

# **GEOCHEMISTRY OF FRESH GROUND WATER OF ARTESIAN BASINS IN THE RUSSIAN PART OF PRIAMURYE**

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Ground waters with increased content of iron, manganese and silicon are common to the artesian basins in Priamurye. Several authors studied regularities of migration and formation of ferriferous and manganiferous fresh ground waters [1-14].

Mountains with intermountain troughs are a typical relief in the region. River valleys have well-developed floodplain and above-floodplain terraces. The region has a continental climate with monsoons in summer. Surrounded with the mountains artesian basins are composed of developed terrigenous-sediment deposits and volcanogenic and intrusive Achaean to Cenozoic formations. The artesian basin mantle is formed with Mesozoic and Cenozoic weakly lithified and loose terrigenous and coal-bearing deposits of a lake-alluvium genesis.

Priamurye belongs to a province of ferriferous, manganiferous and silicon-bearing fresh ground waters with low fluorine concentrations. Iron concentrations fluctuate in the range of 10 - 20 mg/l, maximum values being 30 - 50 mg/l, manganese concentrations are within the range 1 - 8 mg/l and those of silicon are 10 - 40 mg/l. These values by an order exceed permissible condensations of these components for drinking water (0.3, 0.1 and 10 mg/l respectively).

Ultra-fresh and fresh waters of the region are silicate, silicate-hydrocarbonate or sodium bicarbonate. Most ground waters of the mountain areas meet drinking water standards, whereas ground waters of plain areas, where most of the population of the region is concentrated, are characterized with increased concentrations of iron, manganese and other chemical components and as such need special treatment to be supplied to the population as drinking water.

Main sources of iron, manganese and silicon in ground waters are mountain rocks and organic matter (forest litter, peat deposits). Iron is mobilized and migrates in soils of automorphic and hydromorphic type, common to local gley landscapes.

Like iron calcium is also washed out from soil and peat horizons. Migration capacity of both elements is practically the same. That is why soil-ground waters have hydrocarbonate ferriferous-calcium composition. In acid gley medium iron migrates both in the form of an oxide ion and in the form of organic-mineral compounds. Ferrous oxide ion concentrations in soil-ground waters under peat deposits fluctuate from 20 to 60 mg/l.

Although ground waters have hydrocarbonate anion and mixed cation composition their mineralization is rather weak (100—350 mg/l). Waters in mountain areas have subacid and neutral reaction depending on chemical composition of enclosing rocks. Ground water chemical composition within the artesian basin mantel varies. Still there is an evident change of hydrocarbonate natrium waters at the basin edge into hydrocarbonate magnesium-natrium waters and towards the basin center they change into hydrocarbonate ferriferous-calcium

waters. Ferriferous oxide concentrations increased from the basin edge to its center and reach 20 - 40 mg/l. Such ferriferous water zoning is explained with increased permeability of mantle rocks at the basin edges and more intensive swamping in the depression central part and along river valleys.

Vertical zoning in ferriferous waters (downward decrease of concentrations in the mantle profile) reveal that filtration capacity of loose mantle deposits also decrease with their depth. It happens because rock lithification increases with depth and Cenozoic deposits are lithologically heterogeneous.

Increased ferriferous oxide concentrations are observed at lithological barriers (muddy areas of aquifers), where filtration rate reduction causes ground water afflux. Hydrochemical situation in ground water afflux areas is characterized with more rapid loss of oxygen dissolved in water and used for ferriferous oxide and organic matter oxidation and accumulation of carbonic acid, hydrocarbonate and silica in water. Accumulation of ferriferous oxide, hydrocarbonate and free carbonic acid disturbs the balance in the water-rock system causing a right shift of the carbonate balance. Thus iron and carbonate are partially withdrawn from the solution. Carbonate activity decrease and dissolved silica concentration increase create conditions for ferriferous oxide transformation into metasilicate.

Main changes of ground water chemical composition in hydrogeological massifs and volcanogenic basins occur at the stage of atmospheric precipitation penetration through mountain brown-taiga soils. Upper horizons of these soils are characterized with a high humus content (up to 24%), rapidly decreasing with depth; an acid reaction and insufficient bases. With atmospheric moisture seepage especially through an alluvial soil horizon, water is enriched with silicic acid and metals and water mineralization increased due to carbon acid leaching.

In the aeration zone with filtration through fractures and pores mineralization of ground waters gradually increases due to rock leaching. Compared to atmospheric precipitation in ground water concentrations of hydrocarbonate ion and main cations of sodium, calcium and magnesium increase significantly. Chlorine ion concentrations in ground water are practically the same as in precipitations. Amount of dissolved oxygen decreases with depths as it is used for oxidation of minerals of water-bearing rocks. Nitrogen prevails in dissolved gas content. Carbon acid leaching, cation exchange, freezing and thawing of active layers are most important processes in the aeration zone.

Compared to the rate of moisture transfer in the aeration zone the rate of further ground water transformations is reduced. Hydrocarbonates prevail in mixed cation composition of ground waters in the exogenous fractured zone. In general, mineralization here does not exceed 0.1 g/l.

Below the exogenous fractured zone (below 150 m), fracture and vein waters prevail and hydrocarbonate calcium waters with mineralization 0.2—0.4 g/l are common. Such water content is observed here irrespective of the type of water-bearing rocks. Hydrocarbonate sodium waters prevail in permafrost areas and sulphate calcium waters prevail in areas of sulphide mineralization of polymetallic ore deposits.

Groundwater composition formation in the aeration zone of artesian basins has much

in common with that in hydrogeological massifs and volcanogenic basins. Nevertheless it has some of its own specifics due to decelerated water movement in plain conditions. It is mostly characterized with intensive enrichment with organic compounds, which occurs in meadow and bog soils, and hindered infiltration due to abundant loam. Mineralization of soil bog water is 0.05—0.15 g/l and its composition is hydrocarbonate calcium. In podzol soils mineralization increases to 0.2 g/l. Silicic acid concentrations in soil waters may be up to 10—25 mg/l. Ferriferous waters with divalent iron concentrations 10—50 mg/l are very common in the region. Relatively homogeneous composition of water-bearing rocks (Cenozoic and Mesozoic sand-clay deposits) determines the formation of ground waters of the artesian basin mantle. Water mineralization increases with depth: from 0.1–0.2 g/l at less 200 m depth to 0.5–0.8 g/l at 400-800 m depth. These waters are hydrocarbonate sodium.

Based on the comparison of concentrations of chemical elements in ground water with their permissible levels for drinking water, two element groups may be identified. The first group includes elements (copper, molybdenum, lead, zinc), which permissible levels for drinking water are much higher than their concentrations in fresh ground waters. The second group includes elements, which concentrations in groundwater are close to or exceed permissible levels. They are iron (0.3 mg/l), fluorine (0.7—1.5 mg/l), beryllium (0.0002 mg/l), selenium (0.001 mg/l), strontium (2 mg/l), manganese (0.1 mg/l), silicon (10 mg/l). Such concentrations of these elements in fresh ground waters are the results of natural processes of water chemical composition formation in this region. Composition of ground water with concentrations of such elements as iron, manganese, silicon, which exceed drinking water permissible levels, and with fluorine lower permissible concentrations is quite natural and common to Priamurye.

Regularities of iron distribution in ground waters are mostly well-studied in the Amur-Zeya and Middle-Amur artesian basins (Fig. 1).

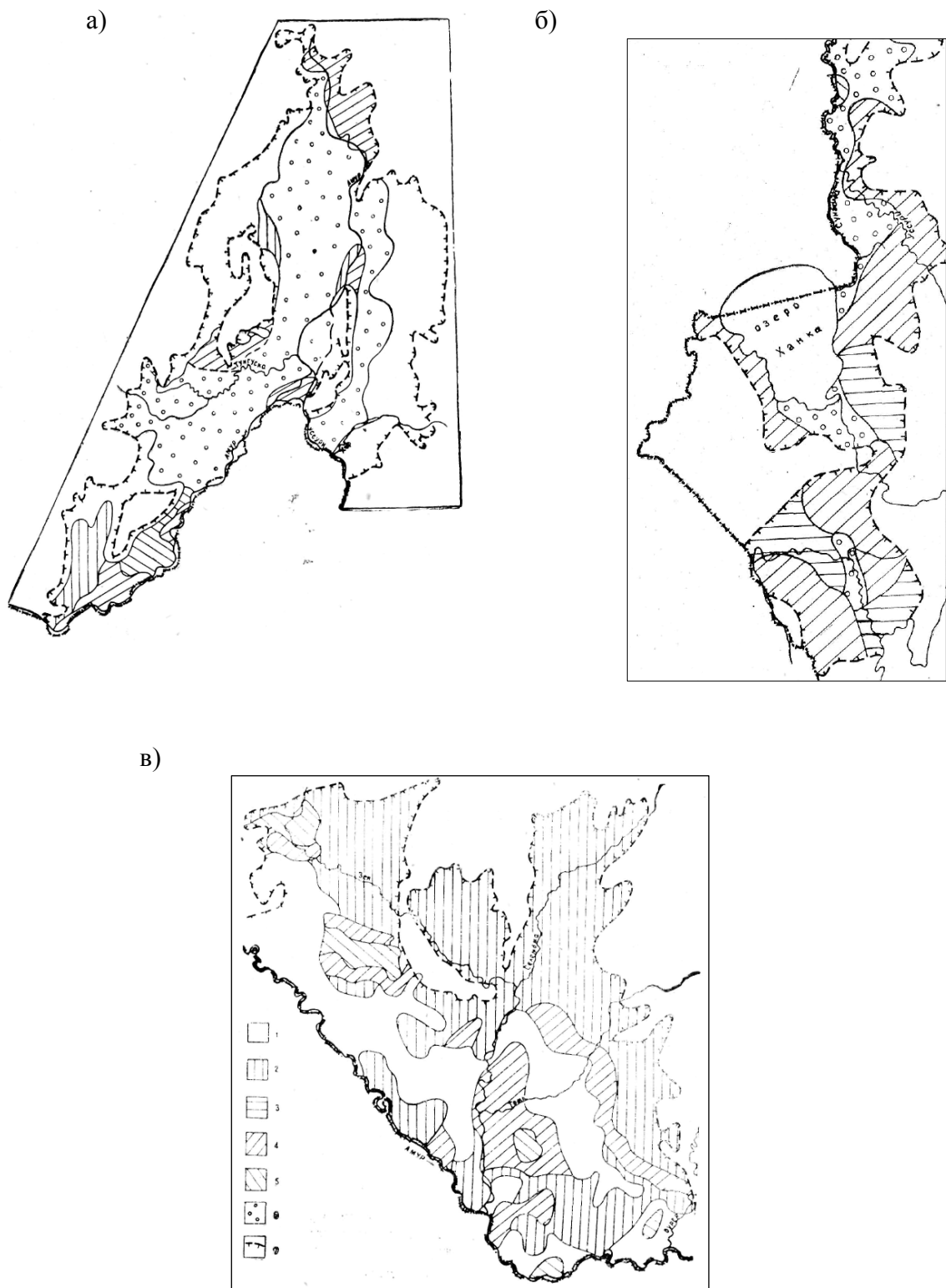


Fig. 1. Ferriferous oxide in underground waters of: a – Middle-Amur artesian basin; б – Ussuri-Khanka artesian basin, в – Amur – Zeya artesian basin [14].  
 Ferriferous oxide concentrations (mg/l): 1 – up to 0.5 or absent; 2 – up to 2; 3 – from 2 up to 5; 4 – from 5 up to 10; 5 – from 10 up to 15; 6 – from 15 up to 20; rarely up to 25-40; 7 – artesian basin boundaries.

Iron concentrations are differently distributed in the basin. Non-ferriferous waters (iron concentrations are less 1 mg/l) are common to the mountain boundary of artesian basins. Iron content in water increases towards the depression center and sometime reach 50—100 mg/l. There is a gradual change from hydrocarbonate natrium water at basin edges to hydrocarbonate manganese-natrium and further to calcium ferriferous waters close to the depression center.

A vertical zoning, i.e. iron concentration decrease with depth, is found in the Amur-Zeya artesian basin, where iron concentrations in ground water are 5—10 mg/l at 100 m depth, decrease to 1 mg/l at 100—300 m depth and 400 m deep do not exceed 0.3 mg/l. Geochemical specifics of manganese and iron in some areas Priamurye artesian basins are common and in some areas are different. Both elements intensively migrate in the divalent ion form in reduction conditions in acid water medium. In natural environment iron sediments in neutral waters with pH of 5.6—7.5. Manganese remains in the solution and migrates till it encounters more oxidizing conditions with pH over 8.5. This process causes manganese accumulation at the artesian basin peripheral. Thus manganese geochemical peculiarities and specifics of landscape and climate in the region cause the formation of ground water with high manganese concentrations.

In ground waters of the Upper-Zeya artesian basin mantle manganese concentrations vary from 0.12 to 0.60 mg/l, those of the Upper-Bureya basin vary from 0.17 to 0.55 mg/l, and those of the Middle-Amur basin vary from 0.12 to 5.0 mg/l. The highest manganese concentrations are registered in ground water of shallow horizons.

Ultra-fresh silicate-hydrocarbonate waters are abundant in the most part of the Priamurye region and are well-defined [15]. Hydrocarbonate waters with silica concentrations higher those of hydrocarbonate and alkali element prevalence in cation composition prevail among ultra-fresh waters. These waters can be called silicate or silicate-hydrocarbonate. Towards lower parts of the relief ground water mineralization increases, silicic acid concentrations decrease and these waters become ordinary fresh hydrocarbonate calcium waters. Silicic acid in natural environment is usually in a dissolved form. A colloid part of silicic acid does not exceed 3 — 20% of total silicon concentrations. The transition from dissolved silica form proper into its colloid form goes slowly.

The Priamurye region can be ranked as a region with a fluorine deficit in ground waters. Studies of ground water chemical composition of hydrological massifs, artesian and volcanogenic basins revealed that fluorine concentrations fluctuate within the range of 0.05—0.3 mg/l, which is noticeably lower optimal concentration recommended for drinking water supplies (1.5 mg/l). Such low concentrations of fluorine may be explained with dominance of hydrocarbonate calcium waters in the region.

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