Hydrogeological Windows Impact on Groundwater Contamination in Moscow

Irina Galitskaya, Irina Pozdnyakova, Irina Kostikova, and Leonid Toms

Abstract

This paper presents the results of assessing the hydrogeological windows' impact on the Podol'sko-Myachkovskii aquifer contamination in Moscow as the most important reserve source of drinking water supply. Groundwater contamination in these territories can occur due to rapid mixing of contaminated groundwater of the overlying above-Jurassic aquifer and pure groundwater of the Podolsko-Myachkovskii aquifer. The study consisted in the analysis of the water chemistry data of these aquifers; the choice of the elements—indicators of groundwater contamination; the analysis of the indicators' distribution schemes and comparison with the boundaries of hydrogeological windows. The research results testified to the significantly elevated concentrations of contamination indicators in the Podolsko-Myachkovskii aquifer at the sites of hydrogeological windows allocated within the specific geostructural and hydrogeological conditions.

Keywords

Hydrogeological windows • Groundwater contamination • Hydrogeological condition • Aquifer vulnerability

1 Introduction

Significant anthropogenic contamination of groundwater is one of the most pressing problems that our world is facing today. Particular attention is paid to the study of groundwater contamination in the territories of hydrogeological windows location, where "contaminants can penetrate rapidly from near-surface into deeper aquifers in the areas where continuity of separating low-permeability deposits is disturbed and their permeability is relatively high" [1, 2]. The aim of our study, carried out within the framework of the project of the Russian Foundation for Basic Research, is to assess the impact of the hydrogeological windows on the contamination of the Podol'sko-Myachkovskii aquifer in Carboniferous deposits as the most important reserve source of drinking water supply in Moscow. This aquifer is the most vulnerable to contamination in the sites of hydrogeological windows where the transport of contaminants can occur from overlying the above-Jurassic aquifer. As a result of water abstraction and drainage from the underground workings, the groundwater levels in all Carboniferous aquifers are significantly reduced and are everywhere set below the levels of the above-Jurassic aquifer. Thus, there are hydrodynamic prerequisites for the penetration of contaminants from the above-Jurassic aquifer into the Podol'sko-Myachkovskii aquifer. In this article are presented and discussed the results obtained in the first stage of research. At this stage, the main tasks were the research of the spatial distribution of contaminants' concentrations in the overlying and the exploitable aquifers, the choice of the elements—indicators of the contamination—and then the construction of schemes on the basis of combining the schemes of the indicators' concentration and the map of the boundaries of hydrogeological windows.

2 Materials and Methods

This study consisted in the collection and synthesis of the groundwater chemistry data of the exploitable aquifer and also the overlying aquifer; the choice of elements—indicators of groundwater contamination on the basis of the study of the groundwater chemistry in the overlying aquifer; the construction and analysis of the elements'/indicators' distribution schemes in the exploitable aquifer and the comparison with the boundaries of hydrogeological windows. Groundwater samples were collected from monitoring 52

I. Galitskaya (✉) · I. Pozdnyakova · I. Kostikova · L. Toms
Institute of Environmental Geoscience, Russian Academy of Science, Moscow, 101000, Russia
e-mail: galgeoenv@mail.ru

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wells in the above-Jurassic aquifer and 210 wells in the Podol'sko-Myachkovskii aquifer. When constructing the schemes of the indicators' distribution, the software package, "Surfer", was used and the most acceptable result (for a given sampling network) was obtained by the Kriging method. During the data interpolation by kriging, the exponential theoretical variogram model was used. A more detailed comparison of the experimental variograms with the theoretical ones was carried out in the second stage of the research and these results have not been considered in this article.

3 Results and Discussion

Indicators of contamination can be the components of a primarily technogenic origin—ammonium, nitrates, oil products, phenols, surfactants, as well as chloride ion and sodium, significantly higher concentrations of which, compared to the background, also have anthropogenic genesis (the application of anti-icing products). As the main indicator of contamination, it is advisable to use chloride ion, which, unlike other components, is not sorbed by rocks, practically does not undergo physical and chemical transformations, and is characterized by a fairly stable character of the concentration change in the study area. Other components of technogenic genesis—oil products, phenols, surfactants, and nitrogen compounds, can be used as additional indicators, as well as for elucidating the possibility of using the chemical composition of groundwater as hydrogeochemical sign of the hydrogeological windows. The results of the study showed that the change of the natural hydrogeochemical situation in the exploited aquifer due to the impact of technogenesis is insignificant. Hydrocarbonate and sulfate-hydrocarbonate types of groundwater were formed due to the water-rock interactions in the natural conditions. The impact of technogenic processes led to the formation of chloride-hydrocarbonate groundwater in some sites, but in general the area of their distribution is insignificant. In comparison with the overlying aquifer, the concentration of technogenic components in the exploited groundwater are much lower (Table 1).

The higher concentrations of the indicators of contamination such as chloride ion, nitrate ion, oil products, and ammonium ions in the exploitable aquifer are found in the sites of hydrogeological windows location in the Moskva River valley and also in the valleys of its tributaries. The most significant values of indicators' concentrations are restricted to the sites of the hydrogeological windows of the first and second orders: chloride ion, up to 293; sulphate ion, up to 440.0; nitrate ion, up to 37.2; oil products, up to 0.113; and ammonium, up to 183. The vertical filtration time for the windows of the first order is less than 400 days (survival time of pathogenic microorganisms in groundwater) and for the windows of the second order, it is less than 1000 days (the petroleum products' half-life due to biodegradation). The influence of hydrogeological windows on the exploitable groundwater contamination can be seen the most clearly in the scheme of chloride ion distribution (Fig. 1).

Table 1 Concentration of chemical substances in overlying and exploitable aquifers

Element	Concentration, mg/L in overlying above-Jurassic aquifer	Concentration, mg/L in exploitable Podol'sko-Myachkovskii aquifer
Chloride	0.5–12259	<0.05–293.0
Sulfate	0.1–748.9	<0.01–440.0
Nitrate	0.04–83.85	<0.01–37.2
Sodium	0.2–7778	4.4–1069.0
Ammonium	0.05–236	<0.05–183.0
Calcium	0.5–1900	3.2–250.5
Magnesium	0.27–350	0.01–141.0
Oil products	0.005–53.0	<0.005–113.0
Iron	0.1–1693	<0.01–14.2
Manganese	0.001–22.9	<0.01–1.02

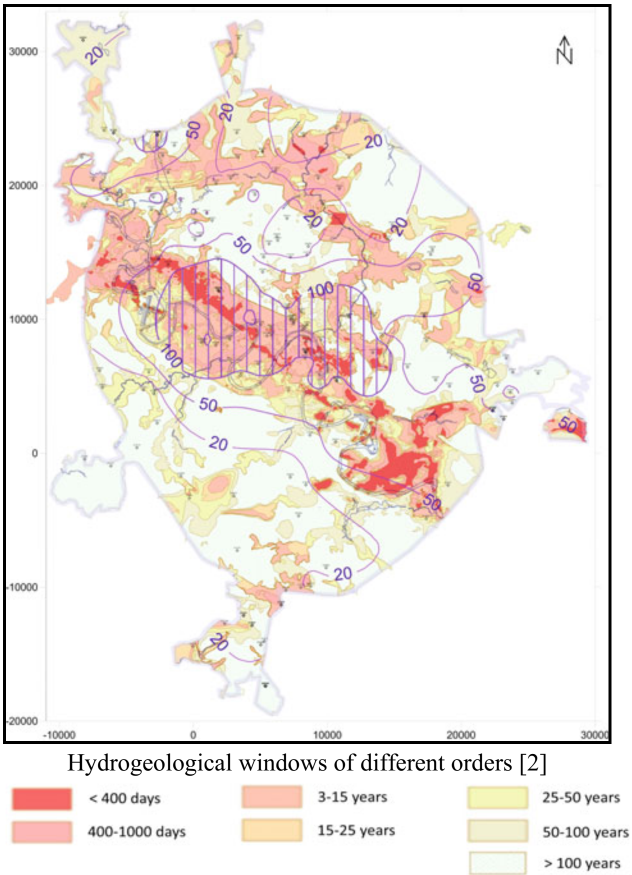

Fig. 1 The concentration of chloride ion in exploitable groundwater, mg/L

4 Conclusions

The results of this study lead to the conclusion that the hydrogeological windows can affect the groundwater chemistry in the exploitable Podolsko-Myachkovskii aquifer, especially in the sites of the hydrogeological windows of the first and second orders. Further studies, some of which are already underway, include: (1) obtaining more detailed spatial estimation using models from the kriging family; (2) selection of the test sites with different types of the hydrogeological windows, simulation of geofiltration and gemigration for the clarification the mechanisms of the transfer of the contaminants and the ways of their entering into the wells; (3) development of a methodical approach to the assessment of the risk of groundwater contamination in the sites of the hydrogeological windows and the risk maps construction; (4) determination of the features of the influence of the hydrogeological windows on the groundwater quality change.

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