Chemical Composition of Groundwater in Kazan

PETROVA Daria[1]

[1] Kazan Federal University, Kazan (RUSSIA)
Email: DaIPetrova@kpfu.ru

Abstract

Based on the processing of hydrochemical data using of mathematical statistics and GIS-technologies, the consequences of the impact of technogenesis on the underground waters of a large Russian city over the past 60 years are considered. Trends of changes in the chemical composition of the underground hydrosphere are shown.

Keywords: Groundwater, Hydrochemistry, Technogenesis, Monitoring, Mathematical Statistics, GIS, Kazan

Introduction

In connection with the growth of cities and the concentration of the population in a relatively small area, the study and assessment of technogenic factors on changes in the composition of the hydrosphere in industrial-urbanized territories has recently become an urgent direction of hydrogeological research, which studies the transformation of a natural hydroshell into a natural-technogenic and technogenic (e.g., [4], [5]). For example, the study of the chemical composition of water allows the consequences of human activity on the underground hydrosphere to be assessed (e.g., [1], [2], [3], [6], [7], [8]).

The city of Kazan is a large (1.25 million inhabitants) industrial and cultural center of Russia, for which the issues of changing the quality of groundwater are an important element of strategic development. Today, about 20% of the city's drinking water supply is connected with underground water intake facilities, and almost all large enterprises have their own underground water source for industrial water supply (Fig. 1).

Object characteristics and research methods

The territory of Kazan includes the following underground aquifers (from top to bottom): Neogene-Quaternary alluvial complex (aN-Q); Lower Kazanian carbonate-terrigenous complex (P2kz1); Sakmarian sulfate-carbonate complex (P1s). Underground waters are exploited in Kazan by a large number of wells (Fig. 1) and are widely used for industrial water supply of industrial enterprises and household and drinking needs. Regular observations are carried out in the wells. I have collected the results of 2267 chemical analyses of water carried out according to standard methods in certified laboratories. Statistical processing of the initial data was carried out using the STATISTICA software. To build maps-models of spatial variability of components, the “ArcGisMap” software package was used, which provides a wide range of different interpolation methods. Inverse distance weighted and kriging methods were used to analyze chemical parameters.

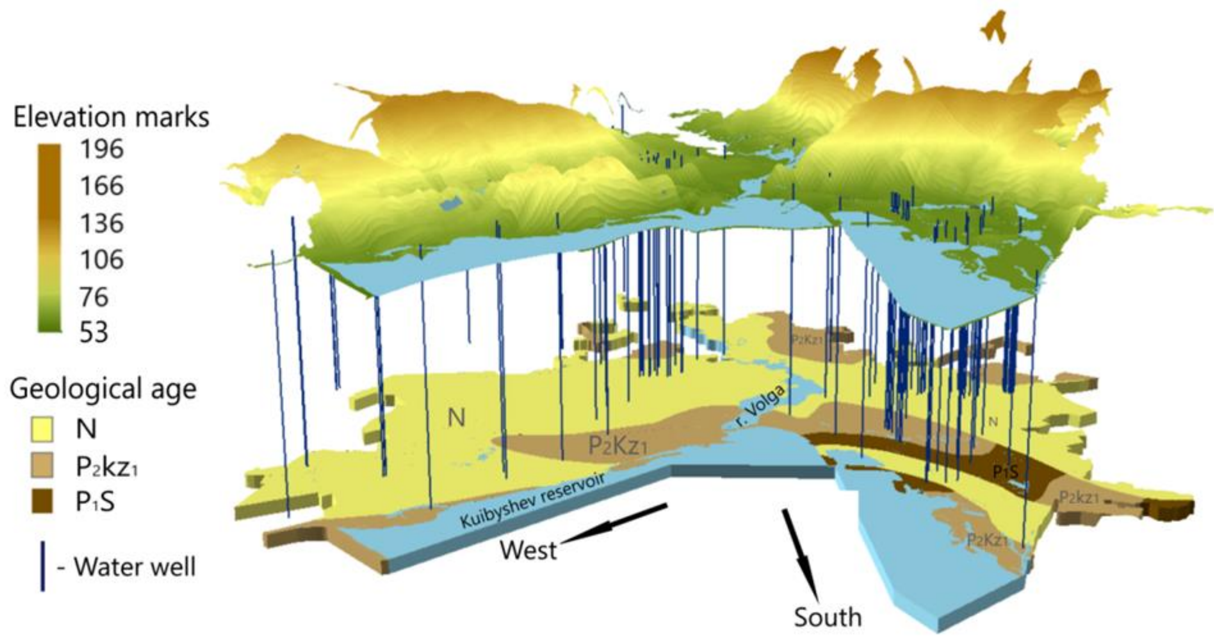

Fig. 1. Modern relief, geological structure and water wells in Kazan

Research results and their discussion

Table 1. Average contens of the main components in the underground hydrosphere of Kazan

Component	Hydrostratigraphic division (observation period)					
	P_1s (1960-2000)	P_1s (2001-2019)	P_2kz_1 (1960-2000)	P_2kz_1 (2001-2019)	N-Q (1960-2000)	N-Q (2001-2019)
Rigidity, ^{O}Ж	15,9	11,2	17,15	17,33	7,55	10,45
pH, unit pH	7.58	7.40	7.16	7.20	7.04	7.27
Oxidizability, mgO/l	1.84	1.35	1.24	1.21	3.34	3.88
Mineralization, mg/l	1048.8	782.3	1266	1227.5	567	653
$Na^{+}+K^{+}$, mg/l	14.1	22.5	23.77	51.6	25.72	16.65
NH^{-}_4, mg/l	0.095	20.76	0.073	0.16	0.14	0.52
Ca, mg/l	176.8	142.6	219.65	274.93	117	108
Mg, mg/l	33.2	39.4	65.84	53.32	32.6	47.7
Fe general, mg/l	0.36	5.58	0.4	0.68	0.78	0.63
Cl, mg/l	7	7.27	16.36	33.23	14.7	25.46
NH^{-}_4mg/l	561.7	231.9	544.94	494.14	131.07	231.12
NO^{-}_3, mg/l	0.94	13.1	1.71	7.61	2.95	8.17
HCO^{-}_3, mg/l	333	364.6	385.5	333.0	347.78	427.16
Number of samples	72	549	970	249	198	205

Data for urban water wells are divided into 2 periods: the first period includes the results from 1960 to 2000, the second period from 2001 to 2019. Some features using the example of the aquiferous Nizhnekazan complex. Most of the components do not exceed the maximum permissible concentrations (MPC) for drinking water according to SanPiN 2.1.4.1074-01. Such components include pH, all cations, chlorides, nitrates, permanganate oxidizability. Excess of MPC relative to drinking standards was noted for mineralization (dry residue), total hardness, sulfates, ammonia, iron. Mineralization is characterized by significant (138-2780 mg/l) fluctuations with average values of 1266 and 1227.5 mg/l, respectively, for the first and second periods (table 1).

Fresh waters with mineralization up to 1000 mg/l are found in the northwestern part of the city on the right bank of the River-Kazanka (Fig. 2).

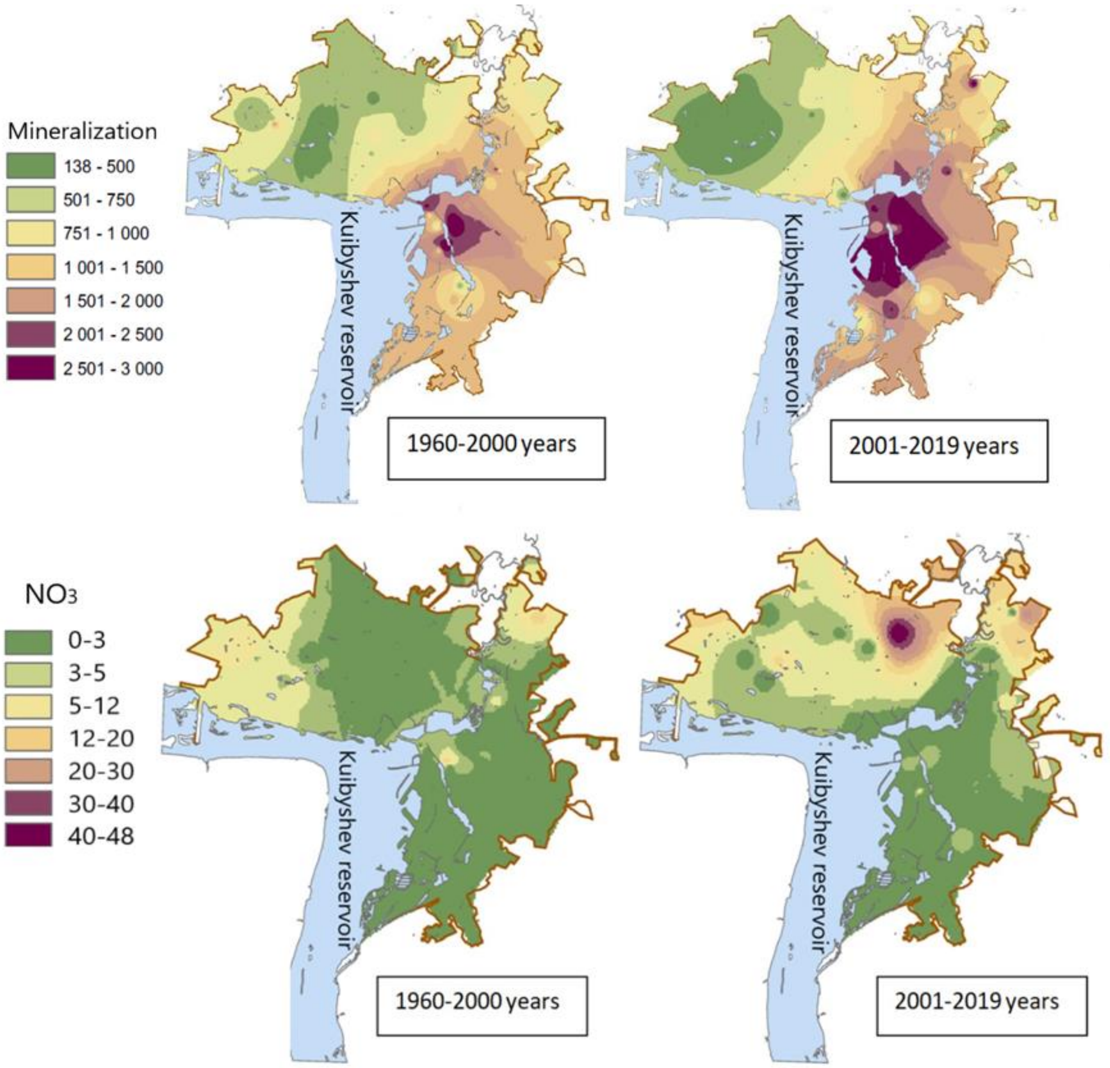

Fig. 2. Models of the contents of the main components (in mg/l) in the underground waters of the Nizhnekazan complex

The central (historical) and southern (industrial) parts of the city are characterized by low-mineralized waters, which may be associated with intensive residential and industrial loads, as well as with a fairly old stock of wells, which has been operating for more than half a century.

For sulfates, approximately the same tendencies are characteristic as for mineralization: significant fluctuations (from the first to 2000 mg/l) with average values of 544.9 and 494.1 mg/l, respectively, for the first (1960-2000) and the second (2001-2019) periods (table 1). There is a noticeable tendency for the expansion of the area of sulfate waters in the central and southern parts of Kazan in the 21st century (Fig. 2) with a simultaneous decrease in the sulfate ions on the right bank of the River-Kazanka. Chlorides are uncharacteristic for the waters of the Lower Kazanian complex (from the first to 270 mg/l), although there is quite a clear tendency toward their increase in recent decades. An increase in nitrate concentrations from 0.43 mg/l in the first period to 9.37 mg/l in the second period may cause relative concern (Fig. 2), although the MPC of nitrates according to SanPiN 2.1.4.1074-01 is 45 mg/l. Presumably, the tendency for an increase in nitrates is due to insufficient treatment of municipal wastewater, which passes through a powerful natural filter of rocks that overlaps the Nizhnekazan complex, and only reaches the aquifers after decades.

The processing of the analysis results of the waters of the Lower Kazanian complex using cluster analysis revealed “natural” and “technogenic” groups of components. The most technogenic components are chlorides and nitrates; less pronounced confinement to this group of mineralization, iron, sulfates and general hardness. The natural components of the water samples of the Nizhnekazan complex are hydrocarbonates, oxidizability, pH, and, possibly, cations. When comparing the data on cluster analysis by observation periods, some differences are revealed, which, in our opinion, may be associated with a different degree of technogenic load on the water of the Lower Kazanian complex of Kazan in the XX and XXI centuries.

Factor analysis showed that technogenic factors for 2 observation periods strongly contrast, while the most significant “natural” factor 1 is rather well distinguished by a set of common components. By the weight of technogenic factors, it is possible to calculate the quantitative contribution of technogenesis to the composition of groundwater. Thus, the technogenic load on the groundwater of the Nizhnekazan complex at the beginning of the 21st century is higher (33%) than in the 20th century (22%), which is confirmed by the contents of the main components (see Fig. 2).

Conclusions

Summarizing the results obtained, the following conclusions can be drawn.

1. For the first time for groundwater in Kazan, a systematic retrospective analysis of hydrochemical data for a long (60 years) observation period was carried out for groundwater in Kazan.
2. The used statistical method of processing hydrochemical information and geoinformation technologies are suitable for monitoring the aquifers of urbanized areas.
3. It is urgent to create, on the basis of modern GIS-technologies, permanent models of groundwater aquifers in Kazan for digital monitoring and development of priority directions of urban environmental policy, taking into account hydrogeological information.

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REFERENCES

1. Krainov S. R., Ryzhenko B. N., Shvets V. M. (2004). Geochemistry of underground waters. Theoretical, applied and environmental aspects. Moscow, Nauka, 677.
2. Lisenkov A. B., Fisun N. V., Malkov A. V. *et al*., (2003). Technogenic processes in groundwater. Scientific world, Moscow, 248.
3. Sungatullin R. Kh. (2009) Chemical composition of underground and surface hydrospheres (on the example of Naberezhno-Chelninskaya area). Uchenye zapiski KSU. Natural Sciences 151 (3), pp. 153-166.
4. Sungatullin R. Kh. (2010) Influence of technogenesis on the formation of modern weathering crusts and water-bearing areas. Geoecology. Engineering geology. Hydrogeology. Geocryology 6, pp. 494-502.
5. Sungatullin R. Kh., Khaziev M. I. (2009). A systematic approach to the study of the hydrosphere in industrial-urbanized territories. Geoecology. Engineering geology. Hydrogeology. Geocryology 1, pp. 19-31.

6. Schwartz A. A. (2005) Chemical composition of groundwater in the St. Petersburg region in the light of new requirements for the quality of drinking water. Bulletin of St. Petersburg State University 7 (1), pp. 85-93.
7. Shchukova I. V. (2005). Formation of the chemical composition of groundwater in the zone of active water exchange on the territory of the city of Perm. Avtoref. dis ... cand. geol.-mineral. sciences. Perm, 23.
8. Barrett M. H., Hiscock K. M., Pedley S. *et al*., (1999). Marker species for identifying urban groundwater recharge sources. A review and case study in Nottingham, UK. Water Res 33 (14), pp. 3083-3097.