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The current state of underground and superficial waters in the area of the liquidated mine *Mgachi* (Sakhalin Island, Russia)

The article is concerned with the hydrogeochemical peculiarities of the underground waters of the liquidated mine *Mgachi*. It has been found that the mine being flooded, technogenic (mine) waters were produced in the exhausted rock mass, which contain hydrocarbonates, sulfates, sodium, iron, mineral oil, zinc, manganese, copper, and chrome exceeding the limits of tolerance. The mineralisation of the mine waters varies between 2.062 and 4.71 g/L. The estimation of the effect the mine waters have on the surface water channels reveals that the flooded mine pollutes considerably the rivers Malyi Sertunai and Rozhdestvenka.

Key words: liquidated mine, polluted underground waters, effect on surface water channels.

Современное состояние подземных и поверхностных вод в районе ликвидированной шахты Мгачи (о. Сахалин, Россия). Тарасенко Ирина Андреевна, к.г.-м.н., старший научный сотрудник лаборатории геохимии Дальневосточного геологического института ДВО РАН, Владивосток; Зиньков Александр Васильевич, профессор, заведующий кафедрой геологии, геофизики и геоэкологии Инженерной школы Дальневосточного федерального университета, Владивосток.

Рассмотрены гидрогеохимические особенности подземных вод в районе ликвидированной шахты Мгачи (Александровск-Сахалинский район, Сахалинская область). Установлено, что после затопления шахты в выработанном горном массиве сформировались техногенные (шахтные) воды, которые характеризуются содержаниями гидрокарбонатов, сульфатов, натрия, железа, нефтепродуктов, цинка, марганца, меди и хрома, превышающими предельно допустимые концентрации. Минерализация шахтных вод колеблется от 2.06 до 4.71 г/дм^3. Оценка влияния техногенных вод на поверхностные водотоки позволила утверждать, что реки Малый Сертунай и Рождественка испытывают значительное экологическое воздействие со стороны затопленной шахты.

Ключевые слова: ликвидированная шахта, загрязненные подземные воды, влияние на поверхностные водотоки.

Introduction

Liquidation of the unprofitable coal mines became a mass phenomenon practically all over the territory of the Russian Federation [1]. Sakhalin region turned to be no exception in this regard.

At present, most of coal mines of Sakhalin have been closed down, water pumping in them has been stopped, and mining enterprises, that for many decades drained the vast adjacent areas, have been flooded up to the level of the natural marks of the underground water surface.

Flooding of coal mines became comparable with the natural geological processes proceeding in the hydrolithosphere upper part. Study of these processes is within the field of the interests of hydrogeochemistry of the hypergenesis zone – an actively developing scientific direction. Flooding of big volumes of the underground mine workings is a poorly studied factor of the technogenic action on the Earth's interior and a ground complex of natural objects. So, study of the chemical composition of underground waters of the liquidated coal mines and specific features of their formation is of great importance for solving the problems of the exogenic geological activity of natural waters and for the quantitative estimation of the hydrosphere pollution processes.

The aim of this work was a complex study of the underground water composition of the Mgachi liquidated mine and estimation of the influence of the flowing-out mine waters on the surface water channels.

Geological conditions

The Mgachi mine was put into operation in 1938 and developed the resources of the Mgachinsky carboniferous deposit localized in Aleksandrovsk-Sakhalinsky area of Sakhalin region at 2 km of the Tatar Strait (Fig. 1).

The deposit relief is controlled by its restriction to the western foothills of Kamyshoviy Ridge and its main spur – Brusnichnyi Ridge extended in meridional direction [4]. All main rivers of the district (Rozhdestvenka and Bolshoi and Malyi Sertunai) rise in Kamyshovyi Ridge and discharge into the Tatar Strait. On their way the rivers take the waters of abundant creeks and nameless springs, whose valleys strongly dismember the watershed. All rivers are the fishing reservoirs of the highest category and are spawning for many valuable fish species.

The deposit geological structure involves a sedimentary complex of the Cretaceous, Neogene, and Quaternary rocks (Fig. 1). The deposit structure is of a graben-sincline type. The greatest submergence is observed in the Bolshoi and Malyi Sertunai interfluve where the Neogene deposit thickness reaches 850 m. To the north and south, the fold bend gently rises, and the thickness of the deposits is successively reduced. In the cross section the Mgachinskaya synclinal fold shows almost symmetrical structure. On the limbs, rocks dip at the angle of 25^o to 35^o, and in some cases to 50^o–60^o [8].

The industrial coal content of the deposit is confined to Verkhneduiskaya suite containing 9 workable beds. The coal beds have for the most part low- and medium thickness.

The coals of the deposit are predominantly lustrous and semi-lustrous. Semi-dull and dull coals, whose glance decreases due to a higher content of a mineral admixture, are insignificant in amount. The mineral admixtures are represented by fine-dispersed clayey matter, terrigenous quartz, and infiltration calcite. Siderite and pyrite micro-balls are found. A total content of mineral components varies from 3 to 18 % [4].

Hydrogeologycal conditions

The Mgachi carboniferous deposit is restricted to the Mgachinsky artesian basin of the West-Sakhalin anticlinorium. In mode of feeding, discharge, occurrence, and circulation the following complexes are distinguished in the sedimentary rocks: water-bearing horizon of the Quaternary deposits, water-bearing complex of the Upper-Middle Miocene deposits, and water-bearing complex of the Upper Cretaceous deposits [3].

The water-bearing horizon of the Quaternary deposits occurs ubiquitously. Its thickness varies from 0.4 to 8 m increasing in the river and creek valleys to 40–45 m. On the slopes of coniform mountains the deposits are represented mainly by talus loams with rock debris and gruss of bedrocks, and the river alluvium is composed of lenses of sand and coarse gravel with mud and loam.

Collectors show the lensing bedding, so the water-bearing horizon contains a few underground waters and does not influence the flooding of the mine workings.

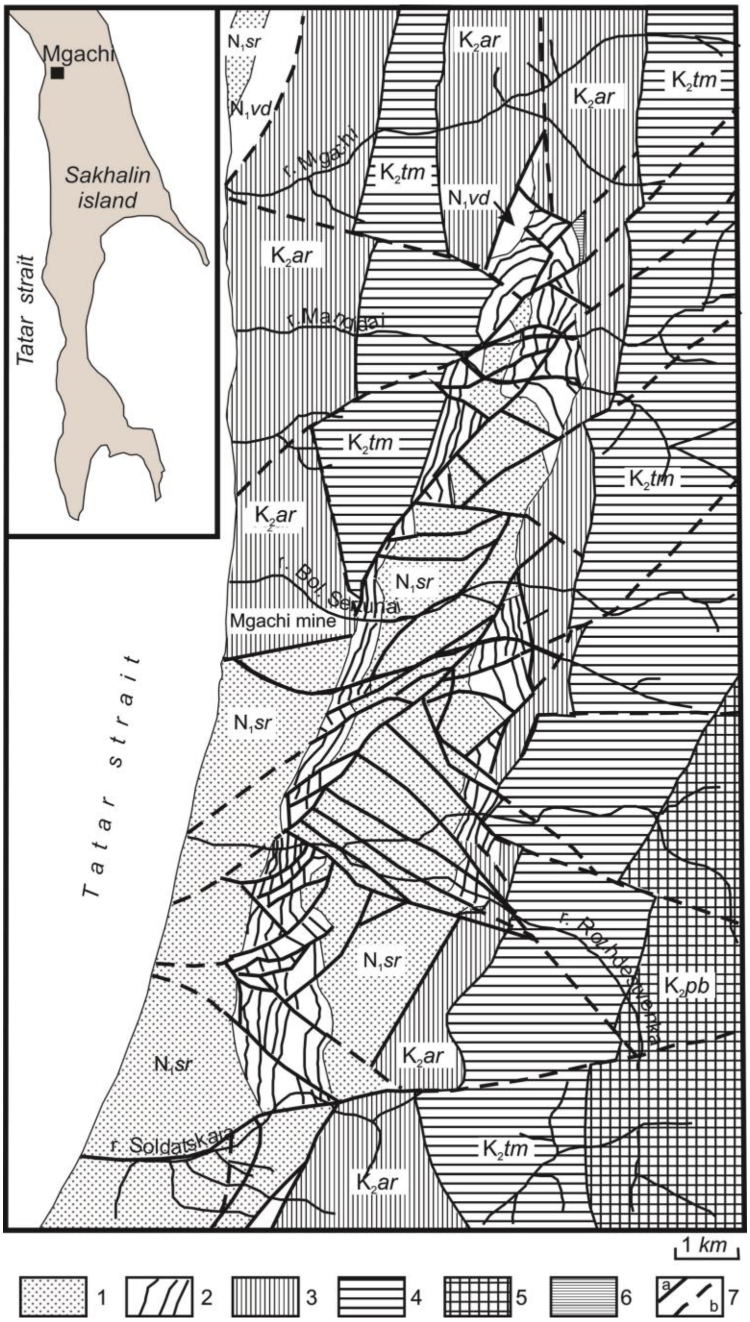

Fig. 1. Schematic geological map of the Mgachi deposit (Coal base of Russia, 1999 with changes): 1–2 – Neogene deposits: 1 – Sertunaiskaya (N_1*sr*) and 2 – Verkhneduiskaya with coal beds (N_1*vd*) suites; 3–5 – Upper Cretaceous deposits: 3 – Arkovskaya (K_2*ar*), 4 – Tymovskaya (K_2*tm*), and 5 – Pobedinskaya (K_2*pb*) suites; 6 – andesibasalts (N_1); 7 – main dislocations with a break in continuity: recognized (a) and supposed (b)

The Upper-Middle Miocene water-bearing complex plays the main role in the flooding of the deposit mine workings. It occurs throughout the deposit area. The water-hosting rocks are fractured sandstones, siltstones, and coal beds. Two water-bearing zones have been distinguished in the complex: a zone of the active water exchange, developed to a depth of 100–150 m, and a zone of the hampered water exchange – below a depth of 150 m. The atmospheric precipitation predominates in the feeding of the upper water-bearing zone. The lower water-bearing zone is the source of the flooding of mine workings at horizons of 130 and 250 m. It is confined to the zones of tectonic dislocations, sandstones, and coal beds. Its feeding source is water of the upper zone and water-bearing complex of the Upper Cretaceous deposits.

The water-bearing complex of the Upper Cretaceous deposits underlies and borders the Mgachinskaya syncline. The water-hosting rocks are the sandstones of different-degree jointing, conglomerates, and more rarely the siltstones of the Arkovskaya and Tymovskaya suites. Due to the presence in the section of the water-resisting siltstones about 30–40 m thick, the complex is subdivided into two water-bearing zones that occur locally and are interrelated. The water conductivity coefficients range from 1.49 (upper zone) to 0.064 m^2/day (lower zone), and debits are 0.026 to 0.001 L/day [3].

During the mine work, an average many-year inflow was 290 m^3/an hour. All waters of the deposit had a hydrocarbonate-chloride calcic-sodic composition. The mineralization varied from 0.09 g/L to 0.79 g/L. In the hardness degree the waters were determined to be very soft (0.4 mg-equiv/L) to moderately hard (5.68 mg-equiv/L). The waters are not aggressive; pH ranged from 6.8 to 9.1 [3].

Thus, the main sources of the flooding of the worked-out space of the Mgachi mine were the atmospheric precipitation and underground waters of the Upper-Middle Miocene water-bearing complex.

The production activity at the mine was stopped in May 1997. At that time the water pumping was also stopped, and the flooding of the mine workings began.

In May 2000 in the wild area of the Rozhdestvenka spawning River, at a distance of about 4.5 km from the mouth, the mine waters discharged onto the surface from the worked-out space of the syncline eastern limb. The mine water discharge was observed from the break incline № 499 with an absolute mark of the mine working mouth of +48.5 m. The discharging debit ranged from 60 to 250 m^3/hour. The water violent stream flew into the river fluvial plain resulted in its flooding at the area 150 m long and 50–100 m wide [7].

The second discharge of mine waters was fixed in the “Nadezhda” adit mouth, liquidated as early in 50s. The mine mouth mark is +43.0 m. The mine water flew from the slope along the kitchen gardens and empted into the Malyi Sertunai River.

Besides, the dispersed discharges of the mine waters were observed in the Malyi Sertunai river bed (left flange) at a mark of +35.0 m and in the Bolshoi Sertunai river flood plain (surface mark is +46 m) at the extension of more than 100 m. It is suggested that at these areas the mine waters discharge along the coal beds ending under the overburdens.

In the places, where the mine waters flew out and discharged, there was a strong hydrogen sulfide smell, a white salt coating was observed on the river gravels, and the river beds were covered with brown flocks of iron hydroxides.

As there were no hydrogeological observation holes on the claim, the absolute mark of the underground water level been recovered in the Mgachi mine area was taken from the mark of the mine water discharge onto the surface (+48 m).

Methods

The pit waters of the liquidated Mgachi mine were sampled from workings (break incline № 499 and “Nadezhda” adit), surface channels crossing the mine field from east to west (the Malyi Sertunai, Bol’shoi Sertunai, and Rozhdestvenka rivers), from the dispersed discharges of underground waters, and sources of the non-central water supply.

For all samples the field chemical analysis has been done and the laboratory research has been carried out (full chemical analysis with determination of microcomponents).

Water sampling for the laboratory investigation was performed in accordance with the current standards on the methods agreed with the laboratory that performed the analyses. The base laboratory was that accredited by The State Standard of Russia – “Primorskoe Hydrometric Agency” of the Federal Survey of Russia on Hydrometeorology and Environment Monitoring (Vladivostok, Russia).

The field method was used to determine the organoleptic factors, pH, total hardness, main ions (chlorides, sulfides, hydrocarbonates, calcium), and biogenic matters (ammonium, iron); the calculation method was used to determine the mineralization, dry residuum, magnesium, and total sodium and potassium.

Evaluation of the ecological situation was done by comparison of the results of analyses with the maximum permissible concentrations (MPC) in accordance with the List of MPC for fishing water reservoirs and Sanitary Rules and Norms 2.1.4. 1074-01 “Potable water. Hygienic requirements …” [5, 6].

The micromorphology and chemical composition of mineral new formations, sampled in the place of discharge of the mine underground waters, were studied using the scanning electron microscope ZEISS EVO 50XVP equipped with the X-ray energy-dispersion spectrometer INCA Energy 350. Microscopy researches were carried out in the regimes of the secondary and reflected electrons at the accelerating voltage of 20 kV and beam currents of $n \cdot 10^{-12}$. The results of the quantitative calculations were normalized to 100.

The degree of balance of the Mgachi mine waters with respect to different original and secondary minerals was calculated using the AquaChem Program Complex 5.1 [2].

Results

Hydrogeochemistry of underground waters

To study the hydrochemical features of underground waters we sampled the waters in the following sites:

- well on the slope surface, Mgachi settlement, background sample;
- well in the Malyi Sertunai River fluvial plain, near the place of the mine water discharge;
- break incline № 499 localized in the Rozhdestvenka River fluvial plain;
- “Nadezhda” adit localized in the Malyi Sertunai River fluvial plain.

As a result we have obtained the characteristics of the underground waters of the water-bearing horizon of the Quaternary deposits and the technogenic horizon of the Mgachi mine.

It was established that the water, sampled from the well, localized on the slope surface in Mgachi settlement, is fresh (total dissolved solods (TDS) – 0.05 g/L), neutral (pH=6.2), very soft (hardness 0.33 mg-equiv/L), and in its chemical composition it is hydrocarbonaceous-chloride-sulfate and magnesium-sodic. The excesses of the maximum permissible concentrations of iron (2.3 MPC) were fixed in the well water.

The water from the well, localized in the Malyi Sertunai River fluvial plain, in its chemical composition is hydrocarbonaceous-sulfate chloride and magnesium-calcic-sodic. The excesses of the maximum-permissible concentrations of the components analyzed have not been detected.

The study of the Mgachi mine waters flowing out onto the day surface showed that the waters flowing from break incline № 499 are neutral (pH=7.0) and belong to the group of subsaline ones (TDS – 4.71 g/L), moderately hard (water hardness – 4.2 mg-equiv./L). In chemical composition the waters are hydrocarbonaceous-sulfate sodic: $M_{4,71} \dfrac{SO_4{}^{51} HCO_3{}^{47} Cl^{2}}{(Na+K)^{86} Mg^{7} Ca^{6}}$.

Water flowing out from “Nadezhda” adit is also neutral (pH = 8.0) and belongs to the group of subsaline ones, but has lower mineralization – 2.06–2.94 g/L and hardness – 2.1 mg/L (soft waters). In ion composition the waters are sulfate-hydrocarbonaceous sodic or hydrocarbonaceous-sulfate sodic. Typical formulae of the salt composition are as follows:

$$M_{2.06}\frac{HCO_3^{52}SO_4^{46}Cl^2}{(Na+K)^{91}Ca^6Mg^2} \text{ and } M_{2,94}\frac{SO_4^{51}HCO_3^{47}Cl^1}{(Na+K)^{91}Mg^5Ca^4}.$$

During the observations the variations of the chemical composition of "Nadezhda" adit waters towards the hydrocarbonaceous calcic-sodic and chloride-hydrocarbonaceous sodic waters were fixed.

Thus, it was established that in the worked-out space of the Mgachi mine four types of waters are formed: hydrocarbonaceous-sulfate sodic; sulfate-hydrocarbonaceous sodic; hydrocarbonaceous calcic-sodic, and chloride-hydrocarbonaceous sodic (Fig. 2).

Comparison of the quality indices of the mine underground waters with the maximally permissible concentrations testifies that the underground water flowing out from break incline № 499 is characterized by the elevated contents of iron (49.5 MPC), sulfates (14.5 MPC), sodium (about 10 MPC), hydrocarbonates (1.4 MPC), as well as by high mineralization (4 MPC). Besides, the elevated concentrations of manganese (27.8 MPC), zinc (8.7 MPC), hexavalent chrome (3.7 MPC), phenols (6.6 MPC), and oil products (1.3 MPC) were found.

The underground water flowing out from the "Nadezhda" adit is somewhat better in qualitative characteristics. The excess of the permissible concentrations were marked for contents of sulfates (6.0 MPC), sodium (4 MPC), iron (5 MPC), and mineralization (2.1 MPC). Among other indices, not-corresponding to the normative requirements, are those for the contents of manganese (10.9 MPC), copper (6.3 MPC), zinc (3.5 MPC), phenols (3.3 MPC), hexavalent chrome (2.9 MPC), and oil products (1.9 MPC).

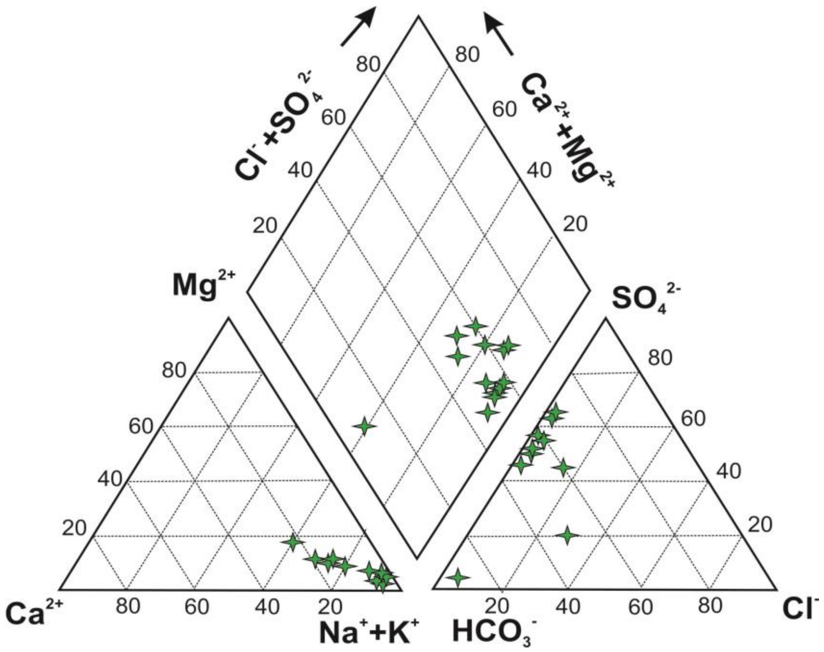

Fig. 2. Hydrochemical types of the Mgachi mine underground waters

To study the chemical composition of the mine waters it is advisable to estimate the character and degree of the balance of underground waters with a wide spectrum of minerals (alumosilicates, carbonates, sulfates, oxides, hydroxides, etc.).

In the mine workings flooded with water there is the unbalance between the water solution and the original minerals of the rock, and at the same time, when the mine water flows out onto the earth surface, there is the balance between the water solution and hypergene new formations. The minerals, with which the water solution is in balance, are formed from the solution unbalanced to the original minerals.

To study the mineral-forming ability of mine waters we used the AquaChem program for the physicochemical calculations and analysis of the position of mine waters on the diagrams of the mineral stability. We have established that through the enclosing rock hydrolysis at the initial stage the mine waters are in balance with kaolinite. Probably due to the increasing rate of the water exchange (abundant precipitation), with decreasing mineralization and pH of underground waters the kaolinite, developed on many alumosilicates, is transformed into gibbsite. Increasing pH and mineralization result into migration of the figurative points of underground waters at first to the fields of Mg-chlorite and Ca- and Mg-montmorillonite and then with increasing mineralization – to the fields of Na-montmorillonite and analcime [7, 8]. As montmorillonite can't bind the total Ca and Mg, released through the hydrolysis of endogenous alumosilicates, its contents in the water solution grow, because the water-rock reactions are still in progress, and this results into the formation of calcite, dolomite and magnesite (Fig. 3) in addition to montmorillonite. The calculations of the extent of the water saturation with calcite show that the Mgachi mine underground waters are enriched in carbonaceous salts of calcium and are in balance with calcite. So, under conditions of interaction of underground waters with rock masses of the liquidated mine carbonaceous salts is not solved but formed that was confirmed by mineralogical methods of investigations also.

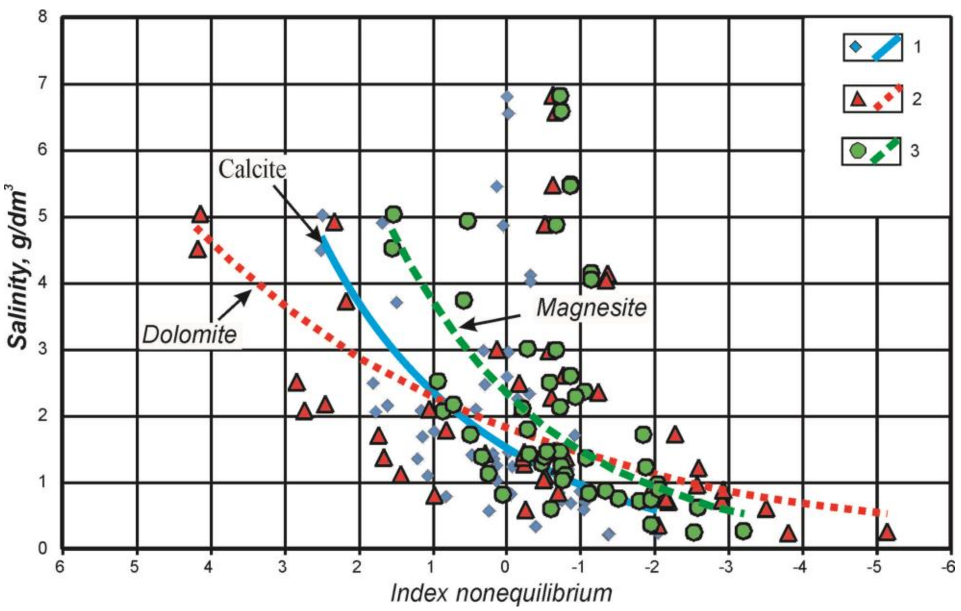

Fig. 3. Dependence of values of indexes nonequilibrium calcite (1), dolomite (2) and magnesite (3) from a mineralization of underground waters

All issues of mine waters are accompanied by the formation of abundant sediments that are the natural-technogenic today hydrogen mineral new formations of a sedimentary type, the study of which is an important task for revealing the specific features of the mine water formation.

The study of the mineral new formations in the places of the mine water issues showed that morphologically they represent highly dispersive ochreous formations dominated by ferrihydrite and goethite. Most widespread are secondary alumosilicates represented by clay varieties.

Secondary carbonaceous formations are polymineral mixtures dominated by nesquehonite ($MgCO_3 \cdot 3H_2O$) and calcite ($CaCO_3$). Aragonite ($CaCO_3$), siderite ($FeCO_3$), and dolomite ($CaMg(CO_3)_2$) are also found. Associated with them are sulfate minerals: thenardite (Na_2SO_4) and astrakhanite ($Na_2Mg(SO_4)_2 \cdot 5H_2O$), identified with X-ray diffractometer D8 Discover.The study of the sample micromorphology revealed their crystalline form diversity (Fig. 4).

Thus, the analysis of the factual material showed that most of the original alumosilicates, composing the rocks (sandstones, siltstones) of the Mgachi coal deposit, are not in balance with waters of the Upper-Middle Miocene water-bearing complex playing the most significant role in the flooding of the Mgachi mine workings. They are capable to solve with the formation of the secondary minerals (kaolinite, montmorillonite, iillite, gibbsite, calcite, and others). In this case, a major portion of chemical elements, entering the solution at the expense of the incongruent dissolution of the original minerals, are bound by the secondary products, and another portion (mobile elements) is concentrated in the solution producing the technogenic (mine) waters that are the main source of the natural water pollution.

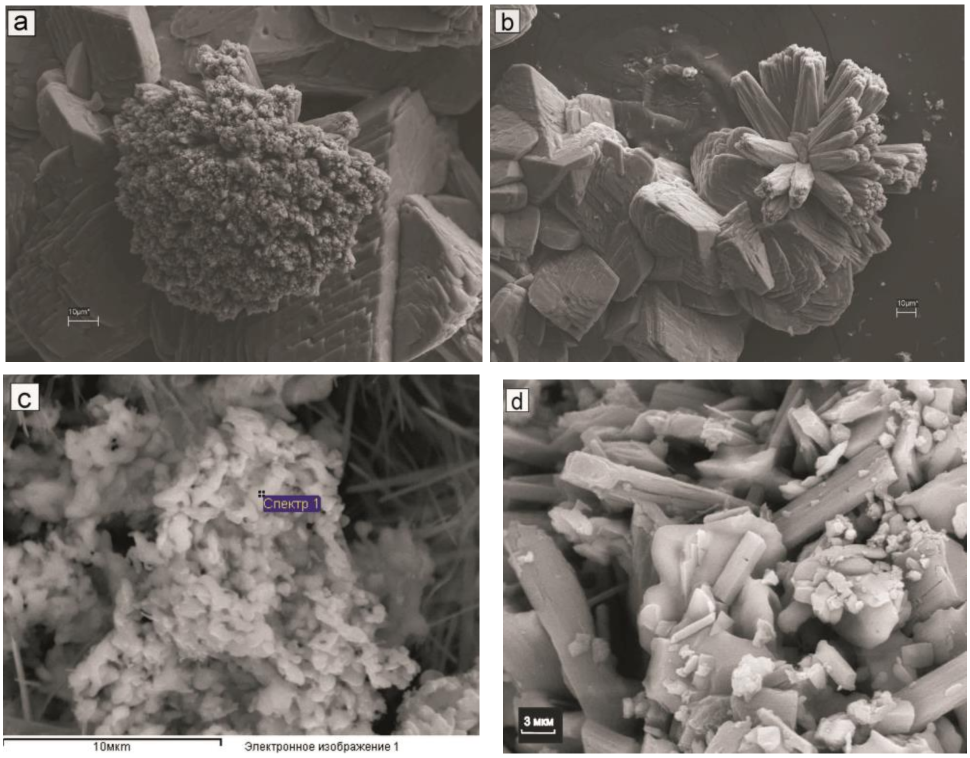

Fig. 4. Specific features of micromorphology of mineral new formations in the places of outflows of the Mgachi mine underground waters: a, b – crystals of aragonite on the dolomite; c, d – thenardite and nesquehonite

Hydrochemistry of surface waters.

To determine the ecological action of the Mgachi mine underground waters on the surface waters we sampled the following channels crossing the mine field from east to west: the Malyi Sertunai, Bolshoi Sertunai, and Rozhdestvenka rivers.

Malyi Sertunai River. A set of the mine objects are within the river drainage area: the main industrial field, the liquidated mine workings, and rock dumps. Besides, the river flows across Mgachi settlement, and upstream from the settlement there is a small operating bay of the open mining works. In the settlement area, the underground waters of the “Nadezhda” liquidated adit are flowing out and run into the Malyi Sertunai River. In the river bed, several dispersed sites of the underground water discharge are available also.

Analysis of the material obtained showed that the background waters of the Malyi Sertunai River are rather fresh (mineralization – 0.1 g/L), very soft (hardness – 0.96 mg/L), and neutral in hydrogen index (pH=7.5). In chemical composition the waters are hydrocarbonaceous magnesium-sodic-calcic.

Downstream, after receiving the run-offs from the industrial bay, the water quality remains practically without changes in both physicochemical properties and ion composition.

Ahead the place of the falling of the “Nadezhda” mine water into the river, there is a zone of the underground water discharge represented by several sites of the water dispersed outflow in the river bed and on its flanges. In the site of the dispersed outflow the underground waters are similar in mineralization and ion composition to the waters flowing out from "Nadezhda" adit. In mineralization degree (2.62 g/L) the waters belong to the group of subsaline waters and in chemical composition – to sulfate-hydrocarbonaceous calcic-sodic ones. In this case, the water contains rather high concentration of practically all main ions, with the exception of chlorine.

In the Malyi Sertunai River waters, due to their mixing with the underground waters flowing out onto the surface, we observed the increased against the background concentrations of sulfates (4 times), hydrocarbonates (1.5 times), sodium (3 times), and mineralization (2 times). In the ion composition, an equivalent share of sulfates and sodium increases, and in chemical type the Malyi Sertunai River waters become sulfate-hydrocarbonaceous magnesium-calcic-sodic.

Downstream from the site of the underground water discharge (downstream of the place where the "Nadezhda" adit outflows enter the river), the polluted water is diluted with the surface one; however, the mineralization and contents of sulfates, hydrocarbonates, and sodium remain rather higher against the background values, and the water chemical type is sulfate-hydrocarbonaceous calcic-sodic (Fig. 5).

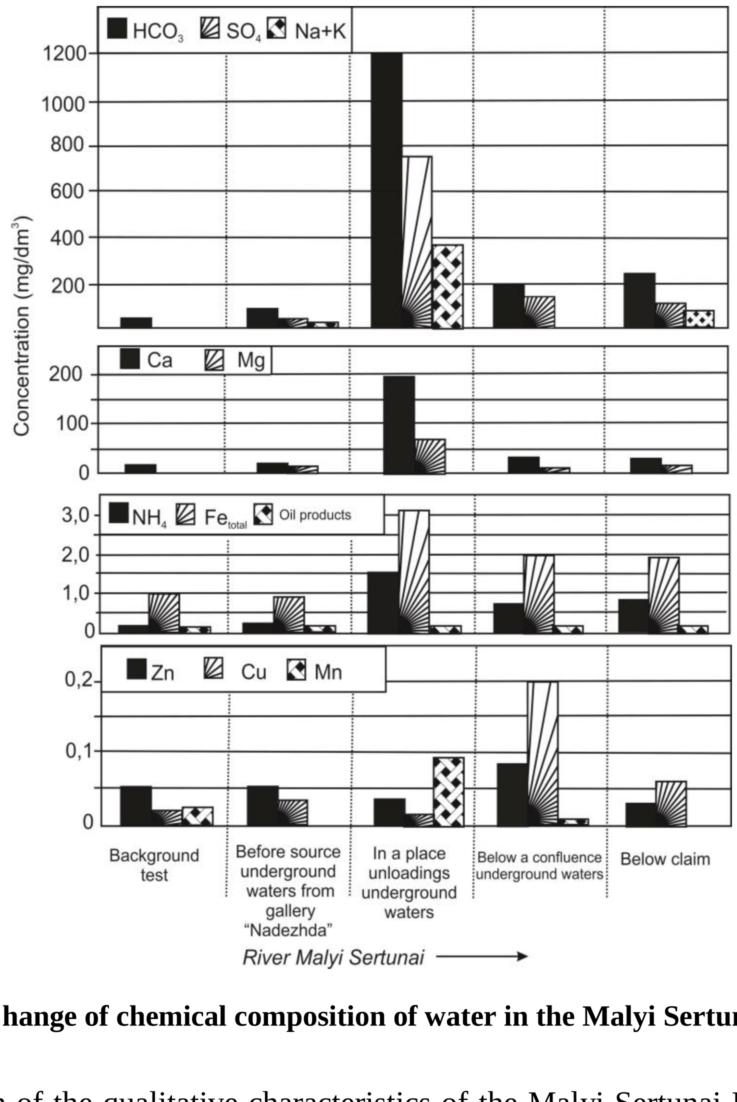

Fig. 5. Change of chemical composition of water in the Malyi Sertunai River

A comparison of the qualitative characteristics of the Malyi Sertunai River waters with the maximally permissible concentrations showed that the river background waters contain higher amounts of phenols (3.1 MPC), oil products (2 MPC), iron (10.1 MPC), zinc (4.9 MPC), copper (2.8 MPC), manganese (2.4 MPC), and hexavalent chrome (2 MPC).

The lowest quality of the water is observed in the site of the underground water discharge. Mineralization here reaches 2.6 MPC, contents of hydrocarbonates – 1.2 MPC, sulfates – 7.5 MPC, calcium – 1.1 MPC, magnesium – 1.9 MPC, sodium – 3 MPC, ammonium nitrogen – 3.2 MPC, iron – 31.5 MPC, oil products – 4.2 MPC, zinc – 3.1 MPC, copper – 3.4 MPC, manganese – 9.8 MPC, chrome – 2 MPC.

Downstream, at the boundary of the mine allocation, the quality of the river water becomes significantly better: contents of hydrocarbonates, calcium, sodium, magnesium (Fig. 5), and mineralization are fixed within the permissible values. However, the exceeding of the maximally permissible concentrations in the river is marked for the contents of sulfates (1.1 MPC), iron (20 MPC), ammonium nitrogen (1.6 MPC), phenols (4.6 MPC), oil products (2.9 MPC), zinc (2.8 MPC), and copper (12.2 MPC).

Thus, the main source of the water pollution in the Malyi Sertunai River are the Mgachi mine underground waters. However, the water composition is influenced not only by the water outflow from “Nadezhda” adit, but also by the sites of the dispersed discharge of underground waters in the river bed and its flanges.

Rozhdestvenka River is in the southern part of the mine field. The river bed lies on the woody land, practically not cultivated. Any settlements are absent within the river drainage area. The main source of the anthropogenic action on the water channel is the mine water outflow from break incline № 499 localized on the river right bank. Downstream, the Rozhdestvenka River receives the waters of the Noyami River, in whose up-stream there are several liquidated mine workings.

Interpretation of the data available testifies that the background waters of the Rozhdestvenka River are rather fresh (mineralization 0.12 g/L), very soft, and neutral in the hydrogen index (pH = 7.1). In chemical composition the water type is hydrocarbonaceous magnesium-sodic-calcic. In the background sample, the excess of the permissible concentrations was detected for the contents of iron (6 MPC), phenols (6.1 MPC), oil products (15.4 MPC), zinc (2.8 MPC), and copper (2.5 MPC).

Downstream, below the place where the underground waters, flowing out from break incline № 499, fall into the river, the mineralization increases 3 to 4 times, the equivalent portion of sulfates and sodium also grows, in this case the cation composition becomes to be dominated by sodium ions, and sulfate ions rank next to them. Correspondingly, the water ion type becomes sulfate-hydrocarbonaceous sodic:

$$M_{0.31}\frac{HCO_3^{62}SO_4^{31}Cl^{7}}{(Na+K)^{68}Ca^{17}Mg^{14}} \text{ and } M_{0.48}\frac{HCO_3^{49}SO_4^{46}Cl^{5}}{(Na+K)^{75}Ca^{14}Mg^{10}}.$$

Contents of iron increase to 9 MPC, phenols – to 18.6 MPC, zinc – to 4.8 MPC, and copper – to 3.2 MPC.

Downstream the Rozhdestvenka River, below the claim and below its interflow with the Noyami River the water quality in the Rozhdestvenka River ameliorates.

The contents of sulfates, hydrocarbonates, sodium (Fig. 6), as well as the mineralization decrease, however, continue to exceed the background values. Sulfate content reaches 1.1 MPC, iron – 7 MPC, oil products – 9.5 MPC, zinc – 4.6 MPC, and copper – 60 MPC.

The water quality in the Noyami River, above its interflow with the Rozhdestvenka River, corresponds to that of the natural surface waters both in ion composition and in physicochemical properties. The Noyami River waters are rather fresh (mineralization 0.14 g/L), very soft, neutral, and in chemical composition they are hydrocarbonaceous magnesium-sodic-calcic. In spite of the fact, that the Noyami River crosses the claim, it does not influence the water quality in the river.

Thus, the analysis of the surface water quality in the Rozhdestvenka River basin allowed the statement that the main source of pollution of the water channel are the underground waters flowing out from break incline № 499, that results in the deterioration of the water chemical composition in the river and change of its ion type and physicochemical properties.

Bol'shoi Sertunai River is in the south of the Mgachi Mine allocation. The river bed lies on the woody not-populated land. Above the claim there is the water intake of the settlement. The main source of the anthropogenic action on the water quality in the river is the dispersed area of the underground water discharge sites.

Interpretation of the data obtained showed that the background waters in the Bol'shoi Sertunai River are rather fresh (mineralization is 0.13 g/L), very soft (hardness – 1.12 mg-equiv./L), and neutral in the hydrogen index (pH = 7.5). The water ion composition is typical of the natural surface waters of the region – hydrocarbonaceous magnesium-sodic-calcic.

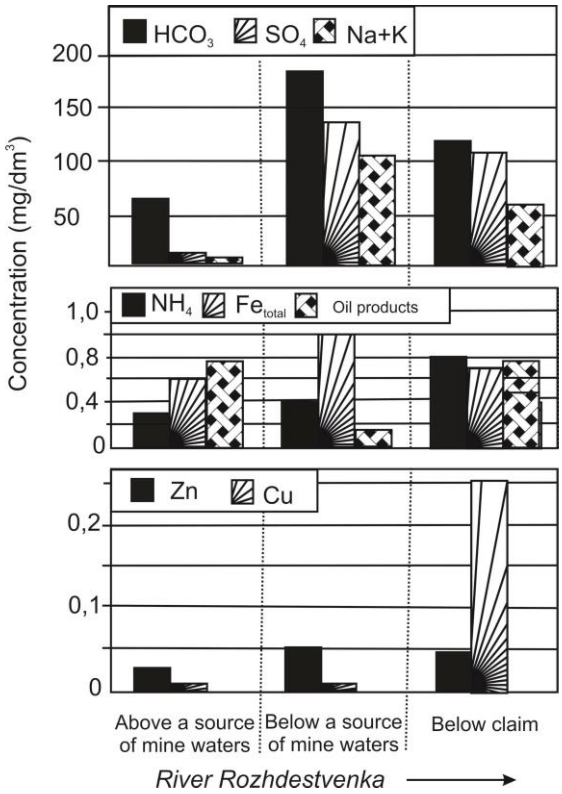

Fig. 6. Change of qualitative characteristics of water in the Rozhdestvenka River

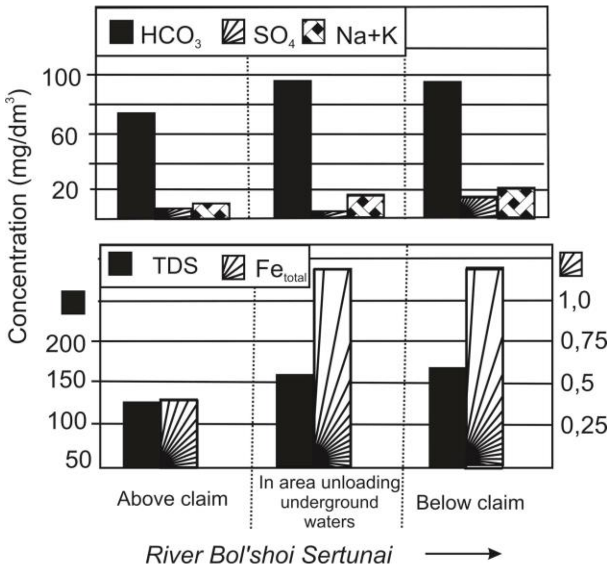

Fig. 7. Change of contents of mineral matters, iron, sulfates, sodium with potassium (in sum), and hydrocarbonates in water of the Bolshoi Sertunai River

Downstream, in the area of the underground water discharge, the water mineralization and the concentrations of hydrocarbonates, sulfates, and sodium increase insignificantly (Fig. 7). The contents of all sited components, however, are within the permissible values. As compared with the background sample, the iron content grows significantly from 0.36 mg/dm^3 (3.6 MPC) to 1.14 mg/L (11.4 MPC). In addition, the influence of underground waters manifests itself in the change of the water ion composition – the cation composition becomes to be dominated by sodium ions, and water type becomes magnesium-calcic-sodic.

The microcomponents in the background waters of the Bol'shoi Sertunai River are represented by rather high concentrations of phenols (3.3 MPC), oil products (6 MPC), zinc (3.5 MPC), and copper (28 MPC). Downstream of the claim, the list of the contaminants remains in total the same. The contents of oil products increase to 7.7 MPC, copper – to 44 MPC, and manganese to 3.6 MPC. It is possible that the source of these contaminants are the underground waters. At the same time, the phenol and zinc contents decrease.

Thus, interpreting the data obtained we can state that the dispersed outflow of the underground waters into the Bolshoi Sertunai River bed does not influence essentially the water quality. This is probably explained by an insignificant volume of the underground waters coming into the river.

Conclusions

The interpretation of the results, obtained through the study of the underground water composition of the Mgachi liquidated mine and through the estimation of the influence of the flowing-out mine waters on the surface water channels, allow the following conclusions.

• In the process of liquidation of the mine in the broken mountain massif the underground (mine) waters were formed; they significantly differ from the natural waters in the ion type, chemical composition, and organoleptic properties.

•In the worked-out space of the mine, four types of waters are formed: hydrocarbonaceous calcic-sodic, sulfate-hydrocarbonaceous sodic, hydrocarbonaceous-sulfate sodic, and chloride-hydrocarbonaceous sodic.

• As compared to the natural waters the mine waters contain higher mineralization (2.06–4.71 g/L) and components (hydrocarbonates, sulfates, sodium, iron, oil products, zinc, manganese, copper, and chrome) whose amounts exceed MPC being the contaminants of the environment.

• The Mgachi underground waters are not in balance with most of original (endogenous) minerals composing the rocks of the Mgachi coal deposit (sandstones, siltstones, etc.), and dissolve them forming the secondary minerals (kaolinite, montmorillonite, illite, gibbsite, calcite, and so on).

• Morphologically the mineral new formations in the sites of the mine water outflows are the highly dispersed ochreous minerals dominated by ferrihydrite and goetite. Most widespread are the secondary alumosilicates represented by clay varieties.

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