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Ecological and radiation safety of Central Asia

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Abstract. Previous calculations showed that in the Kyrgyz Republic 7.2% of the total population are exposed to the "radiation risk", in the Republic of Kazakhstan - about 3%, in the Republic of Tajikistan - 1.7% and in the Republic of Uzbekistan - 0.3%. The number of radiation-contaminated territories in the Republics of Central Asia is equal: the Kyrgyz Republic contains about 132 million m^3 of waste, the Republic of Tajikistan contains about 180 million m^3 of waste, the Republic of Uzbekistan contains 640 million m^3 of waste, and the Republic of Kazakhstan contains approximately 10,000 million m^3 of waste. Total: in the four Republics of Central Asia, the total amount of radioactive waste is 10952 million m^3. Taking as a basis the limited liability company "Vismut GmbH" from Germany, which carried out the reclamation of uranium tailings with a volume of 160 million m^3 of tailings at a cost of about 8 billion euros for about 37 years. Using a thermodynamic approach, it is shown that the costs of reclamation of uranium tailings for the four Central Asian Republics will be 548 billion euros, and the duration will be about 40 years.

1 Introduction

Uranium mining operations have been carried out in Central Asia, including the Republics of Kyrgyzstan, Kazakhstan, Tajikistan and Uzbekistan, since the 1940s. After the collapse of the USSR (in 1991), these works were stopped. Tailings ponds, dumps, quarries, mines, wells of uranium deposits pose a serious environmental hazard. The main contribution to the effective dose of human exposure at uranium mining enterprises, as well as in the radiation-contaminated territory of spent uranium deposits, quarries and dumps, is made by three radiation-hazardous factors: volumetric activity of short-lived daughter products of radon in the environment; specific activity of long-lived radionuclides of the uranium-radium series in the environment; dose rate of external gamma radiation. If the areas of radiation-contaminated territories are left without reclamation for ten years, then they will be sources of radioactive effects for a long time on the health of animals and people.

In mid-2017, the reclamation plan was presented at the UN General Assembly as its basis and was approved at the 61st session of the IAEA already at the end of 2017.

In [1], we proposed a model for assessing the "radiation risk" of residents of territories where dumps and tailings of uranium mines are located. For the number of inhabitants Nm who have a probability of radioactive contamination, we obtained the formula:

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$$N_m = \frac{mnS_I^2}{S} \cdot \left(1 - \frac{E_f}{E_I}\right). \tag{1}$$

Here S is the total area of the region with population density n, m is the number of sources of ionizing radiation, S_I is the area of radioactive contamination from all sources of ionizing radiation, E_f is the natural background radiation, and E_I is the background radiation generated by one source of ionizing radiation.

Calculations have been carried out for four Republics of Central Asia. In the Kyrgyz Republic, 7.2% of the total population is exposed to "radiation risk", in the Republic of Kazakhstan - about 3%, in the Republic of Tajikistan - 1.7% and in the Republic of Uzbekistan - 0.3%.

In [2, 3], we propose a thermodynamic approach to radiation-stimulated processes in solids. This is the approach we use in this article.

2 The area of radioactive contamination of Central Asia

The total number of tailings in the Kyrgyz Republic [4] is $m_1 = 35$, which contain 48.31 million m^3 of waste. The total number of mining dumps is $m_2 = 37$, which contain 83.58 million m^3 of waste. Thus, the total number of radiation sources is 72, which contain about 132 million m^3 of waste. The average height of tailings and dumps is $h_I = 20$ m, so the occupied area by ionizing radiation sources (IRS) is estimated as $S_I = 6.6$ million m^2. The background radiation from the Earth and cosmic radiation ranges from 5 to 25 μR/hour, i.e. the average value of $E_I = 15$ μR/hour. The radiation background from the dumps of uranium mines ranges from 150 to 250 μR/hour, i.e. the average value of $E_f = 200$ μR/hour.

Radioactive waste in the Republic of Tajikistan [4] is concentrated in 10 tailings (m = 10) with a total area of 180 hectares ($S_I = 1.8$ million m^2). Area S = 142 million m^2. The average values of the radiation parameters E_f and E_I are similar to those given above.

In the Republic of Uzbekistan [4] there are m = 58 tailing dumps with a total area $S_I = 6.4$ million m^2. The average value of the radiation background of IRS is equal to: $E_I = 1100$ μR/hour. The territory of Uzbekistan is 447,400 million m^2, and the flat part is S = 89,480 million m^2.

In the Republic of Kazakhstan [4], the conducted studies revealed m = 127 sites of contaminated sites from uranium processing and mining in three regions: North Kazakhstan, South and Central Kazakhstan, West Kazakhstan. The total area exposed to radioactive waste from the uranium industry is currently estimated at SI = 100 million m^2. The average value of the radiation background of IRS is equal to: $E_I = 250$ μR/hour. The area of the three regions of Kazakhstan noted above is S = 1,846,328 million m^2.

3 Thermodynamics and Economics

To carry out the reclamation of the radioactively contaminated territory of Central Asia on such a scale, it is necessary to calculate the economics of all these processes using the example of one enterprise, which we will do in this section. Let's start with an approach to thermodynamics in economics. In [5], on the basis of the Carnot cycle, the concepts of thermodynamics and economics were compared and they were expressed between macroeconomics and thermodynamics. The work [6] uses a comparison between microeconomic and thermodynamic systems. We used the analogy method in work [7]. Many phenomena in technology and physics have analogies between thermal and electric fields, between electricity and magnetisms, and much more. This method was used by J.

Maxwell, R. Feynman and many others. Often these analogies lead to the same mathematical equations. A special case of the analogy method is the theory of similarity.

The work [8] demonstrated thermodynamics to different systems that are in a nonequilibrium state. This applies to solids and liquids, information systems and any other complex system. The authors considered the particle system as a system of non-interacting particles immersed in a thermostat. Quantum transitions caused by the interaction of particles with a thermostat will be dissipative (with probability P), in contrast to interaction with the external environment (with probability F). As a result, the following expression is obtained for the probability of dissipative processes:

$$P = \frac{2\Delta S}{k\tau} exp\left\{ -\frac{E_m - G^0/N}{kT} \right\}, \tag{2}$$

where ΔS is the change in entropy in the dissipative process; Em is the average energy of particles; τ is the relaxation time in the dissipative process; G^0 - thermodynamic potential of the thermostat; N is the number of particles. Using the method of analogies and work in [7], for the efficiency of the economic activity of the enterprise, we find:

$$\eta = \frac{\tau}{2\sigma U} \cdot \left(\frac{M}{N} - E \right), \tag{3}$$

where σ is the dissipation of capital (production costs), τ is the production cycle time, E is the profitability of the enterprise, M is the basic resource, N is the resource stock, U is the total capital (U = M + F).

From the obtained expression (3) it can be seen that the efficiency of the economic activity of the enterprise depends on a small number of basic parameters. This makes it possible to analyze the financial and economic activities of an enterprise in a short and long time interval of the production process.

4 Radiation safety of Central Asia

Thus, the number of radiation-contaminated territories in the four Central Asian Republics is: the Kyrgyz Republic contains about 132 million m^3 of waste, the Republic of Tajikistan contains about 180 million m^3 of waste, the Republic of Uzbekistan contains 640 million m^3 of waste, and the Republic of Kazakhstan there is approximately 10,000 million m^3 of waste. Total: in the four Republics of Central Asia, the total amount of radioactive waste is 10952 million m^3.

Comparison of the state of the environment and applied technologies in the places of spent uranium facilities on the territory of Germany (mines of SGAO "Vismut") will be carried out according to [11]. During the cessation of production, Vismut State Joint-Stock Company had 2 enrichment enterprises, 10 tailings dumps with a content of more than 160 million m^3 of tailings. The Government of the Federal Republic of Germany has assumed responsibility for overcoming the huge legacy of Vismut State Joint-Stock Company. For this purpose, a limited liability company "Vismut GmbH" was established in 1991. At the initial assessment of the cost of reclamation of the object in the budget of the Federal Republic of Germany, it was planned to allocate about 13 billion German marks for this work. By the end of 2015, more than 85% of the remediation of the legacy of the uranium mining industry in East Germany had been successfully completed. In total, about 8 billion euros will be spent until the end of the reclamation. The remediation objectives will be fully completed in 2028. Thus, the production cycle time τ for the remediation of uranium tailings in Germany will be about 37 years at a cost of about 8 billion euros for 160 million m^3 of tailings. In other words, the cost of 1 ton of radioactive waste for its reclamation will amount to approximately 50 euros.

For the four Central Asian Republics, the costs of reclamation of uranium tailings will amount to approximately 548 billion euros, i.e. almost 70 times more than Germany's costs for almost 40 years. For each Republic: in the Kyrgyz Republic, the costs of reclamation of uranium tailings will amount to approximately 6.6 billion euros, in the Republic of Tajikistan - 4.0 billion euros, in the Republic of Uzbekistan - 32 billion euros, in the Republic of Kazakhstan - 500 billion euros.

Let us turn to equation (3) and find out the production costs (σ) for the reclamation of uranium tailings for the four Central Asian Republics under the following approximations: the efficiency of the economic activity of the enterprise is set equal to $\eta = 1$, the profitability of the enterprise is $E = 0$, the resources are $M = N$, the total capital $U = 548$ billion euros, production cycle time $\tau = 40$ years = 480 months. Will have:

$$\sigma = \tau/2U. \tag{4}$$

The monthly costs for the four Central Asian Republics will be $\sigma \approx 0.438$ (billion euros)$^{-1}$ = 438 (million euros)$^{-1}$.

7 Conclusion

The analogy method can be used to analyze and diagnose the financial and economic activities of an enterprise. In particular, the basic resource is proportional to the square of the price of the product, and not just the price, as is usually taken into account when calculating the available resources of the enterprise. The price changes periodically, but of course according to a more complex law. With the growth of the basic resource, the associated capital also grows. It decreases when prices rise in the market. The more tied capital, the greater the economic losses (costs) of the enterprise. They decrease with the increase in the operating time of the enterprise.

From the obtained expression (3), it can be seen that the efficiency of the economic activity of the enterprise depends on a small number of basic parameters. This makes it possible to analyze the financial and economic activities of an enterprise in a short and long time interval of the production process. The monthly costs for the four Central Asian Republics will be $\sigma \approx 0.438$ (billion euros)$^{-1}$ = 438 (million euros)$^{-1}$.

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