Natural radioactivity in aquatic ecosystems formed by self-flowing wells: the case of a water flow, a well “Cherkashinskaya 36-RG – stream – Aremzyanka river”

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Abstract. The article is devoted to the assessment of the radiation hazard of water and nearby bottom sediments of self-flowing hydrogeological wells, as well as the assessment of the radiation safety of personnel working with these materials for geological prospecting and national economic enterprises. The article is devoted to the study of the impact on the ecosystem of the geothermal waters of the self-flowing exploratory well “Cherkashinskaya No. b36-RG.” In 1965, it was drilled to study a group of iodine-bromine water deposits. The article presents data from a survey of natural background radiation, as well as data on the natural radioactivity of bottom sediments and the volume content of radium in water. The relevance of the work is due to half a century of pollution by highly mineralized iodine-bromine waters of the Irtysh catchment as one of the largest transboundary rivers in Western Siberia. The Aremzyanka River is a tributary of the 1st order of the Irtysh River, a stream flowing from the flowing well No. 36-RG flows into this river.

1. Introduction
The Tyumen region is extremely rich in resources of underground mineral thermal waters, the reserves of which are about 3 million m³ per day and belong to the West Siberian basin [1]. These resources were discovered almost throughout the south of the Tyumen region when searching for oil and gas fields, as well as iodine-bromine waters by exploration wells drilled in 1950-1980. Aquifers were found in the Mesozoic sediments of the Cretaceous (Apt-Cenomanian and Hotheriv-Barrem longlines) at a depth of 1-2 km, as well as in deeper Upper Jurassic sediments (more than 2 km). Many geothermal wells were drilled during the exploration in the 1950-60s of the last century. And now, they are abandoned. The total number of self-inflowing geothermal wells in the south of the region is 22, 13 of which are in the Tobolsky district [2].

There are the Cherkashinskoe and Tobolskoe deposits of thermal iodine and iodine-bromine waters in the territory of the Tobolsk district of the Tyumen region [1].

The well survey has been conducted since 2008. It shows that the manifestation of fluids is noted in 13 of the 27 suspended wells of the Tobolsk group [2], including the Cherkashinskaya well No. 36-RG, which was drilled in 1965 (Fig. 1).
2. Materials and Methods

The object of the study is the area near the well No. 36-RG of the Cherkashinsky iodine-bromine water field, which is located on the II above-flood terrace of the Aremzyanka River (in the east of Tobolsk district). The river flows into the Irtysh River, on the right, at the 576th kilometer from the mouth, 0.5 km north of the Panushkova Village. The length of the river is 98 km, the basin area is 957 km², the riverbed is meandering, sandy-muddy, [3] the stream flowing from the well flows into the river. Mineral geothermal waters of the well No. 36-RG are opened in the depth interval of 1681-1747 m and 1797-1889 m; they are confined to terrigenous sediments (sandstones, mudstones, siltstone) belonging to the Apt-Cenomanian and Goteriv-Barrem tiers of the Lower Cretaceous [4].

The flow rate of the well is 42 m³ / hour. Water temperature at the spout is 73 °C. At present, water is drained into a lowering of the relief and into the Aremzyanka River through a stream. The length of the stream of constant flow is 223 meters.

The study of natural radioactivity included the following: (a) studying bottom sediments in the area of the well and the stream flowing from it into the Aremzyanka River, which was conducted in the Laboratory of Radiation Ecology of Tyumen State University; (b) selecting and studying water samples for radium volumetric activity in the Testing Laboratory of “Regional Analytical Center” JSC; and also (3) measuring the level of surface radioactivity with a radiometer SRP-88N.

Table 1. Classification of industrial waste of oil and gas enterprises.

| Waste category | Effective specific activity of natural radionuclides (Aeff), kBq / kg | Gamma radiation dose rate of natural radionuclides contained in waste (N), μGy / h |
|----------------|-------------------------------------------------|-------------------------------------------------|
| First          | Aeff ≤ 1,5                                      | N ≤ 0,7                                         |
| Second         | 1,5 < Aeff ≤ 10                                 | 0,7 < N ≤ 4,4                                   |
| Third          | Aeff > 10                                       | N > 4,4                                         |

Figure 1. The well “Cherkashinskaya No. 36-RG,” February 2019 [author’s photo].
The studies were conducted in January-February 2019 on three sections (Fig. 2).

In accordance with SanPiN 2.6.6.1169-02, the classification of industrial waste is introduced according to the effective specific activity of natural radionuclides (Aeff) in them. This classification is introduced for the following several reasons: (1) establishing requirements for ensuring the radiation safety of the population and employees of organizations of the oil and gas industry; (2) limits on human pollution of the environment by natural radionuclides; (3) planning the types and amount of radiation control when handling industrial waste, as well as to establish radiation and hygienic requirements for handling them. The classification is given in Table 1.

Figure 2. Sampling sites: (1) The Well No. 36-RG; (2) A creek is 90 m below the well; (3) A creek is 200 m below the well, before flowing into the Aremzyanka River.

3. Results

Analysis of bottom sediment samples in the area of well No. 36-RG of the Cherkashinsky iodine-bromine field, conducted by the Laboratory of Radiation Ecology of the Tyumen State University at the “USK Gamma Plus” spectrometric complex, showed the results given in Table 2.

Table 2. Natural radioactivity in the area of the well “Cherkashinskaya 36-RG.”

| The name of the indicator, Unit of measurement | A place of sampling, a type of sediment |
|-----------------------------------------------|----------------------------------------|
|                                              | Well No. 36-RG | Creek 90 m below the well | Greek 200 m below the well before flowing into the Aremzyanka River |
| Activity $^{226}$Ra, Bq / kg                  | 18.45          | 13.15                      | 22.22                      |
| Activity $^{232}$Th, Bq / kg                  | 28.00          | 42.70                      | 74.50                      |
| Activity $^{40}$K, Bq / kg                    | 362.70         | 375.40                     | 319.80                     |
| Activity $^{137}$Cs, Bq / kg                  | 3.52           | 2.30                       | 5.36                       |
| Effective activity of the sample, Bq / kg     | 86.00          | 101.00                     | 147.00                     |
| Volumetric activity of radium ($^{226}$Ra) in water, $\text{Bq} / \text{dm}^3$ | 0.68           | 0.31                       | <0.3                       |
| RA, mSv / h                                   | 0.09           | 0.09                       | 0.09                       |
The volumetric activity of radium in water was investigated at the Testing Laboratory of the Regional Analytical Center JSC; measuring the level of surface radioactivity was carried out using a SRP-88N radiometer, the results are also presented in Table 2.

The effective activity of the samples was calculated by the following formula: \[ A_{\text{eff}} = A_{\text{Ra}} + 1,31 A_{\text{Th}} + 0,085 A_{\text{K}} \] (1).

4. Discussion
According to I. I. Pluman [5], the content of thorium and potassium in all sedimentary rocks of the Mesozoic West Siberian Plate is almost the same, different rocks differ from each other only in the concentration of uranium, and the content of uranium increases from sandstones to clayey rocks.

Table 3. The content of natural radioactive elements in the rocks of the West Siberian plate [5].

| Rock                        | Number of samples | Uranus, 10-4% | Thoriun, 10-4% | Potassium, % |
|-----------------------------|-------------------|----------------|----------------|--------------|
|                             |                   | From / to Average | From / to Average | From / to Average |
| Argillite (cemented clay rock) | 58                | 1.0-5.0         | 2.6           | 3.7-13.2     | 7.3           | 1.2-4.8        | 2.2            |

5. Conclusion
The effective activity of all samples of the bottom sediments does not exceed 1500 Bq / kg. According to this indicator, the analyzed bottom sediments belong to the first category of industrial products of oil and gas enterprises according to SanPin 2.6.6.1169-02 [6]. This means that the bottom sediments near self-flowing iodine-bromine wells can be stored and disposed of as normal industrial waste.

According to SanPin 2.6.1.2523-09 “Radiation Safety Standards NRB-99/2009” [6], the maximum content of \(^{226}\text{Ra}\) in water is 0.68. As Table 2 shows, there is no exceedance; therefore, the water flowing today from the Cherkashinskaya No.36-RG well does not represent a radiation hazard.

The level of surface radioactivity also does not exceed acceptable values.

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