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Research article

Hydrogeoecological conditions of technogenic groundwater in waste disposal sites

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Abstract. The specific hydrogeoecological conditions of aquifers of some technogenic formations, mainly iron ore skarn-magnetite and titanium-magnetite formations, are considered. The resulting wastes, which are stored in waste disposal sites during development of deposits, due to the impact of a number of factors (natural and technogenic) form technogenic waters. Waste disposal facilities are complex engineering structures (dumps and sludge storages), which in turn create their own hydrogeoecological conditions, which must be investigated in order to prevent and minimize environmental and economic damage caused by these objects to the aquatic environment. The paper presents long-term field and laboratory studies of the aquatic environment under the influence of a waste disposal facility in the Middle Urals – one of the largest tailings, representing a potential environmental and man-made hazard. This tailing dump contains tens of tons of waste – enrichment tailings and creates specific hydrogeoecological conditions on the territory. Based on many years of monitoring studies, an analysis of these conditions was carried out – the quality of groundwater affected by the tailings was assessed. It is shown that groundwater is of technogenic nature, i.e. are man-made waters that have a significant impact on the surface and underground hydrospheres of the territory.

***Keywords*:** hydrogeoecological conditions; waste disposal facilities; dumps and tailings; groundwater; surface water

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Introduction. During the development of deposits, waste, that must be stored in waste disposal sites (WDS) and which represent technically complex structures, is generated. They can be divided into "dry" storage facilities (various dumps) and "wet" storage facilities (tailing dumps). As a result of natural and technogenic processes impact (precipitation, condensation, discharge of technical water), groundwater is formed in WDS in the form of technogenic aquifers.

The purpose of the study is to research the conditions for the formation and discharge of groundwater in WDS. At the same time, it is necessary to assess the factors of groundwater volume and quality formation in WDS, as well as their impact on the surface and underground hydrosphere.

The studies were carried out in the Middle Urals, where more than 10 billion tons of waste are located. WDS are placed in specific hydrological and hydrogeological conditions in the open structure of the mountain-folded Urals and, in turn, create specific hydrogeoecological conditions. All this determines the need to study the hydrogeoecological conditions of waste disposal sites, the impact of which on the aquatic environment is often assessed as catastrophic [1-3].

Methods. The work used hydrogeoecological analysis, geochemical and retrospective methods. The work is based on a large number of field observations that the authors have been conducting for more than 20 years at waste disposal sites from the enterprises of mining and industrial complex of the Middle Urals. The paper analyzes the results of the own monitoring studies of environmental components – surface and ground waters, as well as geological materials.

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As an example, the sludge storage of the Kachkanarsky Mining and Processing Plant (MPP) was studied, the chemical composition of its waste, mg/dm^2: Sc – 0.013; TiO_2 – 0.7; Y – 0.01; CaO – 19.2; ZnO_2 – 0.1; SiO_2 – 47.5; Fe – 6.3; MgO – 13.4. To control the groundwater quality in the area of tailing dump impact, a regime network of observation wells was created, including 12 wells of the same type, which are located on the first aquifer of groundwater from the surface. The depth of the wells was 21-47 m, the diameter was 112-132 mm, with 127 mm casing of the upper zone of clay-grus formations and isolation of the annular space from the ingress of surface melt and rain water into the aquifer of fractured-pore groundwater to be opened for prevention of distortion of the results of hydrochemical testing of groundwater. The wells are located at the foot of the sludge storage dams outside the outlets of the sludge water filtrate.

The main principles of well placement relative to the tailings boundaries are accessibility of the approach to the places of laying, uniformity of distribution along the tailings perimeter and compliance with the direction of groundwater flows movement.

The impact of discharge from the tailing dump on the underground hydrosphere is reflected by three wells. Ground and surface water samples were taken quarterly according to established methods and analyzed in accredited chemical laboratories. In total, more than 200 samples were analyzed.

Discussion of the results. The mountainous and folded Urals (Sverdlovsk, Chelyabinsk, Orenburg regions and Bashkiria) are assigned to the groundwater basin of fracture zones in the rocks of the Middle and Lower Paleozoic [4-6]. The geological structure of the basin is extremely complex. Long-term continental development led to formation of a relatively low-mountain relief with a preserved weathering crust that plays a dual role. First, the residual crust slows down the infiltration of precipitation; secondly, it helps to equalize infiltration. In areas of clayey crusts development, colmatation of cracks in the weathering zone is noted. Therefore, great importance is attached to linear zones of increased fracturing, which formed in the post-Hercynian and especially in recent times.

With the end of the Hercynian era of folding, geological development of the region did not stop, it continued in the form of physical, chemical weathering and arch-block uplifts with erosion processes. As a result, a vertically regular system of cracks of varying intensity forming fracture zones was formed. The zones were formed at different times, but the basis for the emergence of each subsequent one, according to the principle of inherited development, was the previous one. Although the filtration and storage properties, chemical composition of waters, speed of movement and unloading of fractured zones differ, they form one aquifer.

Thus, two taxonomic units or two aquifer complexes can be distinguished. One of the complexes is composed of loose Mesozoic and Cenozoic deposits, and the second is a single aquifer complex of rock fracture zones from Cambrian to Devonian (Fig.1).

Mesozoic and Cenozoic formations of alluvial, eluvial-deluvial and technogenic genesis contain pore water. All of them form separate aquifers that differ in filtration and storage properties, thickness, sediment composition and occurrence conditions.

The WDS aquifer was formed in connection with the development of numerous deposits of solid minerals in the Urals, inevitably accompanied by excavation of ores and waste rocks from the bowels, which are stored in dumps. They are supplemented by sludge from processing plants and ash from thermal power plants, tailings from dredges in river valleys.

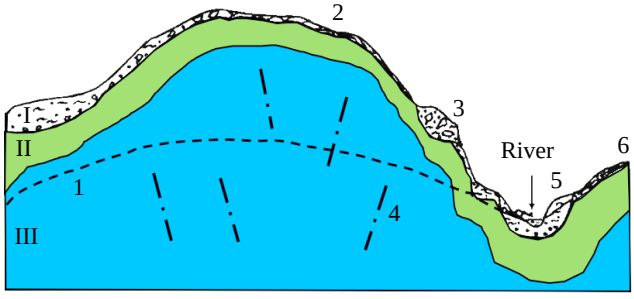


Fig.1. Groundwater layout
in the hydrogeological massifs of the Urals

Aquifer systems: I – loose Mesozoic and Cenozoic deposits;
II – zones of regional fracturing; III – zones of tectonic faults
1 – groundwater level; 2 – zone of aeration and seasonal fluctuations
in the level of groundwater; 3 – groundwater of WDS;
4 – tectonic disturbances; 5 – groundwater of alluvial deposits

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Dumps and sludge storages have a local distribution, but play a significant role in changing the natural situation in the area of mines, forming a technogenic landscape. Large volumes and areas of dumps contribute to the accumulation of atmospheric precipitation, melted snow water, and condensation of vapors from the air [7-9].

Estimation of the factors of groundwater volume and quality formation in WDS. There are dry (for example, dumps of off-balance ores) and wet (tailing and sludge dumps) types of waste storage [10-12]. During dry storage, technogenic waters are formed mainly under the influence of atmospheric precipitation. In wet storage, the main role during the operation of the facility is played by production water, and after the termination of its operation, atmospheric precipitation [13-15]. There are three most characteristic options for the WDS location on the relief [16-18]:

• on the watershed – during dry storage, technogenic waters are formed only under the influence of atmospheric precipitation, and during wet storage – industrial waters (Saldinskoye sludge storage);

• on the slope – formation of the chemical composition of technogenic waters involves flat runoff flowing along the relief into the dump (Tonsky dump of the Vysokogorsky Mining and Processing Plant);

• in the channel part of temporary or permanent watercourses, surface waters are involved in the formation of technogenic waters (Cheremshanskoye sludge storage, open-hearth slag dump of OAO NTMK).

The most important hydrometeorological factors are the amount of precipitation, their average intensity, duration, chemical composition and pH. The morphometric parameters of the WDS can have a great influence on groundwater discharge. Therefore, in dry storage, the determining factor is the capacity of the WDS – the larger it is, the longer the contact of atmospheric water with the dump and the higher the volume of groundwater. In this case, the length and width of the WDS can be significant characteristics [19].

At the Goroblagodatsky deposit, groundwater of technogenic deposits has a wide area development around existing mines and the open pit mine. A certain role in changing the natural environment of the deposit area is played by waste rock dumps and sludge storages, which occupy huge areas (dump 6 – 1120000 m^2, dumps 13, 14, 15 – 2250000 m^2, Polovinkinsky sludge storage – 2.3 million m^2). Large areas of dumps and their height contribute to the accumulation of liquid atmospheric precipitation, melted snow water, condensation of air moisture and their gradual consumption, which manifests itself in the form of hollows, permanent and temporary sources, in feeding small reservoirs.

Infiltration of atmospheric precipitation, snowmelt, replenishment due to surface runoff, and condensation of air moisture leads to accumulation of water under dump N 6 and their sudden breakthrough to the surface. Directly in the area of the breakthrough, the catchment area of dump N 6 is 524 thousand m^2, the volume is 17.5 million m^3. Depending on the amount of precipitation and condensation of air moisture, breakthroughs can occur both annually and with a break of up to two years. Breakthroughs in the summer (starting from the second half of summer) are characterized by suddenness, and in the case of their annual manifestations, the flow rate reaches 60-70 m^3/h, the duration of the outflow 15-20 days. The total reserves of waters pouring out during this time are 21-25 thousand m^3. In cases of water accumulation for two years, breakthroughs also occur suddenly, but the flow rate increases significantly, amounting to approximately 300 m^3/h with a total outflow duration of up to 95 days.

In winter, the flow of water occurs at the initial moment slowly with the formation of ice, which, as it grows, moves towards the village of Blagodat. The gradual movement of water leads to flooding of the basements of houses, road to the crushing and processing plant N 3 is blocked by icing. The height of the icing reaches 0.5-3.0 m, the area is approximately 70 thousand m^2. Only with an increase in the flow rate of the breakthrough, the water makes its way, and the comparatively fast unloading of the water accumulated under the dump takes place along the ditch. The total volume of water, subject to accumulation for several years, is significant – up to 500-600 thousand m^3 (Fig.2).

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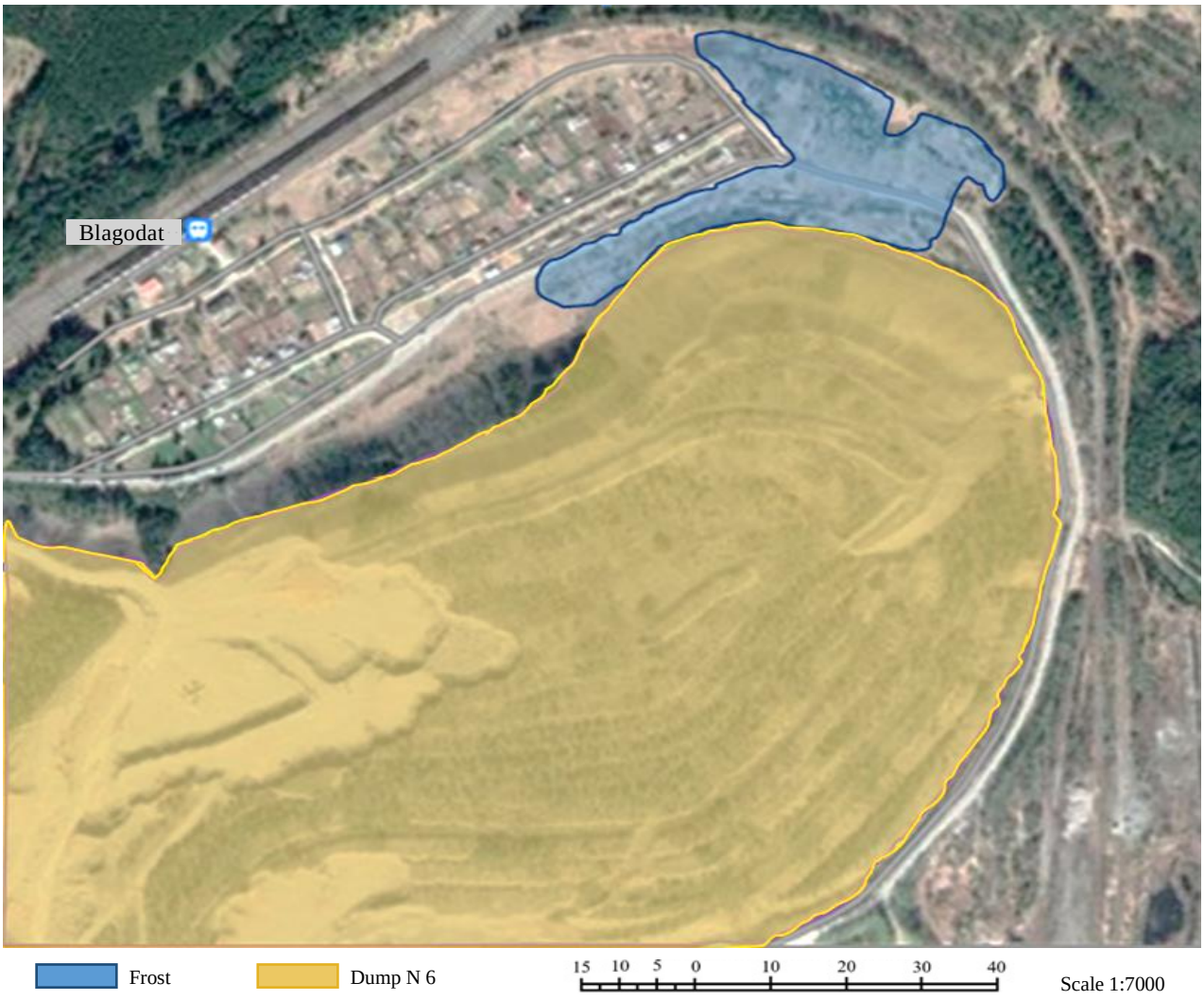


Fig.2. Scheme of the location of ice from groundwater from the WDS at the Goroblagodatsky field

The accumulation of a large mass of water and a sudden breakthrough are explained by the fact that the dump is composed of particles of inhomogeneous size – clay, wood, rubble and blocks. Cold air in winter, warm air in summer ventilates the dump, bringing heat or cold according to the season. In winter, the dump is frozen in the edge parts, the inner parts remain unfrozen due to the high power. Condensation of air moisture occurs both in warm and cold periods with the formation of a rock-ice lens at the border of the thawed and frozen parts of the dump. The accumulation of water occurs both in the form of ice and in liquid form. It is retained as a dam, by a rock-ice lens, and in its marginal parts by layers of clays that create conditions for accumulation. With the accumulation of water to a critical level, the lens thaws and a sudden breakthrough occurs, usually in November-December. Breakthroughs have been occurring continuously for 50 years.

At the Estyuninskoye deposit, a permanent spring was recorded at the foot of the northern dump. At the same time, there was a hidden discharge of water from technogenic deposits into underground workings, which became apparent after the occurrence of a landslide cirque in the area of rock fall. Dumps are located on the surface of relatively flat areas of the terrain, adjacent to the slopes of the mountains and are always above the groundwater level. The thickness and area of the underlying clay deposits are such that they allow water to be retained all year round, so such aquifers can be considered permanent.

Sludge storages occupy low relief areas, for example, in river valleys, in depleted quarries, where, in addition to water involved in the transport of sludge, groundwater is recharged [20-23]. Similar aquifers were formed at the Gusevogorskoye deposit of titanomagnetites (tailing dump),

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at the Cheremshanskoye sludge dump of the Vysokogorskoye deposit, at the Polovinkinsky and Saldinsky sludge storages of the Goroblagodatsky ore field. Under the sludge reservoirs, groundwater level rose by 15-20 m with formation of spreading domes, springs formed at the base of the dams.

Geological and technical section along the observation network well: technogenic deposits tQ (depth of occurrence 0-3 m, layer thickness 3 m); deluvial loam Q (depth of occurrence 3-3.9 m, layer thickness 0.9 m); eluvial light yellow dense loam Q (depth of occurrence 3.9-8 m, layer thickness 4.1 m); gabbro S_1I_{1-2} (depth of occurrence 8-27 m, layer thickness 19 m); drilling diameter 127-132 mm, casing depth 110 mm; drilling depth 6.7 m; water level – appearance 12 m, steady 12 m.

Assessment of groundwater quality formation in WDS. Formation of groundwater composition during their interaction with the solid phases of WDS occurs as a result of leaching [24], i.e., selective dissolution of one or several components of solid phase by liquid. Dissolution occurs until the chemical potentials of dissolving component in the liquid and solid phases are equal. The limiting concentration of the component C_n achieved in this case corresponds to the state of a saturated solution and is called solubility, the value of which depends on many factors. Therefore, when studying the patterns of interaction in the water-rock system, natural modeling methods are of great importance.

To predict the removal of components from the solid phase of WDS into the liquid one, it is necessary to determine the following parameters: leaching rate constant, day^{-1}; initial specific volume of the substance, units; filtration or infiltration rate, dm/day; substance density, g/dm^3; concentration of saturated solution, g/dm^3.

To determine the leaching rate constant, a filtration experiment is carried out on a special stand. A 500 ml test sample is placed in a filtration column, and distilled water is filtered through it with a pH corresponding to the pH of the sediments or filtration waters of the area. Filtration rate should be close to the real situation. From the moment the filtrate arrives, the countdown begins and sampling is carried out.

The study of the removal of pollutants from slimes and slags showed that slags with a higher metal content, a more coarsely dispersed composition and, as a result, a smaller area of contact between the solid and liquid phases, have a lower leaching capacity [25-27]. The authors calculated the time of complete leaching of metals in the considered waste. This period takes into account the contact time of water and solid phases. For dry-storage waste with an average rainfall of about eight hours and an average rainless period of 40 days, the total duration of contact between sediments and solid phase will be about one day per year. With this in mind, the time for complete leaching of metals from sludge by atmospheric precipitation will be hundreds, and from slag – thousands of years [28-30].

When examining the territory of the tailing dump in Kachkanar, carried out in different seasons, seven sources of formation of groundwater discharge were identified (Table 1). Thus, the total permitted wastewater discharge as a result of groundwater discharge from the tailings is 30,796.0 thousand m^3/year. With sewage, suspended solids, sulfates, nitrogen compounds, iron, vanadium, copper, and oil products enter water bodies. The main environmentally hazardous component in the sludge water cycle is the nitrate ion supplied by quarry waters [31].

Assessment of groundwater impact in WDS on the surface and underground hydrosphere. Let us analyze the impact on surface and ground waters of one of the largest tailings in the Middle Urals, which is the object of waste disposal – tailings for the enrichment of titanomagnetite ores of the Gusevogorskoye deposit. The area of the tailing dump is 19.75 km^2. The structure of the tailing dump includes dams: N 1 (filled with a maximum height of 82.5 m), N 2 (filled with a maximum dam height of 61.5 m) and eastern (filled with a height of 79 m). The filtration waters of the dams form three wastewater outfalls that enter the river Vyya. Table 2 compares the volumes of actual wastewater discharge from tailing dump into the river with permitted values in the dynamics of recent years.

As can be seen from Table 2, for all issues over the considered period of time, there are sharp fluctuations in volumes with periodic excesses of the allowable discharge. The increase in the volume of wastewater is due to the growth of the dam body due to its alluvium, the decrease in volume is due to the increase in the dam body due to the loading of downstream slopes with rock.

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Table 1

Groundwater discharge indicators of the tailings in Kachkanar

Source of emission of pollutants		Pollutant	Wastewater discharge volume		
			thousand m^3/year	mg/dm^3	t/year
Rogalevsky compartment	Filtration through dam N 3 (dam outlet N 4)	Suspended solids	1361.0	4.0	5.444
		Dry residue		387.0	526.707
		BOD_{20}		2.5	3.403
		BOD_5		1.9	2.586
		Sulfates		54.0	73.494
		Nitrate ion		45.0	61.245
		Nitrite ion		0.18	0.245
		Ammonia nitrogen		0.1	0.136
		Iron		0.34	0.463
		Vanadium		0.01	0.014
		Copper		0.0126	0.017
		Oil products		0.11	0.150
	Filtration through dam N 4 (dam outlet N 10)	Suspended solids	1499.0	3.75	5.621
		Dry residue		385.0	577.115
		BOD_{20}		5.3	7.945
		BOD_5		3.5	5.247
		Sulfates		53.0	79.447
		Nitrate ion		45.0	67.455
		Nitrate ion		0.19	0.285
		Ammonia nitrogen		0.1	0.150
		Iron		0.3	0.450
		Vanadium		0.003	0.004
		Copper		0.0089	0.013
		Oil products		0.11	0.165
	Total for the Rogalevsky compartment 2860.0 thousand m^3/year				
Intermediate compartment	Filtration through dam N 1 (dam outlet N 2)	Suspended solids	521.0	4.0	2.084
		Dry residue		393.0	204.753
		BOD_{20}		3.0	1.563
		BOD_5		2.0	1.042
		Sulfates		56.0	29.176
		Nitrate ion		40.0	20.840
		Nitrite ion		0.08	0.042
		Ammonia nitrogen		0.39	0.203
		Iron		0.21	0.109
		Vanadium		0.002	0.001
		Copper		0.001	0.001
		Oil products		0.05	0.026
	Filtration through dam N 2 (dam outlet N 3)	Suspended solids	3632.0	2.75	9.988
		Dry residue		384.0	1394.688
		BOD_{20}		2.9	10.533
		BOD_5		2.0	7.264
		Sulfates		51.0	185.232
		Nitrate ion		45.0	163.440
		Nitrite ion		0.13	0.472
		Ammonia nitrogen		0.1	0.363
		Iron		0.34	1.235
		Vanadium		0.01	0.036
		Copper		0.0126	0.046
		Oil products		0.19	0.690
	Filtration through the eastern dam (dam outlet N 9)	Suspended solids	3095.0	2.78	8.604
		Dry residue		388.0	1200.860
		BOD_{20}		2.7	8.357
		BOD_5		1.8	5.571
		Sulfates		53.0	164.035
		Nitrate ion		45.0	139.275
		Nitrite ion		0.2	0.619
		Ammonia nitrogen		0.1	0.310
		Iron		0.34	1.052
		Vanadium		0.003	0.009
		Copper		0.0094	0.029
		Oil products		0.11	0.340
	Total for the Intermediate compartment 7248.0 thousand m^3/year				

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End of Table 1

Source of emission of pollutants		Pollutant	Wastewater discharge volume		
			thousand m^3/year	mg/dm^3	t/year
Vyisky compartment	Siphon outlet from the tailing dump in the river Vyya (dam outlet N 1)	Suspended solids	20688.0	9.0	186.192
		Dry residue		304.0	6289.152
		BOD_{20}		3.0	62.064
		BOD_5		2.0	41.376
		Sulfates		56.0	1158.528
		Nitrate ion		40.0	827.520
		Nitrite ion		0.08	1.655
		Ammonia nitrogen		0.39	8.068
		Iron		0.21	4.344
		Vanadium		0.002	0.041
		Copper		0.001	0.021
		Oil products		0.05	1.034
	Total for the Vyisky compartment 20,688.0 thousand m^3/year				

Table 2

Dynamics of volumes of actual wastewater discharge from tailings into the river Vyya Findings and their comparison with allowed values

Name of wastewater outlet	Wastewater discharge, thousand m^3		Multiplicity of exceeding the actual discharge of normatively permissible discharge value
	Actual	Permissible discharge standard	
2018			
Dam N 1	60	132	–
Dam N 2	3940	3750	1.1
Eastern dam	1130	1910	–
2019			
Dam N 1	521.0	120.0	4.3
Dam N 2	3632.0	5100.0	–
Eastern dam	2090.0	2890.0	–
2020			
Dam N 1	429.7	521.0	–
Dam N 2	4049.6	3632.0	1.1
Eastern dam	3201.5	2090.0	1.5

The concentrations of chemical elements and substances in the outlets show that there are excesses over the permitted discharge for a number of indicators:

• In dam release N 1: dry residue – up to 1.1 times (1 year out of 5); BOD_{20} – up to 1.2 times (1 out of 5); sulfates – up to 1.1 times (1 out of 5); nitrate ion – up to 2.1 times (5 out of 5); nitrite ion – up to 2.5 times (1 out of 5); iron – up to 2.1 times (2 out of 5); vanadium – up to 1.7 times (1 out of 5); copper – up to 3.0 times (2 out of 5).

• In dam release N 2: dry residue – up to 1.1 times (1 year out of 5); sulfates – up to 1.3 times (1 out of 5); nitrate ion – up to 1.8 times (4 out of 5); nitrite ion – up to 2.6 times (2 out of 5); iron – up to 1.3 times (1 out of 5); vanadium – up to 1.4 times (1 out of 5); copper – up to 2.0 times (1 out of 5); oil products – up to 2.2 times (3 out of 5).

• Filtration through the eastern dam: dry residue – up to 1.1 times (1 year out of 5); sulfates – up to 1.4 times (1 out of 5); nitrate ion – up to 1.8 times (5 out of 5); nitrite ion – up to 4.0 times (3 out of 5); iron – up to 1.4 times (1 out of 5); copper – up to 3.0 times (1 out of 5); oil products – up to 2.2 times (2 out of 5).

When conducting mining operations, explosives, containing high concentrations of nitrates, are used, which are also a characteristic pollutant and have significant excesses. For explosions, ammonium nitrate with a nitrogen content of up to 30 % is used. Every year, the enterprise uses thousands of tons of explosives, and, accordingly, thousands of tons of nitrogen enter the environment.

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Table 3

The results of natural waters control at the river Vyya

Composition indicators	MPC_f* for water bodies, mg/dm^3	Background concentrations, mg/dm^3	The content of pollutants in the control section (after all outlets), mg/dm^3
Suspended solids	+0.75 to the background	3.0	3.0
Dry residue	–	67.7	315.0
BOD_{20}	3.0	5.0	4.98
Sulfates	100	4.90	45.0
Nitrate nitrogen (nitrate ion)	9.1	0.99	94.0
Nitrite ion	0.02	0.03	0.055
Vanadium	0.001	0.0015	0.0037
Copper	0.001	0.002	0.0029

* As a criterion for the groundwater pollution degree, the value of the maximum permissible concentration for fishery water bodies (MPC_f) is taken, due to the fact that groundwater in the tailings area is involved in feeding surface water bodies and water-courses of fishery value.

Table 4

Results of groundwater sampling in the area of the tailings

Name of indicator	MPC_f, mg/dm^3	2018		2019		2020	
		Content of components, mg/m^3	MPC ratio	Content of components, mg/m^3	MPC ratio	Content of components, mg/m^3	MPC ratio
Well 9							
Sulfates	100	49.3	–	33.4	–	37.9	–
Chlorides	300	26.0	–	4.86	–	10.2	–
Nitrates	40	3.03	–	2.77	–	0.43	–
Manganese	0.01	1.27	127	0.096	9.6	0.154	15.4
Copper	0.01	0.009	–	0.014	1.4	0.003	–
Iron	0.1	0.466	4.66	0.3	3	3.18	31.8
Zinc	0.01	0.012	1.2	0.014	1.4	0.031	3.1
Vanadium	0.001	0.0664	66.4	0.027	27	0.009	9
Dry residue	1000	232.0	–	53.0	–	172.3	–
Suspended solids	3.25	0.3	–	581.6	179	812.3	250
Well 10							
Sulfates	100	98.1	–	–	–	–	–
Chlorides	300	5.2	–	–	–	–	–
Nitrates	40	3.4	–	–	–	–	–
Manganese	0.01	4.0	400	–	–	–	–
Copper	0.01	0.031	3.1	–	–	–	–
Iron	0.1	0.326	3.26	–	–	–	–
Zinc	0.01	0.034	3.4	–	–	–	–
Vanadium	0.001	0.0328	32.8	–	–	–	–
Dry residue	1000	348.0	–	–	–	–	–
Suspended solids	3.25	2.58	–	–	–	–	–
Well 11							
Sulfates	100	71.3	–	79.3	–	96.6	–
Chlorides	300	3.47	–	8.1	–	12.2	–
Nitrates	40	1.6	–	2.34	–	1.17	–
Manganese	0.01	0.126	12.6	0.058	5.8	0.116	11.6
Copper	0.01	0.022	2.2	0.007	–	0.003	–
Iron	0.1	0.217	2.17	2.83	28.3	1.13	11.3
Zinc	0.01	0.006	–	0.034	3.4	0.009	–
Vanadium	0.001	0.0177	17.7	0.015	15	0.036	36
Dry residue	1000	176.0	–	101.0	–	302.0	–
Suspended solids	3.25	18.98	5.8	545.6	168	812.3	250

Note. As a criterion for the degree of groundwater pollution, it is proposed to take the background well 4-n, due to the fact that some pollutants (for example, copper, manganese, vanadium, iron) are typical for the area, which is associated with numerous ore deposits in the area under consideration and a large number of operating and decommissioned mine workings of various depths and areas, as well as waste storage facilities, wastewater outlets of industrial enterprises.

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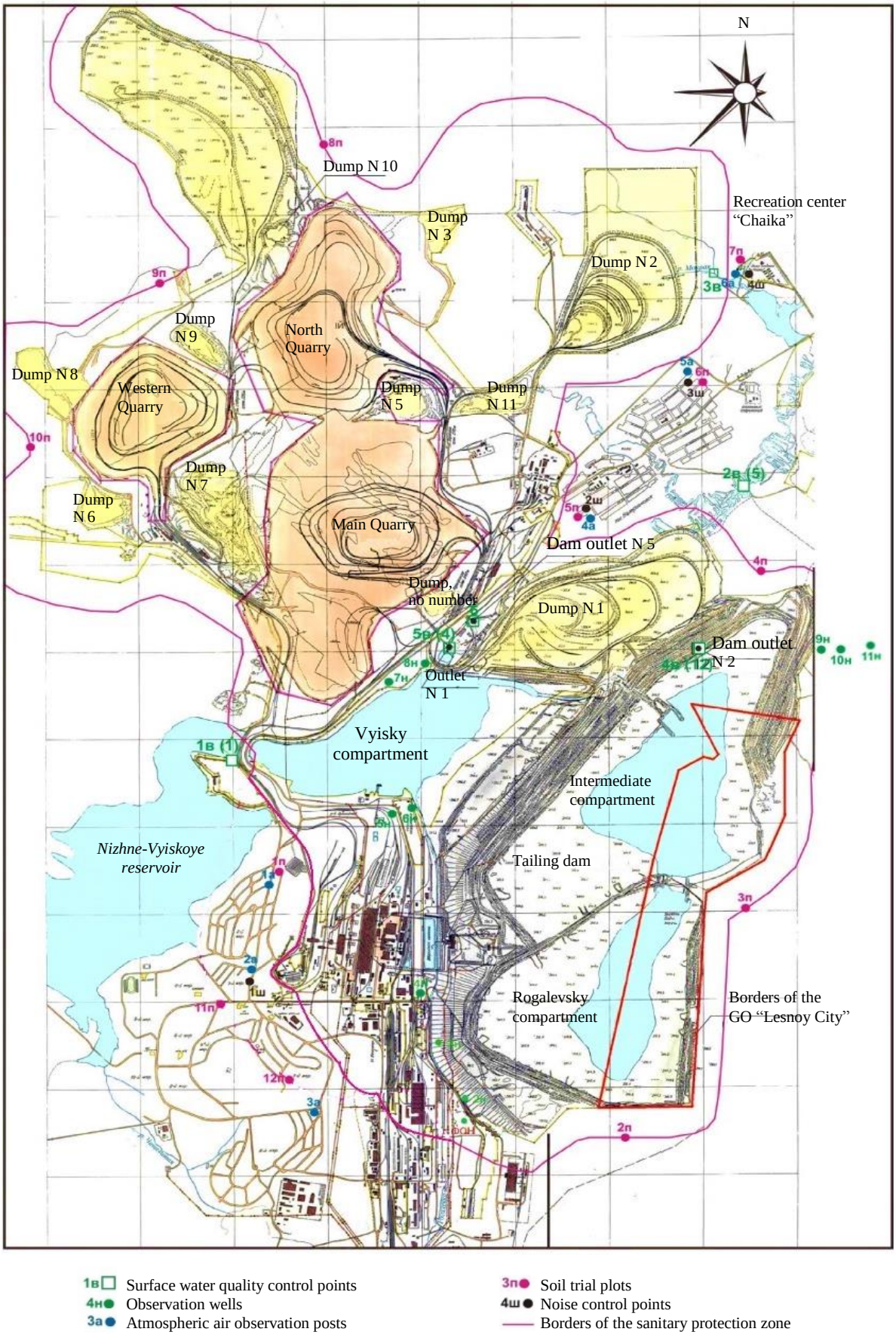


Fig.3. Location of observation points in the monitoring network

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Objective indicators of the level of negative impact of a technogenic object on a watercourse are the background values of pollutants controlled in effluents and the results of analyzes in the control section after all outlets [32-34]. To determine the background concentrations of substances in the rivers, a target located above the outlets of wastewater was taken. Control over the state of the river Vyya after discharges of wastewater from all outlets is made by the enterprise that carries out a survey at a control site located below the outlets. The average annual results of monitoring the natural waters of the river are given in Table 3.

Analysis of Table 3 shows that, compared with the background values of chemicals concentrations in the river Vyya, concentration of the following pollutants in the control section increases: dry residue – by 246.4 mg/l (4.7 times, without exceeding the MPC_f value); sulfates – by 40.13 mg/l (by 9.2 times, without exceeding MPC_f); nitrate nitrogen – by 92.5 mg/l (by 93.5 times); nitrite ion – by 0.05 mg/l (2.5 times); vanadium – by 0.0022 mg/l (2.57 times); copper – by 0.0008 mg/l (1.4 times).

The mechanism of tailings impact on the state of groundwater is the leakage of sludge water through the dam N 1 (outlet of sewage N 2), dam N 2 and the eastern dam (outlets N 3 and 9) in the valley of the river Vyya, where zone of technogenic impact on the state of underground hydrosphere is planned.

The study of groundwater in the area of the tailings is carried out on a network of observation wells specially created for this purpose (Fig.3) [35]. The impact of the tailing dump on groundwater is characterized by the content of pollutants in wells 9, 10 and 11 of the observation network [35]. Testing of these wells was carried out quarterly. The results of testing are presented in Table 4.

The results of studies of groundwater of the regional fracture aquifer, taken in the area of the tailing dump, indicate significant groundwater pollution in terms of the following indicators: manganese (up to 400 MPC), iron (up to 67 MPC), zinc (up to 4 MPC), vanadium (up to 67 MPC), suspended solids (up to 250 MPC).

Conclusion. In hydrogeology, as one of the branches of the Earth sciences, a lot of material has been accumulated for the formation of a new scientific direction on groundwater in waste disposal sites. It has been established that the hydrogeological conditions of groundwater in waste disposal sites are often difficult in terms of the conditions for the costs formation and groundwater quality. The factors of groundwater formation in the WDS, which are associated with the conditions of placement and morphometric parameters, granulometric and chemical composition of the waste, are determined.

Using the example of one of the WDS in the Middle Urals, it is shown that groundwater from waste disposal facilities has a significant negative impact on the surface and underground hydrosphere. Therefore, it is necessary to systematically study hydrogeological conditions of the underground waters of the WDS both at the stage of operation and during the period of waste conservation.

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