessment of land and water management in the areas of development of natural and technogenic raw materials of the Urals]. *Fiziko-tekhnicheskie problemy razrabotki poleznykh iskopaemykh – Journal of Mining Science*, no. 2, pp. 194–200.
11. Makarov A. B., Talalay A. G. 2012, Tekhnogennye mestorozhdeniya i ikh ekologicheskaya rol' [Technogenic deposits and their ecological role]. *Litosfera – Lithosphere*, no. 1, pp. 172–176.
12. Makarov A. B. 2000, Tekhnogennye mestorozhdeniya mineral'nogo syr'ya [Anthropogenic mineral deposits]. *Sorosovskiy obrazovatel'nyy zhurnal – Soros Educational Journal*, vol. 6, no. 8, pp. 76–80.

Zaliya Maratovna Bobrova,
PhD, Associate Professor
eco_safe@magtu.ru
Oksana Yur'evna Il'ina,
PhD, Associate Professor
Nosov Magnitogorsk State Technical University,
Magnitogorsk, Russia

Gennadiy Andreevich Studenok,
the senior teacher
Evgeniy Mikhaylovich Tseytlin,
PhD, Associate Professor
Ural State Mining University, Yekaterinburg, Russia