Water quality assessment of the Perm city’ small rivers

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Abstract. The environmental monitoring since 2009 in various water regime phases has been conducted by the Department of Ecology and Environmental Management for the water quality assessment of the Perm city’ small rivers. Such assessment of the water quality in the urban area of Mulyanka, Danilikha, Yegoshikha and Iva rivers catchments are presented in this study. The analysis is given for the background and mouth sections. The data of river’s water chemical composition was used for periods 2009-2010 and 2015-2018. A comparative analysis of water quality in terms of pollution indices is given.

1. Introduction
Small rivers flowing through the urbanized territory of large cities are often a miserable sight. Their waters are usually heavily polluted, littered and not become an important element of urban infrastructure. Their study is conducted chaotically and without sufficient data. Currently, there is a certain number of research devoted to assess the ecological situation on small rivers within urban areas both in different World countries [17-21] and in Russia [1-16], and in particular within the Perm Territory [6, 8-12].

All small rivers of the Perm city experience the strongest anthropogenic impact. This is rivers pollution with industrial, household and stormwater runoff, dam’s construction, quarries development, collectors construction, banks pollution with garbage, etc. As a result, the rivers ecosystems have undergone significant changes, especially the Danilikha River, which has completely lost the fish population. In connection with all above, the aim of this research was to assess the water quality of Perm city’ small rivers in the periods 2008-2010 (the first years of observation) and 2015-2018. Such assessment is necessary for the effect of environmental protection measures characterization, both in the rivers themselves and in their catchments located in urbanized areas.

2. Materials and methods
Water quality monitoring of the city’ small rivers since 2009 by the Department for Ecology and Nature Management of the Perm city Administration have been assigned to LLC Interdisciplinary Research and Design Technological Institute of Ecology of the Fuel and Energy Complex (IRDTIE FEC). The purpose of the monitoring is a comprehensive assessment of small rivers pollution not covered by the state observation network, and their contribution to the pollution of the Kama River.

Observation section lines on rivers in the zone of the Perm city’ enterprises influences were established in accordance with next principles: 1st – located close to the source (background values); 2nd – located in the small rivers’ mouth. 19 main polluting components in water samples were determined: dissolved oxygen, ammonium nitrogen, nitrate nitrogen, nitrite nitrogen, chlorides, sulfates, iron (total), copper, zinc, oil products, chemical oxygen demand (COD), biochemical oxygen
demand (BOD5), synthetic surfactant, dry residue, phosphates, manganese, pH, aluminum and strontium. The assessment of the city small rivers’ hydrochemical regime was carried out in 2009-2010. It covers all phases of the rivers water regime. This monitoring study on the city small rivers has been carried out for the first time.

3. Results and discussions
A steady excess of the Maximum Permissible Concentration (MPC) in all small rivers was recorded for strontium and aluminum. Over the entire period of observation of small rivers, no excess of the MPC in terms of hydrogen index (pH) was revealed. At all control points on small rivers, an excess of MPC was recorded for the following components: copper, manganese, and strontium.

*Iva River* located in the city and at the site close to the source water is assessed as class 5, rank – extremely dirty, indicators of pollution: COD, BOD5, ammonium nitrogen, nitrite nitrogen, phosphates, copper, manganese. Flowing through the city districts, the water quality in the Iva River at the mouth area at the confluence with the Kama River improves slightly. Water is characterized as class 4, rank "B" (very dirty) due to critical contamination for copper and oil products. According to comprehensive assessment results of pollution in 2010 compared to 2009, water quality in the Iva River has been worsened especially in the background section line (with the water rank change). The water sustained pollution by nitrogen compounds due to an anthropogenic (household origin) in the background section of the Iva River was revealed. The river’ oxygen regime is satisfactory.

Once in the Iva River’ background section line, an excess of MPC for dry residue, chlorides and sulfates, caused by technogenic pollution, was recorded. Most likely, salt-containing anti-icing agents used on Perm city roads in winter time are got into the river with melt water. Throughout the river, pollution with stable oxidizable organic compounds (COD), to a lesser extent – easily oxidizable organic compounds (BOD5) was recorded. At the same time, the river’ oxygen regime is satisfactory. The water pollution of the Iva River with metals (iron, manganese, copper, aluminum, strontium) is stable during the entire observation period. At the same time, the metals’ constant high content in the background section line and slight decrease in their concentration towards the river mouth by the natural dilution of water due to lateral tributaries is explained. The pollution with oil products has most likely of anthropogenic origin and appear more significantly at the river mouth.

The small urban rivers’ survey data in period 2015-2018 indicate that the ecological situation on the rivers themselves and their catchments remains complicated. In the Iva River’ background section line the SCIWP index varied from 2.56 to 3.71. At the same time, there was a tendency for its decrease by the end of the period, which indicates a certain decrease in the technogenic load. The water quality class moved from 4 "A" (dirty) to 3 "A" (polluted). A completely different picture was observed in the mouth section of the river. Here, the Specific Combinatorial Index of Water Pollution (SCIWP) varied from 4.48 to 6.90. At the same time, there was detected a tendency for water quality degradation by the end of the study period. The water quality has moved from the dirty rank to the extremely dirty rank. Thus, the river’ water quality after flowing through the urban area was deteriorated significantly.

Comparing the two studied periods, it can be stated that the situation with water quality remained alarming. Along the river entire, there is a steady pollution of such components as manganese, copper, iron, and especially oil products (30-50 MPC) were observed.

Waters of the *Egoshikha River* in the area close to the source is assessed as class 3, rank "A" (polluted). The water quality at the rivers’ background section line is the best among city’ small rivers. The river at the estuary is assessed as a class 5 (extremely dirty). Critical indicators of pollution include: nitrites, copper, manganese and oil products. At the river mouth, the oxygen level is below the established norms. In the river’ background and mouth section lines the MPC excess for dry residue, ammonium nitrogen, chlorides and anion-active synthetic surfactants were not established.

According to the specific combinatorial pollution index values and water quality class in 2010 compared to 2009 and 2008, the water quality in the background section line of the river was improved. In the river’ waters after the city (mouth section line), an increase in pollutants concentration, due to anthropogenic influence of human activity and technogenic load from the city's
enterprises was observed. At the river mouth the water quality was remained at the level of 2009. The worst water quality among the Perm city’s small rivers according to observations for 2010 in the mouth of the Yegoshikha River were established. Thus, Yegoshikha River according to 2010 observations at the background section line among the Perm city’s small rivers have the most favorable water quality. But it subjected to the most severe technogenic impact, and at the mouth of the river water is characterized as extremely dirty – the most polluted among small rivers.

A later survey of the river’s waters showed that the water quality situation remains difficult. The Specific Combinatorial Index of Water Pollution (SCIWP) during this period in the mouth section was quite stable and varied from 5.05 to 6.13. The water during this period was assessed as dirty (4 "B") and very dirty (4 "D"). Comparing the water quality in the background and mouth sections, it should be noted that flowing through the urbanized territory, the river is still heavily polluted. In multi-year aspect, the situation is not improved. Still, the excess of maximum permissible concentrations for manganese (30-50 MPC), total iron and other components are observed.

The Danilikha River’ water in the background section (close to the source) is of bog origin and, according to complex indicators, is assessed as class 5, the rank is extremely dirty. Stable pollution at the level of critical indicators of pollution with phosphates, copper and manganese was revealed. In the river’ background section line, the oxygen regime is not satisfactory. One of the reasons for this is the river’ swampy origin. The constant pollution of the river with difficult-to-oxidize organic substances was revealed. In most cases, the degree of pollution towards the mouth was reduced or remains unchanged. High values of the COD index are due to the specificity of the river water quality. The source of the river is in a marshy area with a large amount of organic carbon of natural origin.

At sampling "before the autumn flood" at the Danilikha River mouth, a technogenic pollution characterized as high (in terms of COD and BOD) and extremely high in terms of oil products was recorded. The river water is also constantly polluted by metals (iron, copper, manganese, strontium). There is no relation between metal content and hydrological phases. Stable zinc and aluminum contamination joins in the mouth. Flowing through the city’ central districts, the Danilikha River, when it inflows into the Kama River, is characterized as a class 4, rank "G" – "very dirty". According to the obtained data the water quality in 2010 compared to 2009-2008 sharply deteriorated in the background section and slightly improved in the mouth. In 2010, the water state in the river was normalized in terms of ammonium nitrogen and synthetic surfactants content.

Analysis of materials from the second study period (2015-2018) shows that the situation with water quality is not getting better. Pollution indices of the SCIWP were stable and high and varied from 5.55 to 5.84. The waters were characterized as dirty (4 "B") and very dirty (4 "C"). The river is still characterized by the highest background values of pollution indices (from 5.58 to 7.14). Along the entire river length, its stable pollution is noted for manganese (more than 50 MPC), copper, zinc, phosphates, oil products, and total iron. When flowing through an urban area, the river’ water does not worsen its condition in comparison with the background section (where the water is assessed as extremely dirty). Comparison of the ecological situation in the two study periods indicates, despite the ongoing environmental protection measures it remains complicated.

The Mulyanka River’ water at the mouth section before inflow into the Kama River is characterized as class 3, rank "B" (very polluted). High and extremely high levels of pollution have not been identified. In 2010, there was a stable pollution of copper and strontium, periodic pollution of organic matter (COD indicator) and aluminum. In the Mulyanka River, during the entire observation period, no excess of MPC for dry residue, ammonium nitrogen, chlorides, oil products, synthetic surfactants, zinc was found. The water quality at the Mulyanka River’ mouth can be characterized as stable. The water quality class has not changed for 2008-2010. The river at its mouth remains least polluted in the city. In the second study period, the pollution indices of the SCIWP in the mouth section are the lowest indicator of the pollution of the waters of city’ small rivers, and varied from 3.92 to 4.58. At the same time, there is a tendency for their decrease over a long-term period. Despite the fact that the ecological situation in this river is the most favorable among the other rivers, its waters still detected an excess of the MPC of manganese, oil products, total iron, nitrogen, nitrates.
4. Conclusions
1. Assessment of the water quality of the Perm city’ small rivers for the periods (2008-2010 and 2015-2018) showed that the situation remains difficult. So, there is an excess of the existing standards for the content of manganese, oil products, total iron, copper, zinc.

2. Despite the ongoing environmental protection measures, the water quality of the rivers currently does not meet the required standards.

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