Ecological risk assessment of Tomsk region groundwater used for drinking purposes

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Abstract: The present paper is devoted to the chemical composition analysis of Neogene-quaternary and Paleogene groundwater widely used for drinking in the territory of Tomsk region. It has been shown that groundwater under study contains iron and manganese in excessive concentration. Consequently, this water can negatively affect human health. The ecological and human health risk assessment of Tomsk region groundwater used for drinking has been conducted. According to the calculations, it has been defined that in the overwhelming majority of cases there is a great risk to use groundwater of Tomsk region for drinking purposes.

1. Introduction

A peculiarity of water consumption in Tomsk region is priority groundwater use for drinking water supply. Tomsk region groundwater is rather effectively protected from surface contamination by low-permeability argillaceous deposits. However the water quality in its natural condition does not meet the sanitary regulations and standards (SanR&S) 2.1.4.1074-01 "Drinking Water. Hygienic Requirements to Water Quality in Centralized Drinking Water Supply Systems. Quality Control" as evidenced in publications by many outstanding scientists, for example, V.S. Kustovskiy, I.M. Ermashova, Yu.K. Smolentsev, N.M. Rasskazov, S.L. Shvartsev, D.S. Pokrovskiy and others. However, these works do not focus on the risks of using such water for drinking purposes.

In this regard, the objective of the present paper is ecological risk assessment of using groundwater for drinking purposes by population in the territory of Tomsk region.

Human health risk assessment is a quantity and/or quality characteristic of harmful effects which develop or can develop as a result of current or possible environmental factors impact on a definite group of people under specific conditions determined by regional features, whereas "ecological risk" is understood as probability of negative changes in condition of environment and/or natural objects due to certain factors [1]. With regard to impact on human health, the term "ecological risk" can be defined as a ratio of possible health hazard value due to the influence of a harmful ecological factor within a definite time interval to a standardized variable of this factor intensity [2]. The risk assessment data serve as guidelines and are used to justify and make decisions on risk management.

Ecological risk assessment is used in cases when it is necessary to give response about possible impact of chemicals in air, water and soil that is natural environment on human condition and health. The issues related to ecological risks assessment are actively being studied in a number of developed countries, for example, USA, Germany, Japan, the Netherlands, and etc. [3, 4, 5].

2. Ecological risk assessment methodology

The ecological risk assessment of fresh groundwater used for drinking purposes in the territory of Tomsk region comprised several steps:

1. Groundwater sampling.
2. Chemical analysis of water samples from 90 settlements in the territory of Tomsk region.
3. Analysis of groundwater chemical composition in the region under study and selecting priority substances for ecological risk calculation of groundwater used for drinking purposes.
4. Application of the approach to the risk assessment for Tomsk region population including non-cancerogenic ecological risk calculations of drinking water contamination for population health.
5. Interpretation of the obtained results.

3. Characteristics of groundwater chemical composition

Neogene-quaternary and Paleogene groundwater is used for public supply in Tomsk region in the vast majority of cases. According to the scientists [6, 7, 8, 9, 10, 11], the quality of such water in natural conditions does not conform to the regulation requirements upon a number of indications.

The chemical composition analysis of Neogene-quaternary groundwater has indicated that the water mineralization in the eastern and northern regions is basically within the range of 0.15-0,4 g/l. Mineralization value reaches 0.6-0.7 g/l in the right south-west of Tomsk region. Water is hydrocarbonate-sulfate, about neutral, pH ranges between 6.5 and 8.05.

Groundwater is smooth and very smooth over a large area of the region under study. Moderately hard water is almost commonly developed in the southern regions. Calcium and magnesium ratio rises sharply only in Tomsk and Bakcharsky regions where water becomes hard and very hard, its hardness ranges from 7 to 13 mg-equ/l.

Organic substances content (in terms of permanganate value) varies over a wide range between 2.6 and 10 mgO/l. According to the data collected by N.A. Ermashova [6], they are generally represented by humic substances (humic acids and fulvoacids).

Substantially all the water in the region under study contains iron in excessive concentration. Iron concentration is 3-10 mg/l in 70 % of the analyzed water samples. Oxidation-reduction potential (Eh) and dissolved organic solid are the major factors which control iron content in water (Fig. 1) [10, 12, 13, 14]. Our research is in accordance with the data obtained by other authors; in particular, iron is presented in water under study in two forms: dissolved bivalent form and bonded with organic substances [6-10, 12-16].

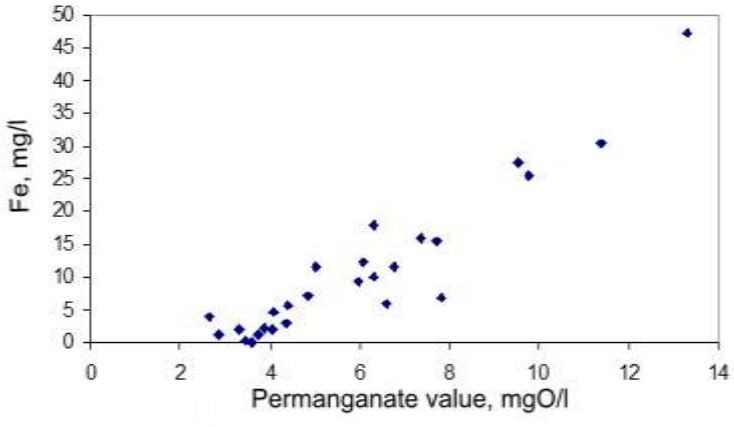

Figure 1. Iron content in the analyzed Neogene-quaternary water in dependence to permanganate value.

The presence of iron combined with organic substances in water has been studied with extractive method in chloroform [10].

The results of the study have shown that the share of iron bonded with organic substances in water samples ranges between 15% and 37% in the area under study. This value increases in the northern direction; it depends on the content and type of the organic substances presented in water. The main problem is that it is very hard to destroy iron combined with organic substances and remove it from water [10].

Manganese is rather widespread in the explored water. The presence of this element in concentration exceeding 0.1 mg/l is 95% with the most typical concentration of 0.1-0.5 mg/l (recorded in 58% water samples); its maximum concentration is 1.1 mg/l.

Paleogene water is most widely used for drinking purposes in the region. It is characterized by about neutral medium, pH ranges between 6.2 and 7.5. They demonstrate basic regularities in distribution of mineralization and its components specific to overlying formation. Water mineralization ranges between 0.09 and 0.5 g/l.

Water is mainly hydrocarbonate-calcium. Water is smooth in the northern and eastern areas; it is mainly moderately hard and occasionally smooth in the central and southern areas.

Organic substances content is almost twice lower than in Neogene-quaternary water. Average oxidability value is 3.6 mgO/l. This value increases in the northern and eastern directions with a decrease in water mineralization in boggy areas and reaches 7.2 mgO/l (which 1.5 times exceeds the maximum permissible concentration).

Iron concentration in the water under study reaches 15.4 mg/l, and is on the average 4.5-5.0 mg/l. Iron concentration in the analyzed Paleogene water samples commonly exceeds the maximum permissible concentration. In the overwhelming majority of cases, Paleogene water contains iron in bivalent dissolved form [6, 9]. Manganese content in water reaches 1.1 mg/l with an average value of 0.3-0.4 mg/l. Its content exceeds the maximum permissible concentration in a large part of the territory.

The chemical composition analysis of the groundwater used for drinking supply in the territory of Tomsk region has indicated that iron and manganese are the major components deteriorating its quality. Rural communities are facing this acute problem as drinking water treatment is exceedingly imperfect there.

4. Assessment of ecological risk level

Iron and manganese that occur in drinking water refer to non-carcinogens. Non-carcinogens are substances which cause negative changes in health condition, in particular, the rise in sickness and mortality rate that can be determined by both short-term and long-term exposure. Non-carcinogenic effects comprise: respiratory system irritant action; toxicity to liver, kidneys and other vital organs; central nervous system changes; fertility disorder and death [1, 16-21].

Non-cancerogenic health risk determination from the presence of chemicals in drinking water has been carried out according to the risk coefficient at per oral route with drinking water (CO_{per}) using the formula [2]:

$$CO_{per} = \frac{C_{per}}{RfD}$$

where C_{per} — substance concentration in drinking water, mg/l;

RfD — reference doses in case of chronic intake (0.3 mg/l for iron (the source is NCEA), 0.14 mg/l for manganese (the source is IRIS). Table 1 presents the calculation data and their interpretation.

The data presented in table 1 show that 60 % water samples conform to extremely high hazard level and 25 % - to high hazard level in terms of iron concentration. 25 % water samples conform to high hazard level in terms of manganese concentration. Extremely high and high hazard levels of drinking water are inappropriate for population. When such water is used for drinking purposes, it is necessary to take emergency curative and other measures to ensure health risk reduction.

Table 1. The data of hazard coefficient and risk level evaluation in case of using groundwater for drinking.

Risk level	Hazard coefficient	Iron concentration limits, mg/l	Sample ratio by iron, %	Manganese concentration limits, mg/l	Sample ratio by manganese, %
Extremely high	Higher than 10.0	3.23-15.4	60	-	-
High	5.0 — 10.0	1.65-3.0	25	1.1-0.86	25
Average	1.0-5.0	0.3-0.82	15	0.59-0.17	65
Low	0 — 1.0	-	-	0.13-0.11	10

15 % water samples by iron and 65 % water samples by manganese conform to average hazard level, which means that such a hazard level is inappropriate for population. This risk requires developing and taking scheduled corrective measures as well as continuous monitoring in population settlements.

Only 10 % water samples by manganese have low hazard level, which means that such water conforms to the conditionally appropriate (acceptable) risk zone; the majority of foreign hygienic regulations and those recommended by international organizations for population in general are established precisely at this level.

5. Conclusion

The present research has shown that in most cases Neogene-quaternary and Paleogene water used for drinking purposes in the territory of Tomsk region contains iron and manganese in excessive concentration. This made it possible to define substances which can have negative impact on human organism when they are ingested with drinking water.

The ecological risk assessment made in the current research has indicated that Tomsk region groundwater in its natural condition used by population for drinking is characterized by extremely high or high hazard level in the vast majority of cases, thus, it required to implement urgent and effective methods to purify groundwater from iron and manganese.

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