Chemical and microbiological characteristics of the agrolandscape Zeya-Bureya plain small river

A P Pakusina, M F Tsarkova, T P Platonova and T P Kolesnikova
Department of Chemistry, Far Eastern State Agrarian University, Blagoveshchensk, Politeknicheskaya St., 86, Russia

E-mail: pakusina.a@yandex.ru

Abstract. The article discusses the results of hydrochemical and microbiological studies of the waters of the small river Arguzikha, the left-bank tributary of the Amur River. The natural landscapes of the Zeya-Bureya plain, along the territory of which a small river flows, are transformed into agrolandscapes. Organic matter, nitrogen and phosphorus compounds accumulated in the waters of the Arguzikha river. The number of heterotrophic bacteria, the main function of which is the destruction of organic matter, in the summer reached 75 thousand cells / ml, which corresponded to the dirty water quality class. The content of nitrogen compounds in water and the number of ammonium-oxidizing bacteria experienced seasonal dynamics. The obtained results of the study of hydrochemical and microbiological indicators of aquatic ecosystems of the Zeya-Bureya plain are the basis for further study of the technogenic load on small rivers of the agrolandscape.

1. Introduction
The agricultural sector is the most developed one in the Amur region. The development of agriculture has led to the transformation of natural territories into agrolandscapes [1]. On agricultural fields, soybean, rapeseed, and grain crops are mainly grown. The use of mineral fertilizers, herbicides and other means of chemicalization has an adverse effect on the condition of soils and small rivers. According to the data of the Federal State Budgetary Institution of the Station of the Agrochemical Service "Amurskaya" about 4000 tons of mineral fertilizers are applied annually to the arable soils of the Tambov region [2]. Mineral fertilizers are sources of compounds of heavy metals and contribute to an increase in heavy metals in the soil [3], change the pH of the soil solution, increase the mobility of compounds of iron, manganese, zinc, copper [4]. Heavy metals pollute the environment; they have a toxic effect on living organisms [5]. Massive plowing of lands in the floodplains of small rivers of the Zeya-Bureya Plain, deforestation, construction of reservoirs, and the introduction of fertilizers into the soil contributed to a change in the quality of the water of small rivers, the accumulation of organic substances in them, and an increase in the content of nutrients [6-8]. Small rivers experience a strong anthropogenic impact, the hydrological and hydrochemical regimes of which depend on the intensity of development of their watersheds. Human activities and processes occurring within the watersheds of small rivers have a negative impact on the state of watercourses. The ecological state of large rivers largely depends on the water quality of small rivers. Of great importance is the activity aimed at identifying, eliminating and preventing the effects of anthropogenic pollution. Therefore, information
is needed that objectively assesses the situation in a particular territory, which determines the need for hydrochemical and microbiological studies of small rivers under conditions of technogenesis.

The aim of this work is to study the hydrochemical and microbiological indicators of the small river Arguzikha, which flows through the agriculturally developed territory of the south of the Zeya-Bureya plain.

2. Object and methods of research

The object of study is the small river Arguzikha - the left tributary of the Amur River. The Arguzikha River flows into the Amur river 1892 km from the mouth, the length of the watercourse 47 km [9]. A reservoir for irrigation was built on the river in the 80s of the last century. In the lower reaches of the river, unique wetlands of the Muravyov Reserve are preserved, and in the middle and upper reaches of the river, natural landscapes are transformed into agrolandscapes, and there are practically no trees. Samples were taken in three sections: I - the river below the village of Lermontovka (50°4′4″ north latitude, 127°53′58″ east longitude), II - reservoir Razdolnoye (50°1′1″ north latitude, 127°50′37″ east longitude), III - the river below the village of Kuropatino (49°58′56″ north latitude, 127°39′5″ east longitude).

Water sampling was carried out during the low water period in May, July and October 2019 according to GOST R 51592-2000. Hydrochemical indices were carried out in accordance with PN PN F. Microbiological methods were used to assess the quality of water in the Arguzikha river, based on determining the number of saprophytic heterotrophic bacteria, ammonium and phosphorus-oxidizing bacteria by inoculating natural water on selective nutrient media by the method of limiting dilutions [10].

3. Research results and discussions

The water temperature corresponded to the time of year. The acid-base properties (pH) of the waters of the small river Arguzikha were within the normal range (6.90-8.20), with the exception of autumn water samples in the Razdolnoye reservoir. A high pH value (8.61) is associated with the activity of phytoplankton in the summer. In the river, seasonal variations in the pH values of water were observed. The specific electrical conductivity (SEC) of water was 80-339 μS / cm. The lowest values of water SEC were observed in spring, the highest - in summer (table 1). The waters of small rivers in this region are low mineralized, soft [7.8]. The color of the water of the Arguzikha River ranged from 22 degrees col. in spring, up to 101 degrees of color (Cr-Co) in summer, the maximum value of color was observed in the water of the reservoir Razdolnoe in spring - 172 degrees of color. The color of the water depends on the type of soil, the content of iron and manganese compounds in the water.

Table 1. Temperature, pH and electrical conductivity of the waters of the small river Arguzikha.

| River | Temperature, °C | pH  | SEC, μS / cm |
|-------|----------------|-----|--------------|
|       | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn |
| I     | 10.0   | 24.2   | 1.2    | 7.57   | 7.78   | 8.03   | 175    | 339    | 231    |
| II    | 11.5   | 23.0   | 2.5    | 7.44   | 8.23   | 8.61   | 100    | 124    | 80     |
| III   | 10.0   | 21.5   | 2.1    | 7.93   | 8.18   | 7.9    | 171    | 187    | 142    |

Note: The table shows the average values of indicators.

The waters of the Arguzikha River are characterized by a high oxygen content. An exception is the low oxygen saturation of water (52%) in the river below the village of Lermontovka (I) in summer, which correlates with high permanganate oxidation (PO) values, which characterizes the high content of organic substances in water. In the fall, after strong summer floods, the value of PO decreased throughout the entire length of the river. The high oxygen saturation of the water and the high BOD₅
values (table 2) in the middle and lower reaches of the Arguzikha River indicate a process of eutrophication.

**Table 2. Oxygen indicators of the water of the small river Arguzikha.**

| River | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn |
|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| I     | 6.8    | 4.2    | 13.0   | 2.0    | 1.4    | 7.1    | 15.5   | 14.8   | 6.1    |
| II    | 10.6   | 12.9   | 13.6   | 6.8    | 8.2    | 4.0    | 11.7   | 11.2   | 5.8    |
| III   | 12.2   | 15.8   | 13.8   | 6.1    | 12.7   | 3.9    | 7.5    | 6.8    | 5.4    |

In spring and summer, BOD$_5$ reached 6.1-12.7 mgO$_2$/dm$^3$ in the middle and lower reaches of the river, and 2 mgO$_2$/dm$^3$ in the upper reaches of the river. In the autumn after the flood, BOD$_5$ in the water of the II and III sections decreased, which is associated with the intensity of self-cleaning processes in the river, and in the first section, on the contrary, increased.

Among the nitrogen compounds in the water of the Arguzikha river, ammonium nitrogen dominates, the content of which was especially high in the summer during the rainy season. Nitrogen compounds entered the river water from the surface soil layers of agricultural arable land during the flood period. The content of nitrite nitrogen in spring in the water of the Razdolnaye reservoir reached 0.017 mgN-NO$_2$/dm$^3$; during the study period, nitrites were found in trace amounts in the remaining sections. In spring, nitrate nitrogen in the amount of 3.45-4.78 mgN-NO$_3$/dm$^3$, which was of pyrogenic origin, was detected in the water throughout the river [11]. In the content of nitrogen compounds, seasonal dynamics are observed: in summer there is a minimal amount. The forms of nitrogen in water are interrelated with physicochemical parameters in different seasons of the year, with the processes of nitrification and denitrification that occur in rivers [12]. Nitrogen compounds are the main factor that affects the water quality of rivers in the rainy season, phosphorus compounds are the main factor in the dry season [13].

A high content of total phosphorus in the river water was noted in the spring. Orthophosphates are probably of pyrogenic origin, since grass is burned out in river floodplains and on agricultural lands every year, fires occur. The excess phosphorus in the catchment area of small rivers, carried by runoff, is the cause of water eutrophication, a serious global problem of water quality [14]. In the autumn after the flood, the phosphate content in the river was minimal (table 3).

**Table 3. The content of nutrients in the water of the small river Arguzikha.**

| River | Ammonium nitrogen, mgN-NH$_4$/dm$^3$ | Orthophosphates, mg/dm$^3$ | Total phosphorus, mg/dm$^3$ |
|-------|-------------------------------------|---------------------------|-----------------------------|
|       | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn |
| I     | 0.40   | 2.34   | 0.36   | 0.330  | 0.132  | 0.005  | 0.337  | 0.133  | 0.007  |
| II    | 0.22   | 1.67   | 0.07   | 0.398  | 0.027  | 0.002  | 0.439  | 0.028  | 0.004  |
| III   | 0.13   | 1.61   | 0.06   | 0.448  | 0.047  | 0.002  | 0.476  | 0.048  | 0.004  |

Many researchers use the indicator of the number of microbial communities as indicators of natural water pollution [15-17]. The leading role in the cycle of substances is played by saprophytic heterotrophic bacteria, the main function of which is the destruction of organic matter. The number of heterotrophic bacteria was the maximum in the summer in the Razdolnaye reservoir (75 thousand cells/ml), which corresponded to the “dirty” water quality class (GOST 17.1.2.04-77). The smallest
number of microorganisms of this group was noted in the spring of 4.5 thousand cells/ml (table 4). The number of heterotrophic bacteria does not correlate with PO values, but depends on the temperature of the water (in summer their number increases). A decrease in the number of heterotrophic microorganisms in July to 25 thousand cells/ml in river water below the village of Kuropatino is most likely due to the mass reproduction of blue-green algae, which in some cases can negatively affect the number of bacteria - heterotrophs [18]. In the autumn after the flood, the number of heterotrophic bacteria decreased.

The number of ammonia-oxidizing bacteria in the river was high in the summer, in the Razdolnoye reservoir - in the autumn. The number of phosphor-oxidizing bacteria was minimal in the spring, when the highest concentrations of phosphates in the water of the Arguzikha river were noted, and maximum in the autumn, when the phosphate content after the flood markedly decreased.

Table 4. The number of heterotrophic, ammonium and phosphorus-oxidizing bacteria in the water of the small river Arguzikha, thousand cells/ml.

| River | Heterotrophic bacteria | Ammonium Oxidizing Bacteria | Phosphorus Oxidizing Bacteria |
|-------|-------------------------|----------------------------|------------------------------|
|       | Spring | Summer | Autumn | Spring | Summer | Autumn | Spring | Summer | Autumn |
| I     | 9.5    | 30.0   | 11.5   | 300    | 2500   | 150    | 3.8    | 12.5   | 22     |
| II    | 4.5    | 75.0   | 30.0   | 2500   | 450    | 5000   | 8.4    | 10     | 10     |
| III   | 45.0   | 25.0   | 11.0   | 750    | 2500   | 500    | 4.6    | 10.2   | 12     |

4. Conclusion
The waters of the Arguzikha River are characterized by high oxygen saturation. The high oxygen content and high BOD₅ values in the middle and lower reaches of the Arguzikha River indicate a process of eutrophication. In spring and summer, high values of permanganate oxidizability (PO) were observed, which characterizes the high content of organic substances in water. In the fall, after strong summer floods, the value of PO decreased throughout the entire length of the river. The high content of phosphates and nitrates found in spring samples was of pyrogenic origin. In summer, the largest amount of ammonia nitrogen was observed in the river water, which was introduced into the river from the surface layers of soils during rains. The lowest concentrations of nitrogen and phosphorus compounds were after the flood in the fall.

An increase in the number of heterotrophic bacteria is influenced by water temperature. The number of ammonia-oxidizing bacteria in the river was high in the summer, when the content of ammonia nitrogen was high. The number of phosphor-oxidizing bacteria was minimal in the spring, when the highest concentrations of phosphates in the water of the Arguzikha river were noted, and maximum in the autumn, when the phosphate content after the flood markedly decreased.

The results of hydrochemical and microbiological studies of a small river are the basis for further study of the anthropogenic load on small rivers of the agrolandscape of the Zeya-Bureya plain.

References
[1] Shchiptsova EA 2015 Analysis of agrogenic transformation of the southern part of the Amur-Zeya plain Regional environmental issues 3 127–31
[2] Dudukalov KA 2017 The state of fertility of arable soils in the southern zone of the Amur region Agriculture 1 30–2
[3] Slabko Yu A and Lopatin A A 2016 Cadmium accumulation in soil and soybean plants under the influence of mineral fertilizers Bulletin of KrasGAU 2(113) 14–21
[4] Zhukova L M and Blagoveschenskaya Z K 1981 Change in the agrochemical properties of soils with prolonged use of fertilizers Agriculture abroad 9 8–15
[5] Kabata-Pendias A and Pendias H 2001 Trace elements in soils and plants (Boca Raton; London;
New-York; Washington: CRC Press)

[6] Pakusina A P, Platonova T P and Lobarev S A 2014 Temporal and spatial variability of the chemical composition of the small river of the Zeya-Bureya plain Regional environmental issues 4 67–71

[7] Harina S G and Tsarkova M F 2007 Assessment of the ecological status of reservoirs of agrolandscapes in the Middle Amur Regional environmental issues 3 13–20

[8] Harina S G, Dimidenok Zh A, Kolesnikova T P and Tsarkova M F 2012 Monitoring of the ecological state of water bodies of the agrolandscape of the Zeya-Bureya plain Bulletin of the Bashkir State Agrarian University 3 69–73

[9] State Water Register: Arguzikha River Available from: http://www.textual.ru/gvr/index.php?card=291705 date of treatment 10/20/2019

[10] Kuznetsov S I and Dubinina G A 1989 Methods for the study of aquatic organisms (Moscow: Science)

[11] Shesterkin V P and Shesterkina N M 2002 The influence of large forest fires on the hydrochemical regime of the taiga rivers of the Amur Region Geography and natural resources 2 47–52

[12] Bu H, Meng W and Zhang Y 2011 Nitrogen pollution and source identification in the Haicheng River basin in Northeast China Science of the Total Environment 409 3394–402

[13] Wang J, Fu Z, Qiao H and Liu F 2019 Assessment of eutrophication and Water quality in the estuarine area of Lake Wuli, Lake Taihu, China Science of the Total Environment 650 1392–402

[14] Goyette J O, Bennett E M and Maranger R 2018 Low buffering capacity and slow recovery of anthropogenic phosphorus pollution in watersheds Nature Geoscience 11 921–5

[15] Muyzer G and Stams A 2008 The ecology and biotechnology of sulphatereducing bacteria Nature reviews microbiology 6 441–54

[16] Kondratyeva L M, Fisher N K and Berdnikov N V 2009 Microbiological assessment of water quality in the Amur and Sungari rivers after an industrial accident in China Water resources 36(5) 575–87

[17] Kondratyeva L M and Chukhlebova L M 2005 The role of microbial complexes in the formation of water quality in the Bureysky and Zeysky reservoirs Readings in memory of Vladimir Yakovlevich Levandov 3 166–73

[18] Glagoleva O P, Zenova G M and Zvyagintseva A G 1992 Features of the functioning of algae in association with bacteria Microbiology 61(2) 256–61