INTEGRAL ASSESSMENT OF ANTHROPOGENIC PRESSURE ON WATER BODIES IN THE LAKE BAIKAL BASIN

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ABSTRACT

The integrated assessment of the ecological state of the main rivers of the lake Baikal basin - Verkhnyaya Angara, Tyya, Barguzin, Selenga, Snezhnaya, Bolshaya Rechka, Khilok, Chikoy is based on the assessment of the variability of the basin system under the influence of two groups of indicators: 1) Direct (immediate) impact - the volume of water intake and wastewater discharge, water use and sequential water supply. Assessment of the impact on the state of the above-listed rivers basins from wastewater was performed using the algorithm proposed by A. Korolev et al. (2007). 2) Indirect (mediate) impact - indicators of areal and linear-network impacts on the catchment area. Based on the calculation of the integral anthropogenic pressure on the territory of the above-listed river basins, only the Selenga river experiences an “average” anthropogenic load. On the territory of most river basins, the anthropogenic load is “lowered” and “low”.

Keywords: *water assessment, Lake Baikal basin, anthropogenic pressure / load, water quality, wastewater*

INTRODUCTION

The integrated assessment of the ecological state of the main rivers - Verkhnyaya Angara, Tyya, Barguzin, Selenga, Snezhnaya, Bolshaya Rechka, Khilok, Chikoy is based on the assessment of the variability of the basin system under the influence of two groups of indicators:

Direct (immediate) impact - the volume of water intake and wastewater discharge, water use for drinking, industrial, agricultural and other needs, the water consumption of industries, the volume of reverse and sequential water supply.

Indirect (mediate) impact - indicators of areal and linear-network impacts on the catchment area: population size and density, agricultural land structure, industrial and agricultural production in value and kind, volumes of pesticides used in agriculture and the amount of agricultural technology used, length of shipping ways, timing of navigation, cargo volume and others.

METHOD AND METHODOLOGY

Approaches to assessment of the direct effects parameters

Analysis parameters direct impact is made on the basis of information on the use of water facilities industries.

The intensity of the load is determined based on the volumes of abstraction and discharge of water:

high -> 100 million m^3 / year
average - 11-100 million m^3 / year
low - 1-10 million m^3 / year
very low - <1 million m^3 / year
insignificant or absent - 0 m^3 / year.

Assessment of the load from wastewater on water bodies of the state of the river basins Verkhnyaya Angara, Tyya, Barguzin, Selenga, Snezhnaya, Bolshaya Rechka, Khilok, Chikoy was performed using the algorithm proposed by Korolev A.A., Rosenberg G.S., Gelashvili D.B. et al. [1]. To quantify the degree of water bodies pollution as a result of wastewater discharge, the authors propose the calculation of the load factor by wastewater on streams within the river basin.

The load factor by wastewater is defined as a ratio of the volume of wastewater discharged into water bodies of the water-resource region to the average annual water flow within the boundaries of this region:

$$k=qW, \quad (1)$$

where k is the load factor;

q - the total volume of wastewater discharged into the water bodies of the water-resource region, mln. m^3/year;

W - is the average annual water flow in within of the water-resource region, mln. m^3/year.

Below is a diagnostic table for assessing the load from wastewater on water (table 1).

Table 1. Diagnostic table for assessing the load from wastewater on water bodies (WB).

Category of water body according to the degree of load by wastewater	The load factor of wastewater at WB	
	value	load characteristic
I	0.00-0.20	very weak
II	0.20-0.37	weak
III	0.37-0.63	moderate
IV	0.63-0.80	significant
V	0.80-1.00	big
VI	>1	very big

An important characteristic of the ecological state of water bodies is a water quality. Assessment of the water quality of water bodies that are sources for centralized drinking water supply is carried out as part of the system of social and

hygienic monitoring carried out by the territorial departments of the Federal Service for Supervision of Consumer Rights Protection and Human Welfare [2], [3], [4]. As an indicative hygienic indicator characterizing the condition and quality of water of water sources , the proportion of water samples of water sources that do not meet hygienic standards for sanitary-chemical and microbiological indicators is used.

The assessment of the water bodies quality by hygienic indicators was carried out on the basis of data from the State reports on the sanitary-epidemiological situation in the Republic of Buryatia, Irkutsk Region and Trans-Baikal Territory.

Approaches to assessment of the indirect effects parameters

To assess the intensity of anthropogenic load, indicators of indirect (including area) impact are important. The following parameters were used as a basic (main):

- the population density of the territory (person/km^2), characterizing the demographic load on the catchment area;
- the density of industrial production (the volume of industrial production in the region in thousand rubles per 1 km^2) indirectly determines the load from industrial production on the catchment area;
- plowing of the territory (the ratio of the area of arable land to the total area of the basin of the rivers in question, in %), indicates the intensity of use of the territory for agriculture;
- the livestock load (the number of livestock cattle per 1 km^2) determines the intensity of the use of the territory of river basins for the development of livestock.

The plowing of the territory and livestock loading together determine the agricultural load on the territory of the river basins.

For each of the indicators, a conventional scale from 8 steps was adopted (table 2), which was based on the gradation of the main regional indicators of anthropogenic load developed by the Institute for Water and Environmental problems SB RAS as applied to the conditions of Siberian regions [5].

The used indicators are grouped by type of anthropogenic impacts: demographic, industrial and agricultural. The average value of each is estimated as the average level of the corresponding anthropogenic load in the basin of the rivers under consideration. The agricultural load is obtained as the arithmetic average of the scores of the intensity of agricultural (plowing) and livestock loads.

Table 2. The scale of the main indicators of anthropogenic load.

Indicator	Load intensity (points)							
	1	2	3	4	5	6	7	8
	Insignificant	very low	low	reduced	average	increased	high	very high
Population density, people/km^2	0.0	≤ 0.1	0.2-1.0	1.1-5.0	5.1-10.0	10.1-25.0	25.1-50.0	> 50.0
Density industrial production, thousand rubles/km^2	0.0	≤ 10.0	10.1-100.0	100.1-1000.0	1000.1-3000.0	3000.1-4000.0	4000.1-5000.0	> 5000
Ploughness, %	0.0	≤ 0.1	0.2-1.0	1.1-5.0	5.1-15.0	15.1-40.0	40.1-60.0	> 60.0
Livestock load, conditional heads/ km^2	0.0	≤ 0.1	0.2-1.0	1.1-2.0	2.1-3.0	3.1-6.0	6.1-10.0	> 10.0

The total anthropogenic load is defined as the average arithmetic mean value of the points of demographic, industrial and agricultural loads.

RESULTS AND ITS DISCUSSION

The analysis of the direct (immediate) impact factors on water bodies, in the form of natural water intake and wastewater discharges, showed that water bodies of the most economically developed area located along the river Selenga, including Lake Goose are experiencing a relatively high anthropogenic load.

Table 3. Intensity of anthropogenic pressure on water bodies as a result of natural water intake and wastewater discharge (indicators for 2013 year)

Water-resource region code	Natural water intake		Sewage discharge	
	Volume of water intake, million m^3	intensity	volume of water disposal, million m^3	intensity
V. Angara			40.409	average
Tyya			0.860	Very low
Barguzin	4.770	low	1.144	low
Selenga	471.062	high	445.840	high
Snezhnaya			0.0715	Very low
Bolshaya Rechka			0.118	Very low
Khilok	27.430	average		average
Chikoy	3.278	low		

Very low anthropogenic pressure is experienced by water bodies of the rivers Tyya, Snezhnaya, Bolshaya Rechka, Chikoy. Water bodies of other river basins experience medium and low anthropogenic pressure.

The discharge of insufficiently treated or contaminated wastewater is one of the most important reasons for the deterioration of the ecological state of water bodies. Depending on the quantity and quality of wastewater, the assimilating

ability of watercourses and reservoirs, the level of wastewater loading on water bodies is formed, which largely determines their current environmental status.

The anthropogenic load of wastewater on water bodies of river basins is assessed as "very weak", which is explained by the incommensurability of the volume of water flow and the volume of wastewater discharged. All water bodies are assigned to category I according to the degree of loading by sewage (table 4).

Table 4. Parameters of anthropogenic load by the total volume of wastewater at the water-resources regions of the Selenga river basin.

Water body	The average annual runoff, W, mln. m^3/year	Wastewater discharge, q, mln. m^3/year	Load factor q / W	Load characteristic
V. Angara	8450	40.409	0.005	very weak
Tyya	1265	0.860	0.0007	very weak
Barguzin	2240	1.144	0.0005	very weak
Selenga	28729.3	445.840	0.016	very weak
Snezhnaya	193.6	0.0715	0.0003	very weak
Boshaya Rechka	135.6	0.118	0.001	very weak
Chickoy	8452	0.61	0.0001	very weak
Khilok	3106	9.78	0.0031	very weak

Analysis of the parameters of indirect effects.

Industrial load. An integral indicator of industrial load on the area of river basins Verkhnyaya Angara, Tyya, Barguzin, Selenga, Snezhnaya, Bolshaya Rechka, Khilok, Chikoy be an indication of the density of industrial production, defined as the volume produced in the area of industrial production in thousand rubles per 1 km^2.

In accordance with the methodology "System of indicators of socio-economic development of a constituent entity of the Russian Federation (RF)" approved by the head of the Federal State Statistic Service of the RF (Rosstat) on March 23, 2006, the volume of industrial production in the region in monetary terms determines the indicator "Goods of own production shipped, work and services completed on our own for a full range of manufacturers on clean activities of sections C, D, E of OKVED". Data on the cost of goods shipped, work and services performed by city districts and municipal districts of the Verkhnyaya Angara, Tyya, Barguzin, Selenga, Snezhnaya, Bolshaya Rechka, Khilok, Chikoy are provided by the territorial authorities of the Rosstat: Irkutskstat, Buryatstat and Zabakalkraistat.

Industrial load. The density of industrial productivity in the Republic of Buryatia is 221.3 thousand rubles/km^2, respectively, "reduced". The intensity of the load is 4 points. In the river basins of Verkhnyaya Angara and Tyya, the industrial production density was 26.011 thousand rubles/km^2, in the Barguzin river basin -

31.91 thous. rubles/km^2, in the basins of other rivers it is characterized as low and very low.

Agricultural load is defined as an integral indicator of agricultural and livestock loads. An indicator of the agricultural load is the plowing of the territory, livestock - the number of conditional heads of cattle (cattle) per 1 km^2.

Agricultural load. The structure of agricultural land use in river basins is formed by two main types of activity - animal husbandry and crop production.

Livestock is the main branch of agriculture. Crop production is mainly an auxiliary industry providing livestock feed. Most of the agricultural products are accounting for livestock.

The territory of river basins, as a whole, is characterized by a low agricultural load. “Average” agricultural load in the Khilok and Barguzin river basins. In the rest of the basin, the agricultural load is “reduced” (table 5). Livestock load in the river basin Selenga changes from “lowered” to “low”.

In the Upper Angara and Tyya river basins, agricultural development is constrained by harsh climatic conditions. The main livestock sector in the region is dairy cattle breeding, which is relatively less unprofitable in comparison with other sectors of agriculture. The main livestock population is concentrated in personal subsidiary plots of citizens (86 %). A significant amount of agricultural products is produced in personal subsidiary plots of the population.

Table 5. Agricultural load intensity in river basins.

Water body	Plowing			Livestock load		
	%	intensity		conv. heads / km^2	intensity	
		characteristic	points		characteristic	points
V. Angara	0,69	Low	2	0.44	Low	2
Tyya	0,07	low	2	0.4	Low	2
Barguzin	9.9	average	5	0.7	Low	2
Selenga	4.5	lowered	4	3.1	Increased	4
Snezhnaya	0	insignificant	1	3.9	Increased	4
Boshaya Rechka	0	insignificant	1	3.9	increased	4
Chickoy	1.8	lowered	4	0.9	low	3
Khilok	5.5	average	5	1.4	lowered	4

The demographic load in the river basins within the boundaries of the constituent entities of the RF is unevenly distributed. The pattern of resettlement has a distinct ribbon character; settlements are concentrated in the valleys of the Selenga river and its tributaries Uda, Khilok, Chikoy, Dzhida, as well as along the Trans-Siberian Railway, Baikal-Amur Mainline Railway (BAM) and the southern railway to Mongolia.

Within the Selenga river basin, the bulk of the population of Buryatia is concentrated (almost 9/10). The average population density in the basin is 6 people/km^2. In the "Buryat" part of the basin, this indicator is 8.7 people/km^2 and almost five times higher than the same indicator in the Trans-Baikal Territory (1.8 people/km^2). The most densely populated is the central part of the basin, including the territories of Ivolginsky, Kyakhtinsky, Zaigraevsky, Mukhorshibirsky, Selenginsky, Tarbagataisky, Kabansky, Bichursky, Pribaikalsky districts of Buryatia. In the territory, which occupies about 30 % of the basin, 77 % of its population is concentrated. East and west, population density is declining. Significantly lower than the average population density in Zakamensky and Dzhidinsky districts is 2-4 people/km^2, the lowest population density (1-1.5 people/km^2) in the north-eastern regions of Buryatia (Eravinsky, Khorinsky), as well as areas of Trans Baikal Territory with relatively less favorable conditions and low transport accessibility.

The settlement frame in the Buryat part of the Selenga river basin is formed by 4 cities, 7 urban-type settlements and 404 rural settlements. More than 3/5 of the population (483.8 thousand people) live in urban settlements.

The average demographic load is experienced the Selenga river basin. The demographic load on the territory of most of the water-resource region is reduced (table 6).

Table 6. The intensity of the demographic load in river basins

Water-resource region code	Population density, people / km^2	Load intensity characteristic	Load intensity, points
V. Angara	0.6	low	3
Tyya	4.9	Lowered	4
Barguzin	1.8	lowered	4
Selenga	8.7	average	5
Snezhnaya	0.13	Low	3
Boshaya Rechka	4.9	lowered	4
Chickoy	1.5	lowered	4
Khilok	1,5	lowered	4

CONCLUSION

Integral anthropogenic load on the territory of the river basins

Among the river basins, only the Selenga experiences an "average" anthropogenic load. On the territory of most river basins, the anthropogenic load is "lowered" and "low" (table 7).

Table 7. Integral anthropogenic load on the river basins.

Water-resource region code	Load intensity, points				
	demographic	industrial	agricultural	livestock	anthropogenic
V. Angara	3	3	2	2	4
Tyya	4	3	2	2	2
Barguzin	4	3	5	2	3
Selenga	5	4	4	4	5
Snezhnaya	3	2	1	4	2
Boshaya Rechka	4	2	1	4	2
Chickoy	4	3	4	3	4
Khilok	4	3	5	4	

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