Radio-Ecological Conditions of Groundwater in the Area of Uranium Mining and Milling Facility – 13525

Titov A.V.[1], Semenova M.P.[1], Seregin V.A.[1], Isaev D.V.[1], Metlyaev E.G.[1], Glagolev A.V.[2], Klimova T.I.[2], Sevtinova E.B.[2] Zolotukhina S.B.[3], Zhuravleva L.A.[3]
[1] FSBU SRC A.I.Burnasyan Federal Medical Biophysical Center of FMBA of Russia, Zhivopisnaya Street, 46, Moscow, titov_fmbc@mail.ru ;
[2] FSESP "Hydrospecgeologiya";
[3] FSHE "Centre of Hygiene and Epidemiology #107" under FMBA of Russia.

ABSTRACT

Manmade chemical and radioactive contamination of groundwater is one of damaging effects of the uranium mining and milling facilities. Groundwater contamination is of special importance for the area of Priargun Production Mining and Chemical Association, JSC "PPMCA", because groundwater is the only source of drinking water.

The paper describes natural conditions of the site, provides information on changes of near-surface area since the beginning of the company, illustrates the main trends of contaminators migration and assesses manmade impact on the quality and mode of near-surface and ground waters. The paper also provides the results of chemical and radioactive measurements in groundwater at various distances from the sources of manmade contamination to the drinking water supply areas.

We show that development of deposits, mine water discharge, leakages from tailing dams and cinder storage facility changed general hydro-chemical balance of the area, contributed to new (overlaid) aureoles and flows of scattering paragenetic uranium elements, which are much smaller in comparison with natural ones. However, increasing flow of groundwater stream at the mouth of Sukhoi Urulyungui due to technological water infiltration, mixing of natural water with filtration streams from industrial reservoirs and sites, containing elevated (relative to natural background) levels of sulfate-, hydro-carbonate and carbonate- ions, led to the development and moving of the uranium contamination aureole from the undeveloped field "Polevoye" to the water inlet area. The aureole front crossed the southern border of water inlet of drinking purpose.

The qualitative composition of groundwater, especially in the southern part of water inlet, steadily changes for the worse.

The current Russian intervention levels of gross alpha activity and of some natural radionuclides including ^{222}Rn are in excess in drinking water; regulations for fluorine and manganese concentrations are also in excess.

Possible ways to improve the situation are considered.

INTRODUCTION

The area of the JSC "PPMCA" impact is located in the Transbaikalia steppes of insufficient moisture. Most of the territory is occupied East Urulyunguy intermountain basin, the upper part of which is called Sukhoi Urulyungui. The production facilities (plants, tailings, heap leach areas, ponds, combined heat and power plant etc.) are concentrated in the right-hand side inflows (small folds) of Sukhoi Urulyungui within the health protection zone.

Krasnokamensk city is located in the upper reaches of Sukhoi Urulyungui.

Umykeyskaya endorheic basin is in the south-eastern end part of the supervision area; economic and discharge of treated sewage of the city and the company, and partly industrial waste heat and power plant are released in the lakes of this basin.

Uranium mining is carried out by underground mode within the mining lease at Streltsovsky ore field.

At the confluence of the Urtuy creek in Sukhoi Urulyungui fold the brown coal deposit is located and developed.

The East Urulyungui groundwater springs is below (in relief) of all industrial and commercial facilities (in the northern part of the supervision area), which is a source of the central drinking water supply to the city and the company.

POTENTIAL SOURCES OF RADIOACTIVE AND CHEMICAL CONTAMINATION OF GROUND AND SURFACE WATER

Potential manmade sources of chemical and radioactive contamination of surface and ground water include:

- industrial sites of mining and smelting and sulfuric acid plants;
- cinder storage facility;
- tailing dams and other industrial ponds;
- central coal power and hydro ash dump;
- temporary streams of canyons Tulukui and Maly Tulukui and reservoir formed by emergency discharges of mine waters, as well as wastewater discharge into Umykei Lakes.

Natural sources of chemical and radioactive contamination of landscapes and groundwater of Sukhoi Urulyungui fold include:

- uranium (uranium-molybdenum), fluorite deposits of Streltsovskoye ore field;
- undeveloped uranium-molybdenum deposit at the southern border of drinking water inlet.

Secondary (natural and man-made) source of impact on mode and quality of groundwater is Umykey lake-evaporator system.

The following objects impact on the hydrodynamic regime of groundwater: all industrial ponds and streams, back reservoir, groundwater intake of drinking water, unwatering system at coal mine Urtuy and uranium mines (figure 1).

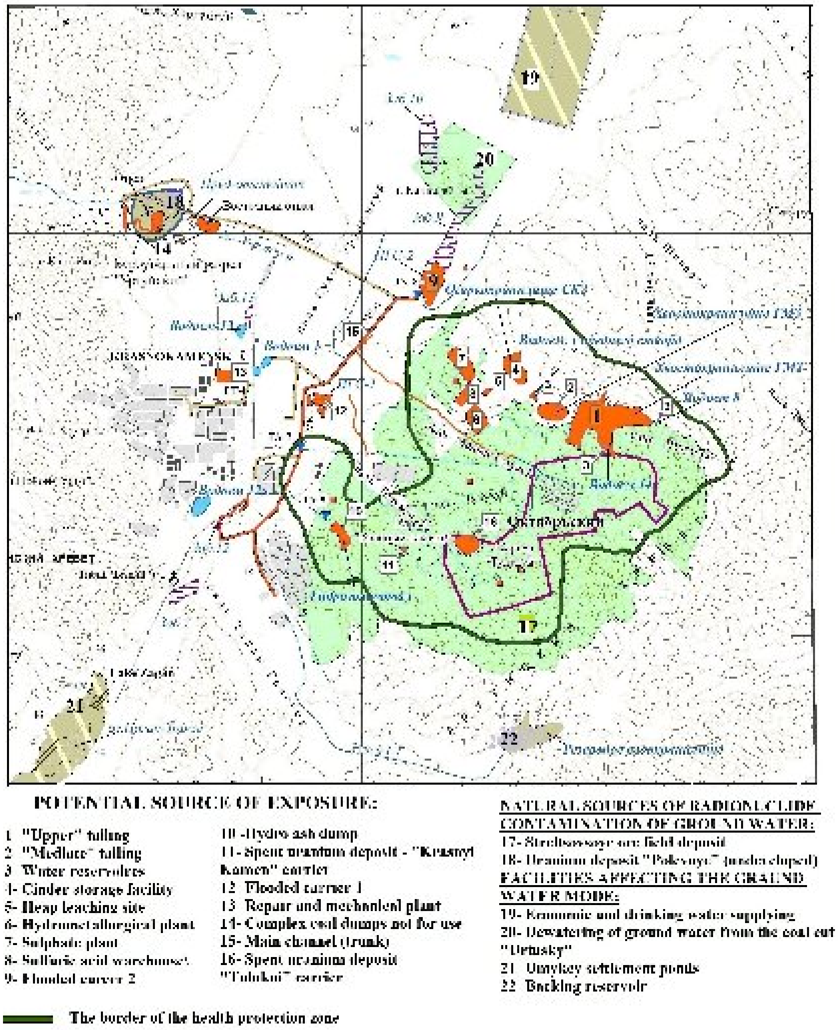

Figure 1. The sources of radioactive and chemical contamination of ground and surface water

HYDRO-GEOLOGIC CONDITIONS OF THE PROARGUN PRODUCTION MINING CHEMICAL ASSOCIATION SITING

At the area of the Association bedding-porous, stratified fissure, crack and fissure-vein ground waters are developed. Pore water is typical for different-genesis Quaternary sediments and the weathering crust, forming the canyons of the valley, and for the Neogene-Quaternary East Urulyungui fold Umykey basin (figure 2).
The artesian basin of fresh groundwater is confined to the deposition of the East Urulyungui intermountain basin; its top floor is presented Neogene-Quaternary complex stratified porous fresh groundwater (aN2-Q) drinking quality; while the lower one is characterized by the development of stratified interstitial waters in the Jurassic-Cretaceous rocks and weak watery.

Aquiferous rocks of the Neogene-Quaternary complex are sand and gravel deposits, separated by layers of clay. The total power of flooded rocks is 3.7-64 m. Pressure head above the roof of the complex varies from 10 to 39 m. The presence of Permafrost Island complicates the situation, breaking the flow of the individual components. The structure of the valley is heterogeneous: water conductivity of the complex in the neighboring areas can vary from 50-200 4000 m^2/day and more.

Test wells drilled in 1966 have revealed the water at depths of 10-12 m and more. The area of the ancient valley development is a kind of mouth, at which groundwater runoff inch Sukhoi Urulyungui unloads in its own valley Urulyungui. Natural food of the Neogene-Quaternary aquifer system is at the expense of lateral inflow of Quaternary horizon of small canyons and fracture zones of surrounding mountains.

The construction and operation of hydraulic structures have led to significant changes in the structure of the flow of groundwater. Following the backwater of the water table, its geometrical parameters and water supply increases and vadose formed. At the same time, in the areas of mining by underground method, large depression funnels were formed in the aquifer system by unwatering and drainage systems. The total amount of manmade water from adjacent canyons, where waterworks are being carried out, to the Sukhoi Urulyungui valley is 160 l/s [1].

In the late 1970s, the water table of Sukhoi Urulyungui fold at various sites increased from the first meters to 34 meters.
In undisturbed conditions, the depth of the water table in the Umykey imposed basin ranged from 0.1-5 m to 12-25 m. In areas of permafrost there are opened above-freezing and under-freezing water at a depth of 0.1-5 m, 11,8-22,6 m. Operation of lakes as water-cooler resulted in a gradual increase in the water table in the center of the lake basin due to increasing the water level in the reservoirs. The presence of Island Permafrost at depths of 10-12 m, contributed to the formation of above-freezing aquifer. Since 2000, groundwater levels became relatively stable. This is explained by the merger of the lake area and stabilization of the level of the water surface. Saturation of soils Umykey basin stopped, the geometric parameters of the aquifer were unchanged, and the flow regime became steady.

Hydro-geological conditions in the basin spans Talan Gozogor is determined by the presence of Reserve Reservoir in its top. Since 1975, due to the infiltration of water loss through the bottom and base of the dam the water table began to rise and water logging of the inch bottom, watercourse formed in the downstream.

At the spit between Sukhoi Urulyungui and Talan Gozogor groundwater levels in undisturbed hydro-geological conditions in December 1973, was at the depth of 16.6 m. Later the relatively stable level was established, and its variations are within the depth 1.3-2.5 m.

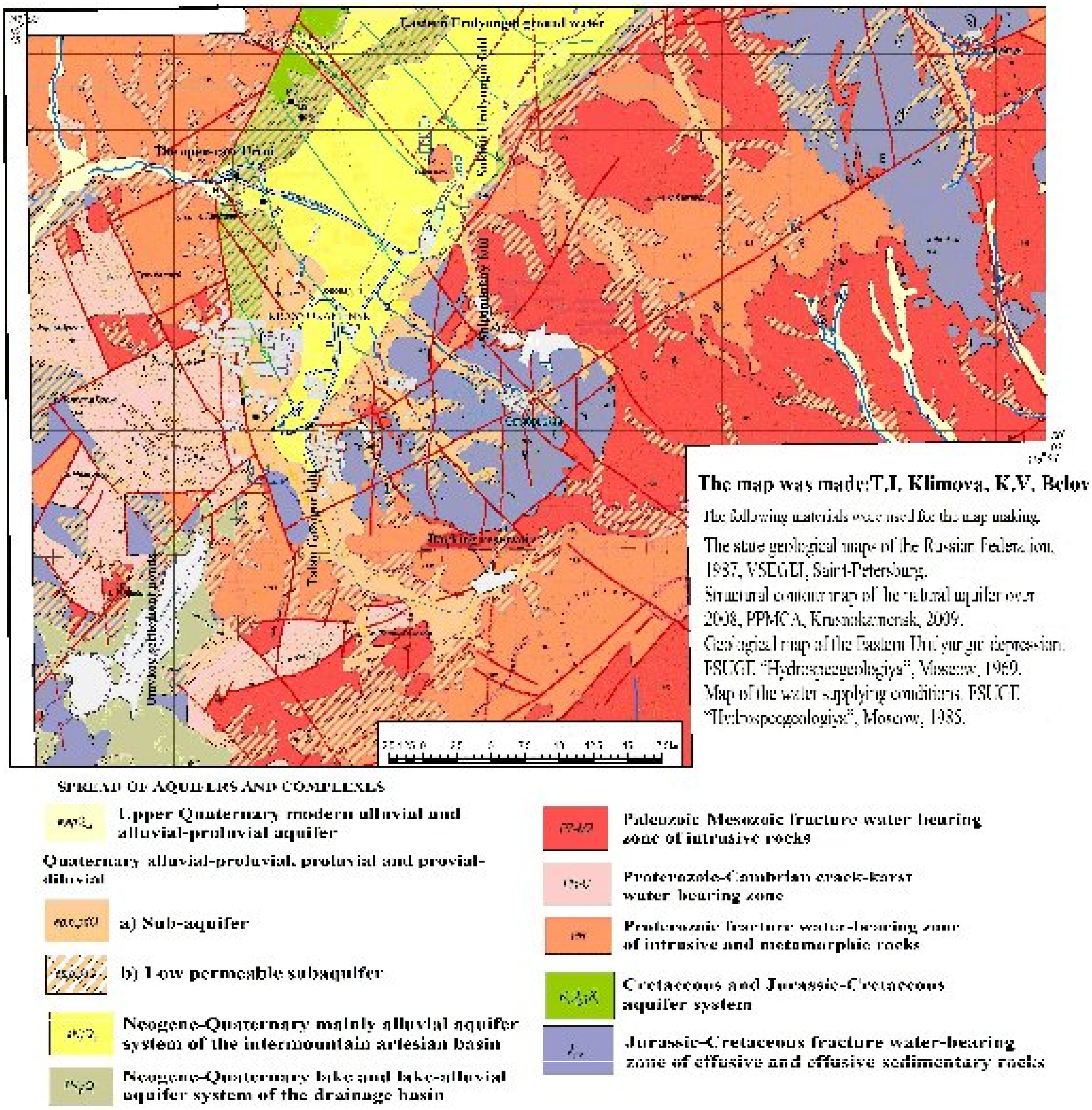

Figure 2. Hydro-geological map of the PPMCA area

At the open-cast Urtui the depression funnel was generated due to mine water drainage. The ground water level in undisturbed conditions occurs at depths of 5.0 m to 13.9 m. Because of dewatering the Quaternary deposits up 50-65 m and partly Lower Cretaceous rocks in the quarry were drained. The depression funnel spread to a distance of 8-10 km. from the career.

Within Streltsovsky ore field, because of drainage, the depression funnel was formed al depth of 600-800 m (the depth of mines), so the water table lowered approximately twice.

Hydro-geological situation at Shirondukuy fold is determined by the presence of two tailings cinder storage facility, a number of small industrial water ponds, leakage of the slurry pipeline, while up to 1974 - by discharge of mine water and sewage of the company Under natural conditions, the water table in the top of Shirondukuy fold lies at a depth 69.7 m, and in the mouth of a depth 12.3 m, and the lower reach of the Upper Tailings at depths of 25-31 m. In 1978, filling of tailings with industrial waste led to a sharp rise of the level, which continued until 1983. Since 1985, direct hydraulic connection between levels of tailings and groundwater has been observed. Since early 1990s, the level became relatively steady.

Filling of the cinder storage facility (the central part of Shirondukuy fold) resulted in intensive increasing of ground water level with its following stabilization at depths 0.77-2.1 m. The commissioning of the Upper Tailings in the mouth part resulted in stabilization of the level) which previously was at depths 11.5-12.3 m) at a depth 3.7-4.2 m in the early 1990s.

Therefore, major changes in the structure of the flow occurred at the beginning of operation of the facility, the maximum rates of increase in the levels were typical before the 1980s, and then they gradually decreased and by 1990-1993, the levels occurred relatively stable throughout. In Umykey basin and upper Sukhoi Urulyungui fold, the levels stabilized in 1999-2000. Part of the territory was water logging: numerous ponds and swampy were formed. The general distribution of underground flow is directed to the valley Urulyungui River, i.e., to the drinking water intake.

MANMADE IMPACT ON THE QUALITY OF GROUNDWATER

Uranium and other manmade materials migrate from contaminated mountain landscapes to Sukhoi Urulyungui fold via surface and ground runoff. Here, the Sukhoi Urulyungui fold landscapes are characterized by contrast geochemical conditions expressed in the presence of geochemical barriers to migration of uranium. The same is true for the water-bearing strata of rocks. Operation of the barriers expressed in periodic leveling of uranium concentrations to background values by removing the uranium out of solution. Figures 3 and 4 show the uranium contents in ground water as of 2009-2010 and maximum values for the entire observation period, respectively.

Over 1983-2002, filtration water from Umykey Lakes formed the flow of groundwater contamination by uranium, which stretches for 8 kilometers (fig.4). In the central part of the aureole, concentrations were 1-10 mg/l, decreasing sharply in the side sections to 0.04 mg/l.

In 2010, maximum uranium concentrations of 0.2-0.3 mg/l were detected on the north-east border of Tsagan Lake in its narrow tongue extended to 1 km along the axis of the flow. At the periphery of the flow in the same direction, the concentration drops to 0.02 mg/l.

In 2009, the SKZ introduced a new technology of the sulfuric acid production, so the discharge of cinders to the cinder storage facility stopped. This has led to a significant decrease in the concentration of uranium in groundwater and reduced configuration of aureoles.

Figure 5 illustrates spreading of uranium in groundwater of Shirondukuy fold, where industrial water reservoirs are located, and Sukhoi Urulyungui (Flooded carrier 2) as of 2009. Migration of contaminators from Shirondukuy fold induced development of contamination aureoles in ground waters, where higher (in comparison with the background) concentrations of sulfate ions, fluoride and long-lived natural radionuclides of the uranium series (uranium,

Ra-226, Th-230, Po-210, and Pb-210) were registered. Over the time range 1995 – 2009, the aureole area declined sharply. Uranium concentrations at short distances from sources of contamination have become close to background values, or some times lower than those recorded until 1994. For example, in recent years in the groundwater in the longitudinal alignment of Shirondukuy to intake (below the tailings and in close proximity to them) relatively low levels of uranium (0.01-0.3 mg/l) was registered. In the early period of operation, in some years, higher values (up to 0.8 mg/l) were abruptly recorded.

Uranium removal from the solution to the solid phase and contribution to its accumulation in the hydro-chemical barriers of restoring media is possible in the presence of organic matter and its radiolysis resulted in hydrocarbon gases or mixed with water to lower Eh values. We did not study this issue.

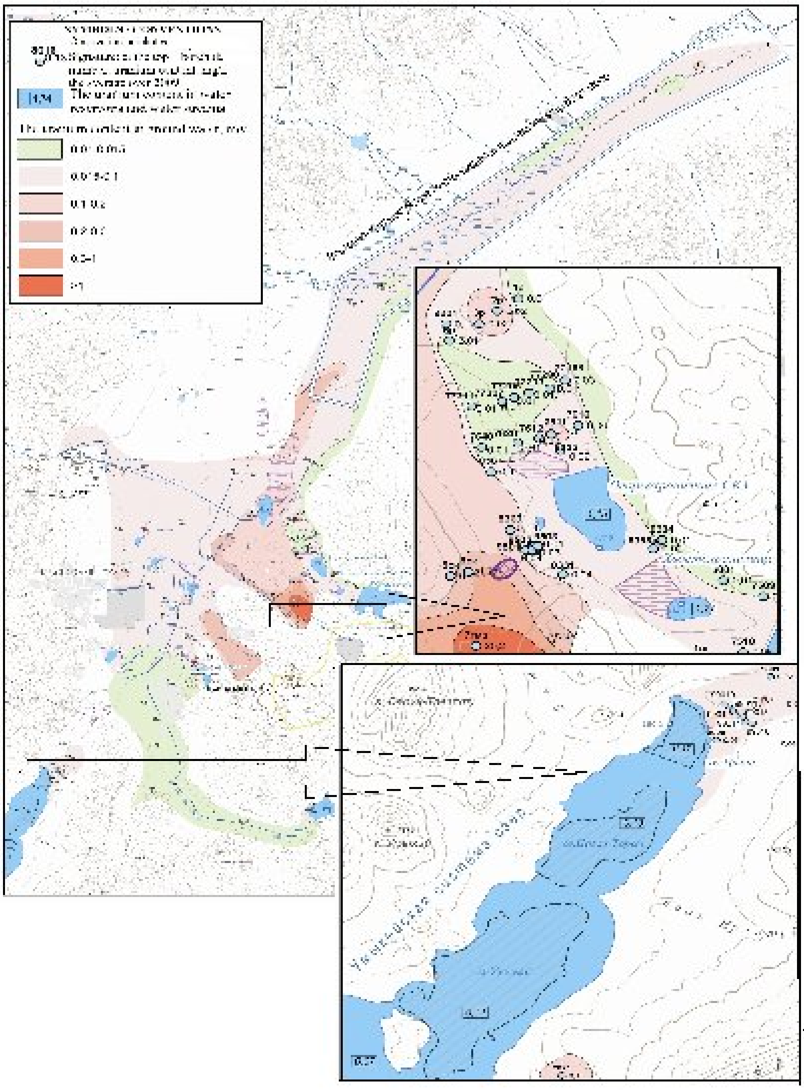

Figure 3. The uranium contents in ground water as of 2009-2010

The qualitative composition of groundwater, especially in the southern part of water inlet, steadily changes for the worse. Mineralization increased from 290 mg/l to 520 mg/l, while the sulfate-ion concentration– from 27 mg/l to 114 mg/l. The contents of fluorine and uranium almost everywhere exceed maximum permissible concentration, and in some wells molybdenum and manganese are in excess (maximum fluorine content is 3.25 mg/l, molybdenum – 0.15 mg/l, manganese – 0.31 mg/l and uranium – 0.10 mg/l – in water inlet wells, and up to 0.24 mg/l – in observe boreholes). In the southern part of water inlet, the uranium and molybdenum concentrations periodically exceed background, probably due to migration of contamination from the facility or migration of these components from the undeveloped uranium deposit "Polevoye" located close to the southern border of drinking water inlet.

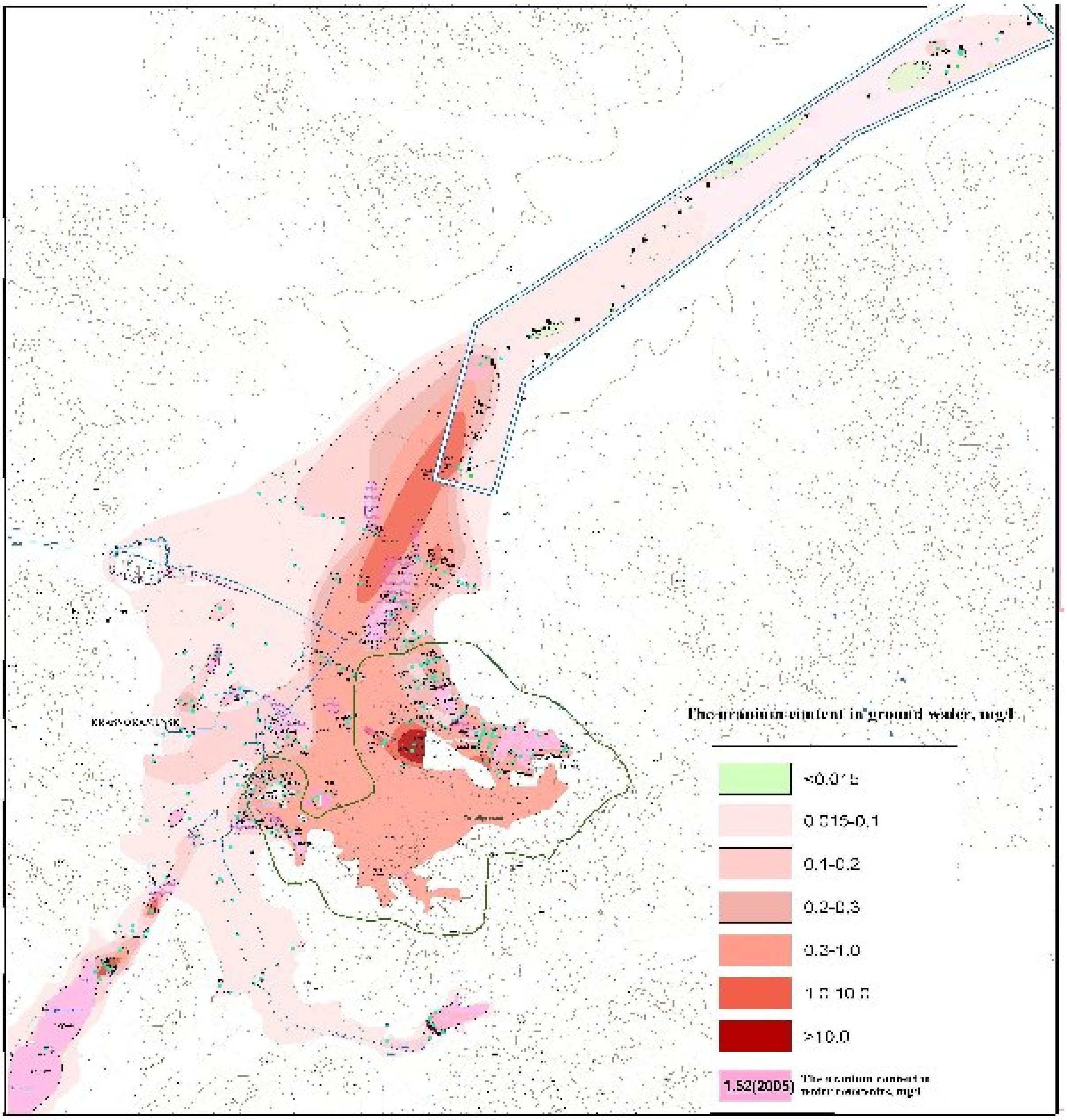

Figure 4. Maximum of uranium contents in ground water for the entire observation period.

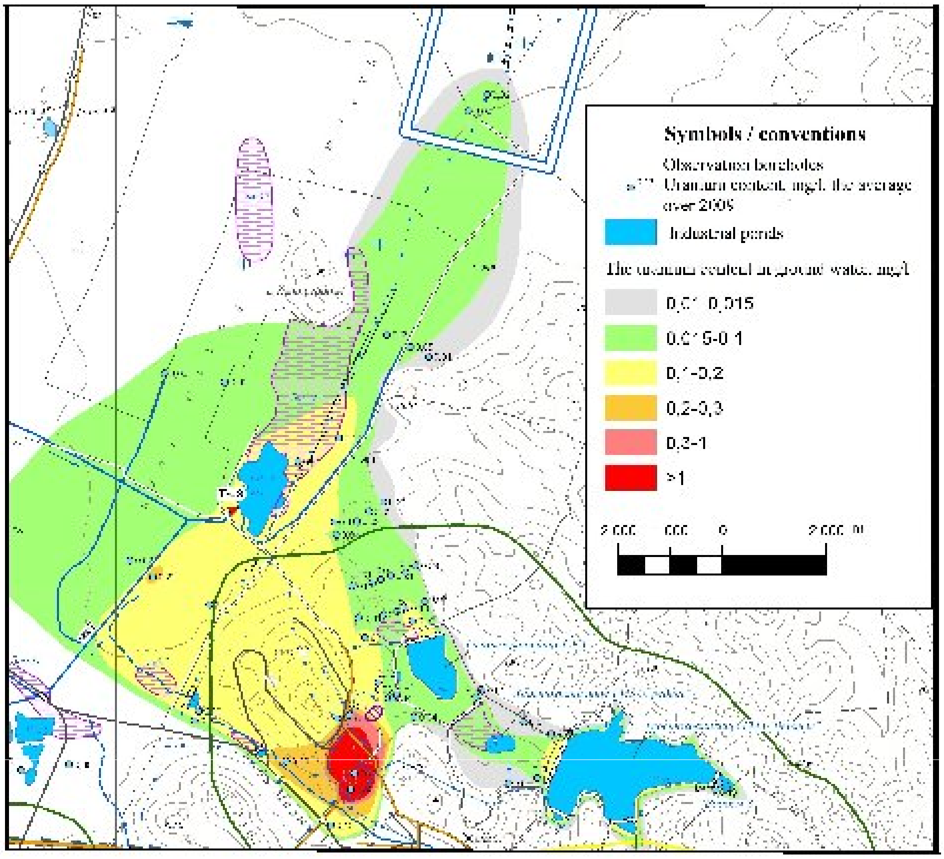

Figure 5. Uranium spreading in ground waters of Shirondukuy and Sukhoi Urulyungui

MANMADE IMPACT ON THE QUALITY OF DRINKING WATER

East Urulyungui groundwater deposits below the relief of all potential sources of contamination (Figure 1). Total runoff from the territory of industrial sites is directed toward the deposition. Domestic hot water intake extends down the valley Urulyungui at a distance of about 40 km. Boreholes (wells) are grouped in three nodes. Mixturing of water from these three pumping stations, water treatment and supply of consumer is carried out at the fourth pumping station. During the operation field groundwater levels worn out slightly - by 0.4-2.0 m. This is due to the increased underground flow of Sukhoi Urulyungui to water intake.

Figure 4 shows that the front of the uranium aureole intersects the southern boundary of the drinking water intake. At the head of household and drinking water intake, at certain periods, uranium concentrations reached up to 5.36 mg/l. The uranium concentration drops to the background value (0.012 mg/l) with a distance. According to the results of inspection of the drinking water quality carried out by Centre of Hygiene and Epidemiology #107, maximum permissible concentrations of uranium, manganese and fluoride were in excess in some years.

Moreover, excessive intervention levels (IL) by total alpha activity and by natural radionuclides established by NRB-99/2009 [2] were registered in drinking water.
The total alpha activity exceeds the established norm up to 10 times (see figure 6 below).

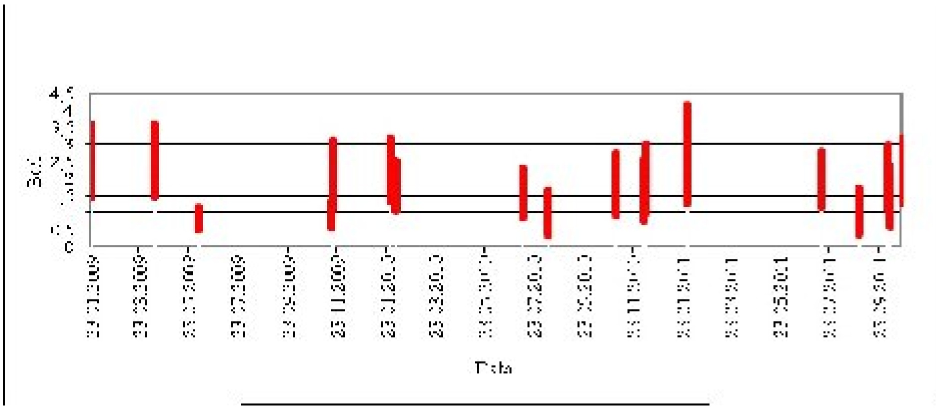

Figure 6. Total alpha activity in drinking water

Total beta activity in drinking water varies over the range 0.14 – 0.54 Bq/l, and norms established in NRB-99/2009 are not exceeded. The table I includes radionuclide composition of drinking water.

Because of significant concentration of Pb-210, Ra-226 and U-238 n drinking water, $\sum_i \frac{Ai}{ILi}$ value varies over the range 1.4 – 2.8. This means that intake of such water will result in annual effective dose of 0.14-0.28 mSv.
Table I. Data of gamma spectrometric measurement of drinking water

Radionuclide	U-238	Ra-226	Th-232	U-235	Pb-210
Activity concentration, Bq/l	1.86	0.33	0.020	0.095	0.64
Intervention level, IL, Bq/l	3.0	0.49	0.60	2.9	0.20

SUMMARY

Activities of JSC PPMCA resulted in manmade contamination of local areas. In general, in terms of the scale of existing anomalies and manmade contaminator levels, the impact on the environment can be characterized as moderately hazardous. In the area of industrial impact of the facility the quote of the most contaminated areas is not more than 10 to 15%, and the flow of airborne industrial contaminators leads to the formation of low-contrast manmade anomalies at the rest territory. At the same time, migration of contaminators toward the adjacent landscape of Sukhoi Urulyungui fold results in hazard of groundwater contamination with uranium and changing chemical composition of this water. At that, the Sukhoi Urulyungui fold landscapes are characterized by contrast geochemical conditions expressed in the presence of geochemical barriers to migration of uranium. Operation of the barriers expressed in periodic leveling of uranium concentrations to background values by removing the uranium out of solution. However, increasing sulfate, hydrogen ion concentration, free carbon dioxide and oxygen in the underground stream can result in the perverse process, including leaching and removal of dissolved uranium in the direction of drinking water intake.

To assess the reality of the threat the detailed study of mechanisms of contaminator fixing in landscapes and water-bearing rocks is required, because contamination of groundwater is largely dependent on the effectiveness of the barrier zone, which prevents migration of radioactive and stable elements.

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