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TECHNICAL REPORT

BAIKAL BASIN TRANSBOUNDARY DIAGNOSTIC ANALYSIS

Surface waters pollution in the hot spots in the Russian territory in the basin of Lake Baikal including the Selenga River Delta

2013

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CONTENTS

ABBREVIATIONS AND ACRONYMS

CFU	Colony Forming Unit
IWBM	Integrated Water Basin Management
SAP	Strategic Action Programme
TDA	Transboundary Diagnostic Analysis
UNDP	United Nations Development Programme
UNOPS	United Nations Office for Project Services

SUMMARY

At its inflow to Lake Baikal the Selenga River represents the largest freshwater delta in the world occupying a territory of 680 sq km. To a great extent it determines the purity of Lake Baikal waters due to intensive self-purification and sedimentation processes taking place in it. The Selenga delta, one of the largest freshwater deltas in the world was included into the Ramsar List of Wetlands of International Importance (Wetlands) in 1994. The delta is a unique natural entity where organic and biogenic continental off-flow transforms both qualitatively and quantitatively due to intensive biotic turnover (of productional-destructional processes), various physical and chemical factors including substance exchange in the water-ground system. It serves as a natural biological filter protecting the lake from the impact of polluted river waters arriving from the catchment area. In its lower reaches the Selenga river splits into numerous branches forming a vast delta with the total area of 1120 sq km [Bogoyavlenskii, 1974]. The most intensive splitting of the main channel is observed downstream from the Murzino settlement where the lower delta begins occupying the area of about 600 sq km, most of which (85 %) is intermittently flooded. The transforming and purifying role of the Selenga delta is at its maximum during the spring-summer period and is minimal in winter. The main accumulators of chemical substances in water passages are submerged aquatic vegetation, phytoplankton, phytobenthos and bacterial plankton, the development of which is limited by the duration of the warm season. In the last decade climate changes in Lake Baikal basin are accompanied with the reduction of aqueous run-off leading to the decrease of the self-purification ability of the river, increase of pollutants' concentration, intensification of bacterial plankton and phytoplankton development. These derangements are most distinctively seen in the periods of extremely low water content. For instance, in July 2003 discharge of water of the river Selenga equaled just 52 % of the monthly norm. As a result, the ion sink of the river dropped to 0.34 million tons despite the elevated mineralization indexes at July average values of 0.48-0.51 million tons. In average in the period from 1996 to 2005 the ion sink of the Selenga was 20 % below the norm due to low water content. In the most low flow year 2002 it was 32 % below the norm [Sinyukovich et al, 2010]. Under these conditions the development of phytoplankton reached values characteristic of hyper-eutrophic water bodies [Sorokovikova et al, 2009]. Based on the long-term studies conducted by the research teams from the Baikal Institute of Nature Management and the Limnological Institute of the Siberian Branch of the Russian Academy of Sciences in the period from 2001 to present the most representational water sampling stations in the lower reaches of the Selenga and the delta branches were selected (Fig. 1).

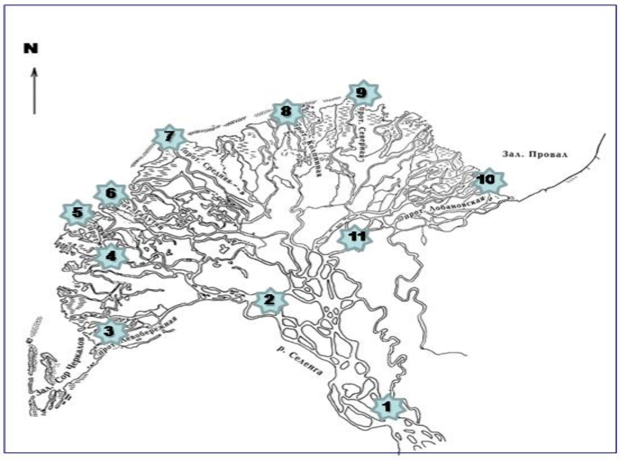

Fig. 1. Schematic map of water sampling

Measurements of the water discharge rates and sample collection for the analysis of various chemical components (dissolved gases, pH, principle ions, biogenic elements, heavy metals, organic compounds) were carried out at selected stations. Simultaneously, samples were taken for the determination of numerosity, biomass and species diversity of bacterial and phytoplankton at the same stations. For the evaluation of water quality and a possibility to select additional sampling stations monthly studies along the Kharauz, the main branch of the delta were carried out from its confluence with the delta to its inflow to Lake Baikal.

The hydrological characteristics

For the fulfillment of hydrological objectives measurements of water discharge rates were carried out on the main branches of the delta in the beginning of their cutoff from the main river channel. Despite some peculiarities of the river off-flow distribution between the branches depending on the water content level it is generally plausible to say that until recently the bulk of the river off-flow (50-55 % in summer and up to 90 % in winter) still goes through the left part of the delta. The most profluent stream in the right part of the delta is the Lobanovskaya branch (about 30 % of off-flow during the summer period and about 10 % in winter). The least inundated was the central sector of the delta (the Kolpinnaya and Srednyaya branches) through which about 3 % of the river off-flow went. From the middle of winter to springtime these branches usually freeze through and there is practically no off-flow here. Taking into account earlier scientific works and based on the results of the conducted research it is plausible to state that beginning from 1973 the changes in the distribution of the Selenga river off-flow in its delta had a directed character manifested in the reduction of the “transit” role of the southern arm of the delta in general and the main river channel in particular. After 1993 these phenomena considerably weakened. Possibly, this fact is explained by the low water content of the Selenga in the following years, during which no rare floods were registered. Relatively small water rises, including that in July 2012, contributed to insignificant variations of the general distribution pattern of the Selenga’s off-flow in its delta, at least for the discharge rate not exceeding 1400-1500 cubic meters/sec. In general, their role in the off-flow transit over the last 15-20 years even grew a little (by 3-4 %) mostly at the expense of the Levoberezhnaya branch. The most significant redistribution of the off-flow took part in the northern part of the delta where the Dologan branch is nowadays the most profluent stream. Its share in the total off-flow of the river Selenga grew up in the period after 1993. At the same time the off-flow through the Galutai, Srednyaya and Kolpinnaya branches grew up. Simultaneously, the off-flow through the Lobanovskaya branch decreased threefold.

The sanitary and microbiological characteristics

Over the observation period in 2012 the level of total coliforming bacteria exceeded the permissible norms set by the sanitation and epidemiological control for drinking water because the standard level presupposes absence of total coliforming bacteria in 100 ml of water. In autumn the total coliforming bacteria levels decreased (1-168 CFU/1 ml) (CFU- colony forming unit) but their presence in water was permanent. Over the recent years [Sorokovikova et al., 1995, 2005] the number of coliforming bacteria has been steadily growing up in the examined area. This is connected with the intensive agricultural activity and intake of industrial and residential waste waters along the entire length of the river. Maximum values exceeded even the norms for public water supply (not more than 1000 CFU/100 ml) as well as norms for recreational water use (not more than 500 CFU/100 ml) [Water. Sanitary Regulations and Standards, 2004]. Presence of the Enterococcus bacterium genus is an additional microbial contamination index. If their number is over 50 in 100 ml of water an excremental contamination intake and a potential epidemiological danger are presupposed. The number of bacteria of the Enterococcus genus changed within 12-56 CFU/100 ml in summer and 8-50 CFU/100 ml in autumn. In summer the maximum values were detected in the Kharauz branch waters, in autumn they were detected in the Srednyaya branch.

The hydrochemical characteristics

The conducted studies showed that regardless of a season water temperature is 1-1.5˚ C lower at the mouth of the delta (the Murzino settlement) than in the branches of the central part and the estuary. Besides, the temperature varies approximately by 0.5-1.0˚ C in large and small branches of the delta. In July, during the increase of water content the water temperature in all branches was the same 20.3˚ C. In autumn the temperature varied within 7.3-8.8˚ C range. Gas conditions and pH media in the branches were favorable for the life sustenance of aquatic organisms. Oxygen concentrations did not drop lower that 7.3 mg/l and pH value varied within 7.88-8.90 range. The electric conductivity index in the water of the delta branches varied from 118 to 178 mS/m. Its maximum values were observed in October, while minimal values were registered in mid-July.

Concentrations of principle ions HCO^{3-}, SO_4^{2-}, Cl-, Ca2+, Mg2+, Na+ и K+ in the water of the delta branches varied within 65-96.4, 6.9-10.2, 0.6-1.2, 15.1-19.9, 2.9-5.1, 3.7-6.2, K+ - 1.1-1.5 mg/l. The water of the branches as well as of the river Selenga is related to hydrocarbonate class, calcium group (Fig. 1). According to the seasons of the year and the length of branches the relative composition of ions remains constant. Slight variations of the relative water composition in large and small branches may be connected with the specifics of water exchange in them.

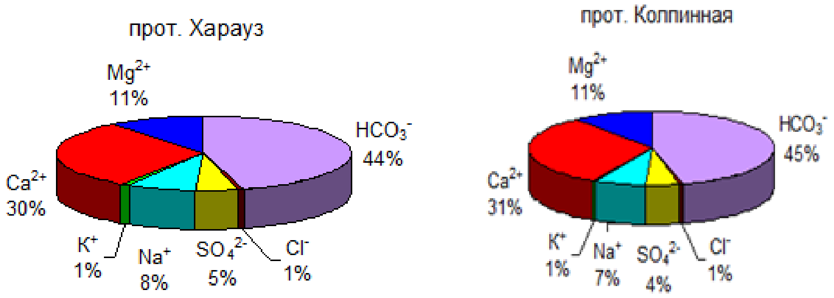

Fig. 1 Relative ion composition in the water of the Selenga delta's branches, 2012 % equivalent.

Concentrations of biogenic elements in the water varied within a wide range, and the maximum values of mineral nitrogen sum (0.50 mg N/l), total and inorganic phosphorus (139 and 24 µg P/l) reached rather high values corresponding to those in the excessively trophic water bodies. Water quality in the branches mainly fell into the categories of "rather clean" and "moderately contaminated" according to the content of biogenic elements and organic substances. Total iron in the examined water samples varied within the interval 63-88 µg/l. Zinc concentrations varied from 0 to 0.2 µg/l. Cadmium concentrations varied from 0.2 to 0.3 µg/l and were within the allowable concentrations and did not exceed the MPC for fishery water bodies. The elevated concentration of iron is characteristic of almost all water sampling stations. Manganese concentration in the examined waters varied within 3-27 µg/l. Specifically high concentrations of manganese were found in the branches of the central part of the delta, Severnaya, Srednyaya and Kolpinnaya. It should be noted that the increased contents of iron and manganese are characteristic of wetland areas due to vegetation decomposition. An elevated content of copper was noted in the Kharauz branch (2 µg/l). Zinc concentrations varied from 0 to 0.2 µg/l, cadmium – from 0.2 to 0.3 µg/l and were within the allowable concentrations and did not exceed the MPC for fishery water bodies. Changes of water content conditions of the river exercised considerable influence. Heavy metals' concentration in the surface water significantly decreased due to a diluting effect, contents of iron and manganese dropped five to tenfold, copper twofold to threefold, zinc from 8 to 12 times in comparison with 2003. On the background of low values of heavy metals contents in the surface waters of the branches of the Selenga a reduction of their concentrations in benthic deposits in the summer-autumn period of 2012 was observed. For the first time the composition the lipidic components (various fatty acids, aldehyds and sterols) in the benthic sediments of the Selenga's branches was determined by the GS-MS (Gas Chromatography-Mass Spectrometry) method. Over 100 compounds were found. Among them specific lipidic markers enabling to identify various groups of microorganisms were determined. Also a screening of the microbial community was carried out using the method of Mass Spectrometry of microbial markers. On the basis of assay content of lipidic markers the microbial composition of benthic sediments was determined. The analysis of lipidic components of the samples demonstrated that some of them may be related to quite certain geni and even species of microorganisms. Representatives of *Firmicutes, Proteobacteria, Actinobacteria u Cyanobacteria* gens play the leading role in the formation of the qualitative composition of the community. In 2012 in the main channel and delta branches 112 species of plankton algae were found. Among them there were 16 blue-green (Cyanobacteriae) algae, 3 Dinophysis, 2 Cryptophytic, 8 Chrysophyceae, 22 diatomic algae, 3 Euglenophyta, and 56 green algae. Very poor development of blue-green algae is a characteristic feature of the Selenga's phytoplankton. It is caused by a significant turbidity of water that contains a mass of SPM of mostly mineral origin and a high river flow rate. In July 2012 a high flood was observed that had an effect on the composition and quantitative indexes of phytoplankton. In the water of the main river channel a large number of mineral SPM was detected. Water transparency was very low and did not exceed 15 cm. This led to a reduction of the quantity of parvicellular centric diatomic algae in comparison with the dry years [Popovskaya, Tashlykova, 2008]. The development of phytoplankton during the elevated water content in the Selenga corresponded to an oligotrophic type of water bodies. The biomass did not exceed 1 g/cubic m. The saprobity index in the main channel and delta branches varied from 1.6 to 2.4, which corresponded to the 3rd class of purity (moderately contaminated). The elevated content of microorganisms, including pathogenic microbial flora is indicative of a low water quality and a necessity to limit its use for recreational purposes.

INTRODUCTION

An elevated content level of some heavy metals, such as copper, zinc, lead and iron connected with the specificities of Transbaikalian geological province is characteristic of the basin of Lake Baikal. In regionally mined coals there are also elevated contents of heavy metals and rare-earth elements. Therefore, slags, cinder dumps of thermal stations and boiler-houses of the region are dangerous for surface and underground waters. Emissions of the same thermal stations and boiler-houses also contaminate the environment since pollution of soils with heavy metals takes place.
Thus it is extremely difficult to separate natural anomalies from an anthropogenic heavy metals contamination.
According to the methodology – [1,2,3] the following "hot spots" are singled out
On a map:
Title: The Territory of Catchment Area of the River Selenga
1:5000000
Descriptive text:
Conventional signs
Populated areas
Nation's capital
Subject of the Russian Federation's capital
Cities
Boundaries
State
Of the Selenga basin
Railroads
Sources of technogeneous pollution
Contaminated territories

POLLUTION HOT SPOTS

The town of Baikalsk, Baikalsk Pulp and Paper Mill

In Lake Baikal basin there currently functions the Baikalsk Pulp and Paper Mill (BPPM) located right on the shore of Lake Baikal in a town of Baikalsk. Discharge of industrial effluents, after insufficient treatment, is produced right into Lake Baikal. The Baikalsk Pulp and Paper Mill resumed operation in 2010. However, even when the pulp and paper mill was out of operation it still produced discharges of drainage into the lake since the waste treatment facilities of the Baikal Pulp and Paper Mill also treat sewage water from the town of Baikalsk.
In 2011 defects in water quality of Lake Baikal were registered according to the content of sulphate-ions in August and October up to 1.2 maximum permissible concentrations (MPC); chloride-ions in April and August up to 1.7 – 1.9 MPC and up to 2.6 MPC in October, volatile phenols up to 2 MPC during the entire observation period, and in February and June – up to 3 MPC. Elevated concentrations of a mineral substances sum were detected only in October. In 2011 in all surveys violations in lake water quality in the monitoring section were detected. In 2010 violations were detected only in five out of nine conducted surveys. Lake water was most polluted in October 2011. At the same period in 50 selected water samples the content of non-sulphate sulphur was within 0.3-0.4 mg/l.

In comparison with the period when the mill was closed down (2009), in 2011 maximal concentrations of the sum of mineral substances, including sulphates and chlorides increased. Frequency of volatile phenols detection also increased. In 2009 when the mill was closed down violations of lake water quality were conditioned only by the discharge of ordinary sewage water, which sometimes was detected based on an increase of volatile phenols concentration in the lake water to 2-3 MPC. In this way, resumption of discharge of industrial effluents of the Baikalsk Pulp and Paper Mill caused a decrease in water quality of Lake Baikal by the monitoring section located in 100 meters from the deep-water scattering discharge of the mill's industrial effluents.

It seems obvious that the Baikalsk Pulp and Paper Mill remains the most serious pollution threat for surface and underground waters of Baikal ecosystem in the Central Ecological Zone of the Baikal Natural Territory. The Baikalsk Pulp and Paper Mill will be taken into account, but will not be a focus of attention due to the current efforts of the government to finance a closed system of re-circulating water and a considerable public pressure aimed at a closure or at least a significant improvement of environmental management at the enterprise.

Slyudyanka industrial hub – the town of Slyudyanka, Kultuk and Vydrino villages, village of Bol'shoe Goloustnoe

These towns are situated right on the shore of Lake Baikal and their sewage waters get immediately into the lake. Here cargo ports are concentrated increasing chances of petrochemical pollution. Besides, railroad works (repair depots and terminals) function, there is also a concentration of warehouses and transportation facilities of many enterprises operating in this region, and fuel storage depots. Marble, mica, break-stone and sand and gravel mix extraction is underway too. In the town of Slyudyanka there are industrial enterprises producing cement and they remain major sources of environmental pollution. There are also a large railway station and small boiler-houses. The area of pollution distribution from the town of Slyudyanka approximately equals 20 sq km while a considerable part of polluting fallout takes place over the water area of Lake Baikal.

In 2011 the Baikalsk Center for meteorology and monitoring of environment conducted a research in the south Baikal area encompassing the village of Kultuk and town of Slyudyanka. In comparison with the water of open Baikal and the Selenga shallow waters in the area of Kultuk and Slyudyanka a relatively elevated content of biogeneous elements was found. Their average content in the water was as follows: total nitrogen – 0.186 mg/l; organic nitrogen – 0.176 mg/l; nitrate nitrogen – 0.03 mg/l: ammonium nitrogen – 0.01 mg/l; total phosphorus: organic phosphorus – 0.008 mg/l: phosphates – 0.006 mg/l. In the water of this region the nitrite nitrogen was detected within the limits from 0.000 - 0.003 mg/l. Number of water samples containing nitrite nitrogen equal to 0.002 – 0.003 mg/l figured up to 19 per cent. In water sampling points located closer to Kultuk village nitrite nitrogen was found more often.

An average petrochemicals concentration in 2011 equaled 0.01 mg/l and a maximum one was 0.03 mg/l (June, village Bol'shoe Goloustnoe). Maximum concentrations of volatile phenols were equal to 0.002 mg/l in 2011. Elevated concentrations of volatile phenols were detected in the area of Vydrino and Kultuk villages in April.

There is a great influence of these settlements located on the shore of Lake Baikal on the quality of surface and underground waters. The available waste treatment facilities are old and in bad condition, waste treatment technologies are obsolete and unable to provide standard treatment of sewage waters discharged directly into Lake Baikal, creeks and small rivers flowing into the lake.

The town of Babushkin

According to [5] waste treatment facilities of the town of Babushkin are in an advanced state of disrepair. They are unable to provide a proper purification of sewage coming jointly to these waste treatment facilities. Frequency of MPC excesses by phenols in the Mysovka river flowing through the town made up 52 per cent in 2011 (45.4 per cent in 2010). Industrial enterprises of Babushkin mainly servicing the Trans-Siberian railroad together with the local population discharge petrochemicals, heavy metals, phenols and sulphates into Lake Baikal.

The town of Zakamensk

In ecological respect the territories of Zakamensk and of the former Dzhida tungsten and molybdenum plant are the most troubled parts of the Baikal Natural Territory.

The Dzhida plant was in operation for over 60 years and ceased its activity in 1996 due to unprofitability of production under the new economic conditions. With discontinuation of the plant's activities the negative impact of its wastes on the environment and the population not only did not decrease, but significantly grew. The tungsten and molybdenum ores processed by the plant contain dangerous elements of the second and third classes, such as lead, zinc, fluorine, molybdenum, beryllium, tungsten, ruthenium, and cesium. The technology of extraction of the tungsten concentrate presupposed the use of sulphuric acid, xanthate and kerosene.

During the operation period of the plant 44.5 million tons of tailings were formed. For many years they have been a source of pollution of the town of Zakamensk.

At present inoperative objects of the plant, such as rock dumps, drainage mine waters, tailings dump, etc. continue to create high technogenic pressures on the environment. A pollutants complex and the intensity of contamination of the surface waters of the Gudzhirka creek (a left-hand tributary of the

Myrgenshena) in the influence zone of “Pervomaiskii” mine are determined by the following indicators: sulphate-ion, sodium-ion, lead, fluorine – up to 6 MPC; zinc, cobalt, nickel – up to 20 MPC; copper – up to 60 MPC; manganese and cadmium – up to 500 MPC and more. Water reaction is acidic (pH 4.5-5.4). Surface waters in the estuary of the Inkur river (a right-hand tribute of the Modonkul) where mine waters drain contain cobalt, copper, and lead within the MPC, cadmium and chrome in concentrations from 3 to 5 MPC.
Waters filter out from the tailings dump contain fluorine with about 20 mg/l concentration, iron – over 8 mg/l, Cd, Mo, Li, Pb within the frameworks of 1 to 5 MPC. They pollute surface and underground waters in the estuary of the Modonkul river. The Modonkul is a small tributary of the Dzhida. It carries the heaviest man-induced impact on the territory of Buryatia. Disorderly discharges of mine waters and drainage of the inactive JSC “Dzhidakombinat” are carried out into the Modonkul. Mines waters, drainage waters and stormwater runoffs from the tailings dumps contain large amounts of metals, fluorine, and sulphates and considerably influence the quality of water in the river Modonkul in both cross sections (2 km above the town of Zakamensk and down the river from Zakamensk, in 1 km lower the discharge point of sewage waters of water treatment facilities). In the estuarial cross section there is also influence of sewage waters of the municipal waste treatment facilities belonging to the Municipal Unitary Enterprise for Housing and Communal Services (hereinafter – MUE HCS) “Zakamensk”. Copper, zinc, total iron and fluorine are the critical indicators of pollution.
Observations were carried out in two cross sections, 2 km up the river from Zakamensk and 1.3 km down the river from the town, 1 km above the estuary. Water mineralization changed from low (176 mg/cubic decimeter) to elevated (864 mg/cubic decimeter). In this period the concentration of sulphates was 2.1 MPC. Medium reaction changed from neutral (7.01 points pH) to slightly alkaline (7.97 pH). Excess of MPC was observed according to 9 ingredients of chemical water composition out of 14 considered. Fluorides and total iron brought in the largest share into a general evaluation of water pollution. Four cases of high pollution were registered (over 10 MPC). The water contamination rate in the cross section up the river from the city with copper, zinc, total iron, fluorides and easily oxidable organic substances is estimated as characteristic. The water contamination rate with phenols is estimated as persistent. The maximum concentration reached the following values: copper – 7.4 MPC, zinc – 1.3 MPC, total iron – 21.5 MPC, phenols – 2 MPC, easily oxidable organic substances – 1.3 MPC.
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Photo: Influx of shaft waters into Modonkul river (by E. Batotsyrenov)

Water contamination rate in the river at the cross section down the town with copper, zinc, total iron, fluorides, phenol, resistant to oxidation organics and sulphates is estimated as characteristic, while that with easily oxidable organic substances and nitrogen of the nitrites – as unstable. The maximum concentrations reached the following values: copper – 4.0 MPC, zinc – 1.4 MPC, total iron – 13.4 MPC, phenols 0.2 MPC, resistant to oxidization organics – 1.7 MPC, easily oxidable organics – 1.2 MPC, nitrite nitrogen – 1.5 MPC.

Contamination of the Modonkul river flowing through Zakamensk is particularly dangerous because it directly affects drinking water intake from wells and drill holes. Underground waters on the territory of Zakamensk and its vicinity are polluted with iron, fluorine and metals (Cd, Mn, Fe) up to 10 MPC, lead is detected at the level of 10 MPC, concentrations of sulphate-ion (300-330 mg/cubic decimeter) and calcium-ion (100-120 mg/cubic decimeter) are elevated. Pollution of drinking water with heavy metals negatively affects population's health.

Photo: Ettles of "Dzhidakombinat" with technogenic lake (by E. Batotsyrenov)

Photo: Mengen-Sheno river (by E. Batotsyrenov)

The area of the ecologically troubled territory is 867 hectares, including 452 hectares in Zakamensk (68.53 per cent of the total town area).
Water passageways of the Dzhida river basin (the rivers Inkur, Barun-Naryn, Zun-Naryn, Modonkul, Gudzhirka and Myrgen-Sheno are the most polluted in the basin of Lake Baikal.
At present at the Kholtoson and Inkur deposits in the basins of right tributaries of the Dzhida (the Modonkul and Myrgenshena rivers) a restoration of the earlier operational mining objects of the Dzhida tungsten and molybdenum plant of JSC “Dzhidakombinat” is underway as well as a construction of new plant sites, a modern ore mill and hydrometallurgical facility for processing of tungsten headings.

Lake Gusinoe. The town of Gusinoozersk

Before the 1990s the Gusinoozersk basin was an area of intense brown coal mining in the Republic of Buryatia. The development of the deposit was carried out by “Kholboldzhinskii” coal strip mine and “Gusinoozerskaya” mine along the shore of Lake Gusinoe. Nowadays the mine is closed down. However, on the “Kholboldzhinskii” coal strip mine there are still 1596 hectares of lands spoiled by mining operations and over 400 hectares are under spoil dumps of overburden rocks with the volumes of dump sites over 260 million cubic meters, which represents the biggest threat of lake contamination.

Pollutants get into the lake, which is a source of water supply for the town of Gusinoozersk, from the area of former coal mining during the filtration of atmospheric precipitation through rock dumps and with drainage (mine) waters. Mineralization of these waters reaches 2 g/cubic dm and more (2 MPC according to Sanitary Regulations and Standards (SanPiN 2.1.4.1074-01 for drinkable waters), total hardness of water – 17-53 mM/cubic dm (2-7 MPC), content of sulphate-ion and sodium-ion – up to 1-3 MPC, manganese – 21 MPC, strontium – 3-4 MPC, aluminum and iron – up to 1,2 MPC. Concentrations of ammoniacal nitrogen were elevated to the MPC level.

In the south-western part of Gusinoozersk a ground subsidence section is formed above the former mine of “Gusinoozerskaya” mine. This causes deformations of apartment houses, cracks in the walls and foundations, sinkholes, deep fractures in the ground. Here also a process of restoration of a cone of depression may take place after a cessation of mine drainage and a chance of flooding of the built-up area cannot be excluded.

The man-induced impact on Lake Gusinoe is very intense: the largest regional power station the Gusinoozerskaya GRES consumes 83.8 per cent of the total surface water abstraction in the Republic of Buryatia. In 2011 a discharge without treatment of warm normative clean waters after cooling of the equipment made up 334.1 million cubic m (in 2010 – 367.9 million cubic m, in 2009 – 288.94 million cubic m, in 2008 – 442.0 million cubic m, in 2006 – 284 million cubic m, in 2005 – 261.1 million cubic m.)

There are other sources of anthropogenic influence on the shores of the lake, such as the town of Gusinoozersk, a railroad station and the village Gusinoe Ozero. Besides thermal discharge of the power station, industrial and storm sewage waters treated to standard quality at waste treatment facilities from the industrial site OJSC “Gusinoozerskaya GRES” as well as sewage waters of the “Baikal Pribor 1” LLC and “ZHEU Gusinoe Ozero” LLC (from the latter the sewage waters get to the lake through the river Tsagan-Gol).

According to the observation data of Buryat Center for hydrometeorology and monitoring of environment in 2011 average annual concentrations of suspended substances amounted to 1.6 MPC in the air of Gusinoozersk. Total emissions of pollutants by stationary sources amounted to 28.172 thousand tons in 2011 (40.272 thousand tons in 2010). Partially getting into the lake, the emissions increase the man-induced impact on the reservoir.

Water quality in Lake Gusinoe in 2011. Water mineralization throughout the year was average. The highest value (358 mg/cubic dm) was observed during the period of closed channel. The pH values varied from 8.20 pH (slightly alkaline) to 8.70 pH (alkaline). Dissolved oxygen level during all hydrological periods was within the standard norm. During the year excess of MPC was registered according to 6 indicators (7 indicators in 2010). Concentration of copper was 5 MPC, total iron – 1.7 MPC, phenols – 2 MPC, easily oxidable organic substances (BOD5) – 1.6 MPC, oxidization resistant organic substances (COD) – 1.8 MPC. Pollution by organic substances was characteristic (according to the BOD and COD indicators); steady pollution by copper and phenols and unstable – by total iron and zinc.

In 2011 according to 2-TP (water supply organization) sewage waters discharge by the industrial enterprises of Gusinoozersk into Lake Gusinoe (“Vodokanal” of Gusinoozersk, a subsidiary of “Baikal Pribor – 1” and OJSC “Gusinoozerskaya GRES”) amounted to 336.5 million cubic m (in

2010 – 367.9 million m). The reduction of sewage water discharge volumes is connected with the reduction of electricity generation by the branch of JSC "OGK-3" "Gusinoozerskaya GRES".

At industrial enterprises of Gusinoozersk in 2011 there formed 399.035 thousand tons of waste (overburden dumps being the 5th class dangerous wastes, i.e. safe, were not considered in the volume of wastes that formed in Gusinoozersk. 395.785 thousand tons of wastes are placed in ash dumps of Phase 1 and 2 of the Gusinoozerskaya GRES. Pollution of Lake Gusinoe led to its degradation swiftly taking place. A direct proof of it is the extinction in 2010-2011 of a clam *Colletopterum sedakovi* sensitive to water quality degradation as well as other clams.

The city of Ulan-Ude

The industrial hub of Ulan-Ude hosts many enterprises, such as the aviation plant, locomotive-repair plant, instrument-making plant, etc., and energy enterprises (CHPP 1 and CHPP 2), food, consumer goods industry, timber manufacturing industry, small furniture production facilities, petroleum depots and numerous gas filling stations.

In 2011 on the territory of Ulan-Ude industrial hub near the sections belonging to the locomotive repair plant there was an excess of MPC by phenols (up to 52.6 mg/cubic dm), fluorine (up to 9.9 mg/cubic dm). Underwater oxidizability exceeded 240.0 mg/cubic dm, the hydrogen indicator reached 9.6 units.

Over the recent several decades the river Selenga is badly polluted by petrochemicals in the area of the glass factory "Steklozavod". The discharge zone length along the bank of the river is over one kilometer. Each year, according to the study results, during the groundwater decrement up to 22 tons of petroleum products get into the river Selenga. Man-made petroleum product plumes had formed as a result of a long-term dissipation of petroleum products from the petroleum bases of the Ministry of the Defense of the USSR and the State Committee of Petroleum Products located in 500 m from the river bank and operational since the 1930s. The object for environmental rehabilitation on the "Steklozavod" zone of Ulan-Ude occupies an area of about 143 hectares and the area of film on the water surface of the Selenga river is about 3 hectares (see photo).

Photo

Pollution of the Selenga by petroleum products near Steklozavod suburb.

The pollutant is predominantly diesel fuel. Voluminous deposits of petroleum hydrocarbons on the level of underground waters on the territory of "Buryatterminal" LLC are estimated at 5682 cubic meters. On the territory of petroleum base of the Ministry of the Defense of the Russian Federation the volumes are estimated at 12844 cubic meters.

Intensity of underground water pollution with heavy and toxic metals is, at the moment, insufficiently controlled. Probability of such pollution is high at many industrial objects. In the area of the main water intake of Ulan-Ude (in the upper part of river-borne aquifer) in the samples from certain drill-holes an elevated concentration of chlorides is observed and this leads to an increase of mineralization to 0.5 g/cubic dm (while the background mineralization should be within 0.11-0.15 g/cubic dm).

Over the recent years in all observation bore holes an elevation of oxidization of underground waters has been traced. In some bore holes petrochemicals pollution is detected within the concentrations 0.88-1.41 mg/cubic dm. At abstraction intakes over certain periods of time some increase of sulphate, chloride and fluorine concentrations is observed, iron and nitrates appear and the mineralization of underground waters in summer is somehow higher than in the winter-spring drought period.

According to the 2-TP data (water supply organization) in 2011 the volume of sewage waters discharge amounted to 30.2 million cubic meters (34.1 million cubic m). Reduction of discharge volumes took place due to a decrease of volumes of manufactured produce of industrial enterprises. "Vodokanal" has two discharge outlets. One is located near Divizionnnaya railway station, another – on the left bank of the river Selenga. Effluent is classified as "insufficiently purified".

In 2012 in Ulan-Ude 282 thousand tons of wastes were produced (not counting businesses producing less than 50 tons of wastes per year). In 2010 this figure was 399.000 (including businesses producing less than 50 tons of wastes per year). In 2011 54.2 thousand tons of wastes were recovered. 452.3 thousand tons of wastes were placed at waste disposal facilities (including wastes accumulated earlier) while 73.8 thousand tons were transferred to other organizations for storing and burial. As of late 2011 144.58 thousand tons of wastes were accumulated at the industrial enterprises of Ulan-Ude.

Industrial and housing and utility activity of industrial enterprises of Ulan-Ude considerably deteriorates the quality of both surface and underground waters. The reason is in an insufficient purification of both industrial and service-utility effluents. Hydrochemical indicators of Selenga water down the river from the city consistently deteriorate according to practically all indicators. In 2011 maximum concentrations of zinc compounds of 1.2 MPC were registered near Mostovoi passing loop (below Ulan-Ude); total iron – 17.2 MPC, copper compounds 4.9 MPC, manganese 11.7 MPC, nitrite nitrogen 1.8 MPC, fluorides 1.8 MPC and oxidization resistant organics – 2.5 MPC, phenols – 3 MPC, petrochemicals – 1>8 MPC. This sharp deterioration of water quality in the Selenga in a cross section down from Ulan-Ude provides grounds to relate it to "hot spots".

The Nizhneselenginskii industrial hub (the villages of Selenginsk, Kamensk, Timlyui)

The main ecological stress is produced by the following enterprises: the Selenginsk Pulp and Paper Mill (CKK), the Timlyui Central Heating and Power Plant, the Timlyui plant of asbestos-cement products, the Kamensk cement plant.

The Selenginsk Pulp and Paper Mill is located in 50 km from Lake Baikal. The production of the main produce (sulphate pulp and container board) is followed by the by-products manufacture of sulphate soap and sulphate turpentine. In its turn, tallow oil and clear turpentine are produced from them. Sulphate pulp is produced with the use of water solutions of NaOH and Na2S. The wastes of the primary production are spent slurry-lignin and tallow oil. Hazardous substances resulting from the technological processes of production determine the complex of pollutants in the underground waters in the footprint of this object. The results of the monitoring of underground waters in a network of bored holes controlling the territory of the Selenginsk Pulp and Paper Mill since 1984 show their steady sulphate contamination in concentrations from 50-100 to 1400 mg/cubic dm in various years. The sulphate contamination is followed by elevated concentrations of sodium chlorine and other macro-components with the increase of mineralization (by dry residues) up to 2 g/cubic dm and more. In underground waters lignin and tallow oil are detected. The petroleum products' contamination of the underground waters progresses and it is connected with the seepage of waste waters containing petrochemicals in concentrations up to 14.0 mg/cubic dm.

At the Selenginsk Pulp and Paper Mill there is a closed water cycle. That is why there is no discharge of industrial waste waters from the industrial site of the mill into natural reservoirs. According to the 2-TP (water-supply organization) in 2011 the waste waters discharge by the industrial enterprises of the villages of Selenginsk and Kamensk amounted to 1.29 million cubic m (1.34 million cubic m in 2010).

In 2011 in the village of Selenginsk 170 thousand tons of wastes were produced (in 2010 – 92 thousand tons). 0.942 thousand tons were placed at the village scrap heap.

In 2011 in the village of Kamensk 221.323 thousand tons of wastes were produced (not counting wastes of economic entities that produce less than 50 tons of wastes a year), 312.057 thousand tons of wastes were produced. 85.97 thousand tons of wastes were utilized. 357 tons were placed at the village scrap heap. As of the end of 2011 137.658 thousand tons of wastes were accumulated at the industrial enterprises of Kamensk.

The Nizhneselenginskii industrial hub is a big polluter of the Selenga river since such large industrial enterprises emit tons of pollutants into the atmospheric air, which then descend on the ground and get washed into the river. Huge amounts of accumulated industrial wastes also contaminate underground waters. Among the polluters the Selenginsk Pulp and Paper Mill should specifically be noted because, despite the closed water cycle, it continues to contaminate the underground waters with its wastes, which also get into the Selenga polluting it with sulphates and chlorine-ion.

The town of Petrovsk-Zabaikalskii

Petrovsk-Zabaikalskii is a large industrial hub with the population of 21.2 thousand people.

At present the metallurgical plant and the glass factory, formerly the main industrial enterprises in town, are inactive. However, ashes, sludge and industrial wastes, accumulated over many years of production still pollute the Balyaga river running further into the Khilok.

Nowadays the town industry is represented by food processors and timber enterprises. Underground water pollution by petrochemicals was earlier detected in the area of petroleum depot in Petrovsk-Zabaikalskii. The content of petrochemicals varied within a wide range (from 0 to 9.2 MPC) and was periodical.

Waste treatment facilities of the industrial enterprises and their territories proper with all sewage systems and chemical substance storehouses continue to affect the quality of underground waters. This also applies to town suburbs lacking amenities. Most often the pollutants are nitrogen-containing substances, such as nitrates, nitrites, and ammonium nitrogen. A high content of nitrates is observed in drinking water in the town of Petrovsk-Zabaikalskii.

As a result of the 70 per cent physical deterioration of equipment of the water treatment facilities and system of sewers the technology of treatment of domestic and industrial waste waters is disregarded. Untreated waste waters are discharged on the terrain and then get into the river Khilok.

The water of the Balyaga was classified as highly polluted. An average annual content of suspended substances twice exceeded the background level. The maximum concentration was observed during spring flood in a cross section 0.5 km down the river from Petrovsk-Zabaikalskii and was 3 times higher that the background value (14.0 mg/cubic dm). Manganese compounds reached 6-17 MPC.

The Kholodninskoe deposit

The Kholodninskoe pyrite-base metal deposit is located in the Northern Cisbaikalia on the territory of the Severobaikalskii district of the Republic of Buryatia in 40 km to the north from the Baikal-Amur Mainline Railway.

According to the content analysis of pollutants carried out by the Baikal Institute of Nature Management of the Siberian Branch of the Russian Academy of Sciences in 2006, the Buryat Center for Hydrometeorology and Monitoring of Environment in 2005, the Institute of Geology of SB RAS in

2007 and a group of international experts “ERM” in the same year 2007 a high content of zinc in adit waters (up to 1700 MPC) was detected as well as high content of sulphates, manganese, magnesium metal, sulphur, cobalt and arsenic. The total area of contaminated soils as a result of dump impact amounts to 15.3 hectares (see photo).


The Kholodninskoe deposit. Photo by Malashkevich.

According to the classification of wastes such soils are related to the 1^{st} and 2^{nd} class of danger for the environment. The water-surface area of the Kholodnaya river exposed to pollution is equal to 1.23 sq km.

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