Natural background and transformation of water quality in the Moskva River

O Erina¹,²,³, M Tereshina¹, G Shinkareva¹, D Sokolov¹ and M Lychagin¹
¹ Lomonosov Moscow State University, Moscow, Russia
² Russian Federal Research Institute of Fisheries and Oceanography, Moscow, Russia
³ Author to whom any correspondence should be addressed

oxana.erina@geogr.msu.ru

Abstract. Longitudinal transformation of several hydrochemical parameters in the Moskva River was reviewed based on the data of extensive monitoring studies conducted in 2019-2020. Changes of the chemical composition and their seasonal variation were quantified in relation to the only remaining natural part of the river above the Mozhaysk Reservoir. We found that the overall variability of element concentrations in the part of the Moskva River not affected by anthropogenic pressure is much lower than the magnitude of changes caused by urban influence. The effect of residential and industrial development in the watershed is comparable to, or sometimes much lower than the impact of polluted wastewater discharged by Lyubertsy and Kurianovo treatment plants. Point-source pollution therefore plays the key part in the transformation of the natural water quality in the Moskva River.

1. Introduction
In modern Russia, there is an urgent issue with establishing natural background concentrations of various elements of dual genesis in natural water, as already implemented in many other countries [1-2]. Principles of assessing the water pollution based on current environmental water quality guidelines within the existing water quality management system can be unrealistic, often requiring water users to treat their wastewater from high concentrations of elements that are present in non-polluted water and have a natural origin. This primarily concerns metals – mainly iron, copper, manganese and some others – whose concentrations can be very high even in pristine rivers and lakes in some landscape zones [3]. However, despite the great variety of natural landscapes on the territory of Russia, national water quality guidelines are completely unified for all water bodies [4-6].

At the same time, federal institutions responsible for environmental monitoring and developing guidance documents, as well as establishing natural background concentrations, face a number of systemic challenges caused primarily by inadequate funding [7-9]. Because of this, the Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet) is severely understaffed and lacks the capacity for developing the methodology for determining natural background concentrations of various chemical components in natural water. In these conditions, estimation of conditional background concentrations by the Roshydromet operation manual, which is based on statistical evaluation of baseline chemical composition of water above the wastewater discharge, remains the only officially applicable procedure for determining background water quality in calculations of permissible pollutant discharges. This method also relies on official monitoring data, but the network of stations is currently extremely scarce [10-12].
All this raises the question of the possibility of establishing the natural background for water bodies, especially for significantly transformed rivers [13-15]. Situations arise in which elevated concentrations of metals and other elements caused by anthropogenic pollution are mistakenly or deliberately documented as the natural background. Thus, the absence of a clear and precise framework for determining background water quality creates a risk of normalizing the use of already contaminated waters as the natural background, which will inevitably lead to an underestimation of the actual water pollution level, its further deterioration and degradation of aquatic ecosystems.

The aim of this study is therefore to assess the real scale of transformation of the original chemical composition of a river as it is affected by various anthropogenic impacts on the example of the Moskva River.

2. Materials and methods
This study is based on the results of detailed observations on longitudinal variability of water chemistry of the Moskva River and its major tributaries performed in 2019-2020. A network of 43 stations on the Moskva River and 19 gauges at mouths of largest or most polluted tributaries was set up (figure 1). In both years, water samples were taken during the spring snowmelt and in summer low-flow. At five of the stations within the Moscow City limits, water sampling was performed only in 2020.

For a natural background, a section of the river from its source to the Mozhaysk Reservoir was selected – the only remaining part of the river where hydrological and chemical regimes are close to natural. The uppermost station at the source of the river was not included in the analysis of the natural background, as its chemistry is mostly defined by a bogland fed predominantly by precipitation. For each parameter, an average value from three remaining stations in the upper reaches of the river (stations M2-M4 on figure 1) was viewed as the natural background concentration.

Transformation of water quality was evaluated based on exceedances of background values. The ‘transformed’ part of the river’s course was divided into four key sections, at each of which mean
values and their variability were examined, with section boundaries at the Rublyovo Dam (above Moscow Ring Road), the outlet of the Kuryanovo wastewater treatment plant, and the outlet of Lyubertsy wastewater treatment plant.

Only dissolved forms of elements were included in this study, because existing national environmental guidelines for maximum allowable concentrations in fisheries [2], which apply to the Moskva River, are designed only for dissolved forms of various chemical components.

3. Results and discussion

At the part selected for natural hydrological and chemical conditions, the Moskva River has a typical regime for a river of its respective landscape zone, with a high snowmelt flood in spring, when nutrient and organic matter concentrations increase and water mineralization decreases. During the summer low flow, as groundwater dominates in river runoff, nutrient and organic matter content is much lower, and dissolved manganese concentration noticeably increases. In 2020, the manganese concentration increased between spring and summer 2.6-fold – from 36.7 to 97 μg/L. Seasonal variation of concentrations for other metals at this part of the river is much more narrow; only for iron significant differences were found – its concentration increases during the spring flood (on average to 61.5 μg/L) and decreases in summer (to 13.5 μg/L).

Figure 2. Exceedance factors of concentrations of some elements in relation to the natural background at different sections of the Moskva River: 1 – Mozhaysk Dam to Rublyovo Dam; 2 – Moscow Ring Road to Kuryanovo WWTP; 3 – Kuryanovo to Lyubertsy WWTP; 4 – Lyubertsy WWTP to mouth.

Therefore, in the natural background part of the Moskva River concentrations of nutrient elements are typically low and do not exceed maximum permissible values, as well as concentrations of most
metals, with exceptions of iron and manganese, whose concentrations vary significantly between seasons.

Downstream, background characteristics of water chemistry of the Moskva River are significantly transformed. In the section between Mozhaysk and Rublevo dams, changes in water composition are the least pronounced and are caused mostly by flow regulation via hydraulic structures. Rublevo Dam gauges over a half of the entire Moskva River catchment and provides multi-annual regulation of its water runoff, but despite constantly increasing anthropogenic pressure on the river’s tributaries from the growing area of residential land, concentrations of considered elements on average exceed the natural background by less than two times.

Urban infrastructure, especially municipal wastewater treatment facilities of Moscow City, cause much more drastic changes in the river’s water quality. Two groups of elements can be distinguished. The first group includes major ions and nutrient elements, whose content remains essentially unchanged under influences from diffuse pollution and storm drain runoff, but increases several times or even tens of times (for nitrites) below outlets of treated municipal waste. The second group includes primarily heavy metals and metalloids, whose concentrations gradually increase within city bounds and below outlets of Kurianovo and Lyubertsy treatment plants. During the spring snowmelt, flushing from urban areas of the watershed causes a more intense increase of concentrations for some elements, such as manganese and zinc.

At the last section of the river – below the outlet of the Lyubertsy wastewater treatment plant – concentrations of some components (nitrites, biodegradable organic matter (by five-day BOD), nickel and lead) continue to increase, but concentrations of most other pollutants remain constant or even slightly decrease compared to the urban section. This leads to the conclusion that the influence of Moscow metropolitan area prevails in the total transformation of natural water quality of the Moskva River in terms of concentrations of an overwhelming majority of reviewed elements.

4. Conclusion
The analysis of chemical transformation of water quality along the course of the Moskva River revealed that in its upper reaches concentrations of most elements do not exceed environmental guidelines but are subject to significant seasonal variation typical for the natural landscape. Anthropogenic pressures, and specifically urban development and wastewater discharge, lead to manifold increases of pollutant concentrations in river water.

The outcome of this work indicates the need for conducting additional monitoring studies to establish natural background concentrations with much more extensive coverage than currently provided by Roshydromet.

Acknowledgements
Analysis of the effect of urban development on water chemistry of the Moskva River was funded by the RSF, project number 19-77-30004. Fieldwork was supported by the Russian Geographical Society (project “The Moskva river from the headwaters to the mouth: hydrological and geochemical assessment of ecological state”). Assessment of seasonal variability of the transformation of the background water quality was funded by RFBR and NSFC, project number 21-55-53039.

References
[1] Van Dam R A, Humphrey C L, Harford A J, Sinclair A, Jones D R, Davies S and Storey A W 2014 Site-specific water quality guidelines: 1. Derivation approaches based on physicochemical, ecotoxicological and ecological data Environmental Science and Pollution Research 21 118-30
[2] Markich S J, Brown P L, Batley G E, Apte S C and Stauber J L 2002 Incorporating metal speciation and bioavailability into water quality guidelines for protecting aquatic ecosystems Australasian Journal of Ecotoxicology 7 109-22
[3] Moiseenko T I, Skjelkvåle B L, Gashkina N. A, Shalabodov A D and Khoroshavin V Y 2013
Water chemistry in small lakes along a transect from boreal to arid ecoregions in European Russia: Effects of air pollution and climate change *Applied Geochemistry* **28** 69-79

[4] Proskuryakova L N, Saritas O and Sivaev S 2018 Global water trends and future scenarios for sustainable development: The case of Russia *Journal of Cleaner Production* **170** 867-79

[5] Pinto G M C, Pedroso B, Moraes J, Pilatti L A and Picinin C T 2018 Environmental management practices in industries of Brazil, Russia, India, China and South Africa (BRICS) from 2011 to 2015 *Journal of Cleaner Production* **198** 1251-61

[6] Primin O 2018 Clean Water of Russia: Problems and Solutions *IOP Conference Series: Materials Science and Engineering* **365**

[7] Kotov V 2009 Russia: Historical Dimensions of Water Management *The Evolution of the Law and Politics of Water* 139-55

[8] Zhulidov A V, Robarts R D and Khlobystov V V 2009 The Need and Requirements for Modernizing Surface Water Quality Monitoring in the Russian Federation *Water International* **29** 536-46

[9] Henry L A and Douhovnikoff V 2008 Environmental Issues in Russia *Annual Review of Environment and Resources* **33** 437-60

[10] Lezier V, Gusarova M and Kopytova A 2017 Water supply of the population as a problem of energy efficiency on the example of the Tyumen region of Russia *IOP Conference Series: Earth and Environmental Science* **90**

[11] Demin A P 2000 Trends in Water Supply and Water Conservation in Russia *Water Resources* **27** 670-87

[12] Trumbull N S 2007 Pressures on Urban Water Resources in Russia: The Case of St. Petersburg *Eurasian Geography and Economics* **48** 495-506

[13] Demin A P 2010 Water management complex of Russia: Concept, state of the art, and problems *Water Resources* **37** 711-26

[14] Venitsianov E V 2019 Modern problems of water protection in Russia *IOP Conference Series: Earth and Environmental Science* **321**

[15] Zhulidov A V, Khlobystov V V, Robarts R D and Pavlov D F 2000 Critical analysis of water quality monitoring in the Russian Federation and former Soviet Union *Canadian Journal of Fisheries and Aquatic Sciences* **57** 1932-9