Aggressive Groundwater Distribution in the City of Barnaul

S S Slazhneva\textsuperscript{1*}, E M Ovchinnikova\textsuperscript{1} and P V Sotnikov\textsuperscript{2}

\textsuperscript{1} Altai State University, 61 Lenina pr., Barnaul 656049 Russia
\textsuperscript{2} Barnaulstroyizyskaniya LLC, 281B Chernyshevskogo str., Barnaul 656049 Russia

E-mail: swetik315@mail.ru

Abstract. The paper focuses on the influence of aggressive groundwaters on concrete and reinforced concrete structures in Barnaul (Russia), affecting their durability. The exposure to aggressive waters can significantly reduce the reliability and safety of the operated buildings. The paper analyzes the chemical composition of groundwaters obtained from engineering and geological surveys in Barnaul. The processing of the products determined the type and intensity of the aggressiveness. The presence of aggressive groundwater was considered for each dedicated aquifer involved in the interaction between the geological environment and construction. The research resulted in the compilation of a map of aggressive groundwater distribution in Barnaul. The authors note that this problem is insufficiently studied, especially considering the technogenic load on the geological and hydrogeological environment and the accumulated experience. It is necessary to continue studies to determine the exact boundaries of the aggressive groundwaters in urban areas. Particular attention should be paid to geological processes of “flooding,” because they affect groundwater aggressiveness.

Keywords: Groundwater · Distribution · Aggressiveness · Type · Intensity

1. Introduction

The aggressive nature of groundwater lies in its ability to destroy various building materials, either by affecting them with dissolved salts and gases or by washing out their constituent parts. The aggressive effect of water on concrete structures is of particular importance. The practical significance of the antagonistic effect of water is so significant that no construction is completed without a preliminary study of the aquatic environment [1].

According to SP 28.13330.2012, the type of damage caused by groundwater on concrete construction is divided into chemical (sulfate, chloride, acidic, alkaline, etc.) and biological. Depending on the intensity of aggressive exposure, they are divided into non-aggressive, low-aggressive, medium-aggressive, and highly aggressive.

The aggressiveness is determined by chemical composition, dissolved components, enhancing dissolution, and the leaching of constructions’ structural components.

The number of factors determining the chemical composition of groundwaters is enormous. They include water properties in various phases, temperature, pressure, radioactivity, climate (precipitation and evaporation), relief, drainage conditions, mineral composition of rocks, filtration properties of stones, etc. [1].

One of the main factors influencing groundwater aggressiveness is the technogenic load: air pollution, untreated wastewater discharges, water-carrying communication leaks (water pipes, industrial sewers), and landfills of household and industrial waste [2].
2. Materials and Methods
The research used archival materials of “Barnaulstroyizyskaniya” LLC and technical engineering reports and geological surveys in the construction of buildings and structures in Barnaul.

We collected and processed the results of the chemical analysis of groundwaters to solve the indicated problems. Abnormal areas were defined with the manifestation of groundwaters and aggressiveness to concrete and reinforced concrete constructions. The samples were studied in the laboratory of “Barnaulstroyizyskaniya” LLC.

3. Results
In Barnaul, the groundwater, participating in the interaction of the geological environment and construction, is represented by the following aquifers:

- “Topwater” groundwater. It is formed due to the anthropogenic load (damage of drain sewage systems, utility leakage) on the natural environment. This type is locally distributed. It is confined to the Priobsky plateau and the Barnaulka River fluvial terraces by geomorphological means, reaching a depth of 5.0 m.
- Groundwater confined to the floodplains of the Ob, Barnaulka, and Pivovarka Rivers (aQIV) are common in alluvial sediments of the upper and lower floodplains. The water-bearing soils are fine and medium-sized sands, well-sorted in some places. The formation depth varies from 0 m to 2–3 m. Groundwaters are fresh and mineralized up to 1.0 mg/dm³. In spots, mineralization increases to 1.6 mg/dm³;
- Alluvial sediment groundwaters of the first fluvial terrace of the Barnaulka River (aQI,III) predominantly spread on the left bank. The water-bearing soils are dust, fine, and medium sands. The formation depth varies from 0 m to 2 m. Groundwaters are fresh and slightly salted in spots. The mineralization is 0.7–3.2 mg/dm³;
- Alluvial sediment groundwaters of the second fluvial terrace of the Barnaulka River (aQII,III) predominantly spread on the left bank. The water-bearing soils are fine sands. The formation depth varies from 2–3 m to 10–12 m. Groundwaters are fresh. The mineralization is 0.5–1.1 mg/dm³;
- Groundwaters of alluvial sediments of the third fluvial terrace of the Barnaulka River (aQII) predominantly spread on the left bank. The water-bearing soils are fine sands, medium sands, and fine sandy loams. The formation depth is more than 10 meters, except for particular areas where groundwaters are at depths of 2–5 m. Groundwater is fresh. The mineralization varies from 0.3 to 3 mg/dm³;
- the Krasnodubrovskaya suite aquifer (QI-II 1rd), by geomorphological means, is confined to the Priobsky plateau. The depth of groundwater is from 10 to 50 meters. The maximum water depths are set within the high banks (left bank of the Ob and right bank of the Barnaulka Rivers). The groundwater is fresh, with the mineralization less than 1.0 mg/dm³.

According to the processed archival materials of “Barnaulstroyizyskaniya” LLC, aggressive groundwater has a local distribution (figure 1).

The aggressiveness of groundwater in Barnaul is shown based on the content of sulfates, chlorides, aggressive carbon dioxide, and the concentration of hydrogen ions.

Sulfate aggression manifests itself in the interaction of $SO_4^{2-}$ ions with various components of the concrete. As a result, the concrete is corroded. The standards of $SO_4^{2-}$ depend on the concrete’s quality and should not exceed 250 mg/dm³ (SP 28.13330.2012). Sulfate aggression is determined by the presence of $SO_4^{2-}$ ion in waters with a concentration of more than 250 mg/dm³. In Barnaul, values exceeding 250 mg/dm³ are observed in the groundwater of the alluvial sediments of the first and second fluvial terrace of the Barnaulka River. They are spread within the boundaries of Korolenko and Papanintsev streets with a concentration of 250–370 mg/dm³.

$Cl^-$ determines chloride aggression in waters with a concentration of more than 250 mg/dm³ (SP 28.13330.2012). The $Cl$-chlorine anion easily migrates through cement grout and destroys reinforced
concrete constructions. Waters with Cl content of more than 250 mg/dm³ are found on the previously designated areas within the first and second fluvial terraces and in groundwater of the “topwater” type common in the subaerial sediments of the Priobsky plateau in the north-western part of the city, on the Kosmonavtov Prospekt. Chlorine content reaches 518 mg/dm³, which makes the water medium-aggressive to reinforced concrete constructions.

The presence of aggressive carbon dioxide is caused by aggressive CO² in the water. It reacts with the CaCO³ in the concrete, which destroys the protective crust and facilitates the penetration of other aggressive components.

Figure 1. The area of aggressive groundwater distribution in the territory of Barnaul city. Source: [4].

Small values are noted in the groundwater of the first and second fluvial terraces of the Barnaulka River with concentrations 17–26 mg/dm³.

In the groundwater confined to the aquifer of the Krasnodubrovskaya suite sediments, the concentration reaches 35 mg/dm³ in Montazhnkov street and Yuzhnyi proezd.

Groundwaters have aggressive properties in spring and autumn in terms of hydrogen indicators. The ratio of carbonate equilibrium forms determines the concentration of hydrogen ions. With
hydrocarbon ions in the water close to zero, the pH becomes less than 5.0. Hydrocarbon ion content is relatively low in spring and autumn, which leads to a decrease in the hydrogen index [1].

In Barnaul, low pH rates are registered in the groundwaters of the Krasnodubrovskaya suite, common in the southwestern part of the city in the built-up area within Vzletnaya and Vlasikhinskaya streets and Yuzhnyi proezd.

4. Discussion
Groundwaters in natural deposits are not aggressive or mildly aggressive if there is no technogenic pollution. They have a hydro carbonate calcium composition and relatively low mineralization (up to 1 mg/dm³). The chemical composition of groundwater significantly varies in urbanized areas (especially in the old part of the city). Due to the increase of SO₄²⁻ and Cl⁻ concentration, the overall mineralization is increasing [2].

The results of the technogenic load on the natural environment affected change in the engineering, geological, and hydrogeological conditions of the urban area, which led to its flooding. When the groundwater rises, the technogenic layer, represented by construction debris and a large amount of slag in the old part of the city, becomes water-absorbing soil. The consequence of the technogenic load on the geological environment is a change in groundwaters’ chemical composition and aggressive properties.

Groundwater in the city is weakly aggressive to the concrete and reinforced concrete constructions. The types of aggression are found mainly on the first and second fluvial terraces of the Barnaulka River, which is considered the “old part of the city.” There are also groundwaters with mineralization of more than 1 mg/dm³.

In Barnaul, aggressive groundwater is local; the intensity of aggressive water exposure is mostly mild. The average degree of water aggressiveness is shown only under the conditions of formed topwater in a loamy soil.

The determination of the distribution, aggression, and intensity of an area’s groundwater impact on concrete and reinforced concrete constructions is essential for the reliable and sustainable development of the city.

The allocated areas of aggressive groundwater in Barnaul are not exhaustive. Since our research was based on only one organization, which did not cover the whole city, there is a need to continue research to identify and prevent contamination hotspots.

5. Conclusion
The technological load on the city’s geological and hydrogeological environment increases every year, leading to a change in groundwaters’ chemical composition and the manifestation of their aggressiveness towards concrete and reinforced concrete constructions. The most polluted are the top waters and groundwaters common in the quaternary deposits.

The mapping of aggressive groundwater spread in Barnaul was carried out. The type of aggressiveness was determined.

In Barnaul, groundwater aggressiveness is local. The intensity of aggressive water exposure is mostly mild. Only an average degree of aggressiveness is shown in “topwater” loamy soils.

Sulfate aggression with a concentration of 250–370 mg/dm³ is found in the groundwaters’ alluvial sediments of the first and second fluvial terraces of the Barnaulka River distributed within the borders of Korolenko and Papanintsev streets.

Chloride aggression with Cl content of more than 250 mg/dm³ occurs within the first and second fluvial terraces and in “topwater” groundwater. Subaerial sediments of the Priobsky plateau are typical. In the north-western part of the city, on Kosmonavtov Prospekt, the groundwater chlorine content reaches 518 mg/dm³.

Aggressive carbon dioxide is observed in the groundwater of the first and second fluvial terraces of the Barnaulka River with a concentration of 17–26 mg/dm³, as well as in the groundwater of the
Krasnodubrovskaya suit deposits with concentrations reaching 35 mg/dm³ within Montazhnikov street and Yuzhnyi proezd.

According to the hydrogen indicator, groundwaters have aggressive properties in spring and autumn. For the studied territory, low pH rates are registered in the groundwaters of the Krasnodubrovskaya suite, typical for the southwestern part of the city in the built-up region within Vzletnaya and Vlasikhinskaya streets and Yuzhnyi proezd.

Further monitoring of groundwaters in Barnaul is needed for a more detailed study of distribution patterns, which may allow identifying sources of pollution and the possibility of their elimination.

In the future, the authors plan to continue the study, given that only a small part of the problem is covered.

References
[1] Bobyleva M, Sotnikov P V, and Chernov M P 2018 Effect of the chemical composition of soils and groundwater on the construction infrastructure of Barnaul Horizons Education 20 Available at: https://edu.secna.ru
[2] Burmistrova S E, Trufanov A I, and Ruvinova L G 2011 Aggressive groundwater in Vologda city. University Science to Region I pp 213-216
[3] Unified corrosion and aging protection system 2017 HOST 9.602-2016) from June 1, 2017 (Moscow, Russia: Standartinform Rossiiskoi Federatsii)
[4] Revyakin V S Ed. 2007 Barnaul scientific reference atlas (Novosibirsk, Russia: FGUP “PO Injgeodesia” Roscartography)
[5] Protection of construction structures from corrosion 2001 SP 28.13330.2012 from January 1, 2001 (Moscow, Russia: Standartinform Rossiiskoi Federatsii)