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SOURCES OF RADIOACTIVE WASTE IN LEACH PLANTS PROCESSING URANIUM ORES*

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A distinctive feature of the enterprises for extraction and processing of uranium ore is the inevitable pollution solid, liquid and gaseous waste. According to its data volume of radioactive waste (RW) are the most significant in the nuclear fuel cycle, and, in spite of their relatively low activity, are the major contributors to the formation of radiation hazards to the public and of the environment. The radioactivity of uranium ore and waste their processing due to natural radionuclides of uranium (^{238}U and ^{235}U) and thorium (^{232}Th) of radioactive decay chains.

Keywords: *radioactive waste, processing of uranium ores, hydrometallurgical plants, management of radioactive waste.*

According to the system of state account and control of radioactive materials and radioactive waste in the nuclear industry, power economy, medicine and scientific research, the Russian Federation accumulated more than 500 million m^3 of liquid radioactive waste (LRW) and more than 180 million tons of solid radioactive waste (SRW) [1]. The share of low level (LLW) and medium level waste (MLW) is 99.5% of this amount. This waste is placed in ~1400 near-surface radiation-hazardous objects (storages) located across all territory of Russia [2, 3].

According to the Federal law of July 11, 2011 No. 190-FZ “About radioactive waste management” (article 10) a Uniform state system for radioactive waste management is being created. Its purpose is managing radioactive waste (collecting, sorting, processing, conditioning, transporting, storing and burying radioactive

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waste). The main information resource of this system is the above-mentioned system of state account and control of radioactive materials and radioactive waste. The creation of this information system was due to the dictates of the present time: the huge amounts and activity of new technogenic radionuclides that appeared in the course of creating the “Nuclear shield” of the Homeland and nuclear power.

A distinctive feature of enterprises producing and processing uranium ores is inevitable pollution of the environment by solid, liquid and gaseous waste. The amount of this waste is most considerable in the nuclear and fuel cycle. Despite its rather low activity, this waste makes the main contribution to the formation of factors posing radiation hazard to the population and environmental medium.

Over the period of the “Nuclear shield” creation, since the beginning of large-scale geological prospecting works and production of uranium ores (1945), 9 integrated plants were built in the USSR. Now they are located in the territories of former six union republics – nowadays independent states. The total area of possible influence of these objects due the penetration of radionuclides and other pollutants into the environment due to air streams, surface and subsoil waters is more than 220 sq. km.

The radiation hazard of uranium mining and processing plants in the operational and post-operational periods depends on different factors. Crucial factors are:

- the technology of ore production;
- the technology of ore processing;
- the method of tailings storage.

The mining-chemical technology of uranium production should be mentioned in this list as a separate category. It includes methods of underground block leaching, heap leaching and underground leaching.

The radioactivity of uranium ores and waste of their processing is caused by natural uranium radionuclides of the uranium (U^{238} and U^{235}) and thorium (Th^{232}) radioactive decay chains. The main role is played by U^{238} [4], because the concentration of uranium-235 in the initial ores of our enterprises is nearly 3 orders of magnitude lower than the concentration of uranium-238. The chain of U^{238} decay is shown in Figure 1.

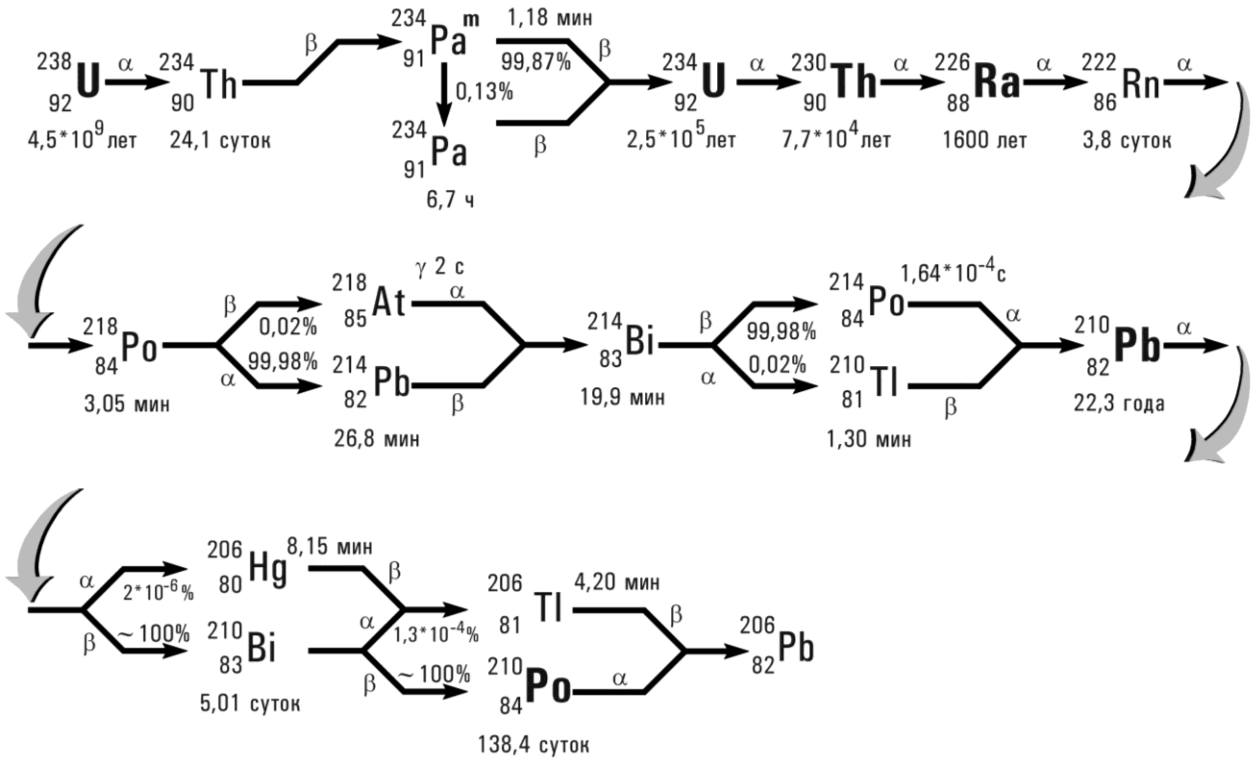

Figure 1. The chain of U^{238} decay.

[Лет means years; суток means days; мин means min; ч means h; года means years; с means s].

It can be seen from Figure 1 that the decay chain includes in total 19 radionuclides, each of which has the activity of a chain initiator. All three natural uranium isotopes (uranium-235, 238 and 234) are extracted at a hydrometallurgical plant (HMP) processing uranium ores. The degree of extraction is 96 – 98.5%. All the other radionuclides are parts of the radioactive waste group. Natural decay is interrupted before thorium-230 (its usual name is ionium). Th^{230} is the first in the broken series of radioactive waste radionuclides of uranium-processing enterprises. The series of radioactive waste radionuclides of an HMP includes 14 elements out of 19 radionuclides of natural U^{238} decay chain.

In order to consider the formation of radioactive waste let us turn to the generalized scheme of basic technological processes implemented at HMP [5–7] shown in Figure 2.

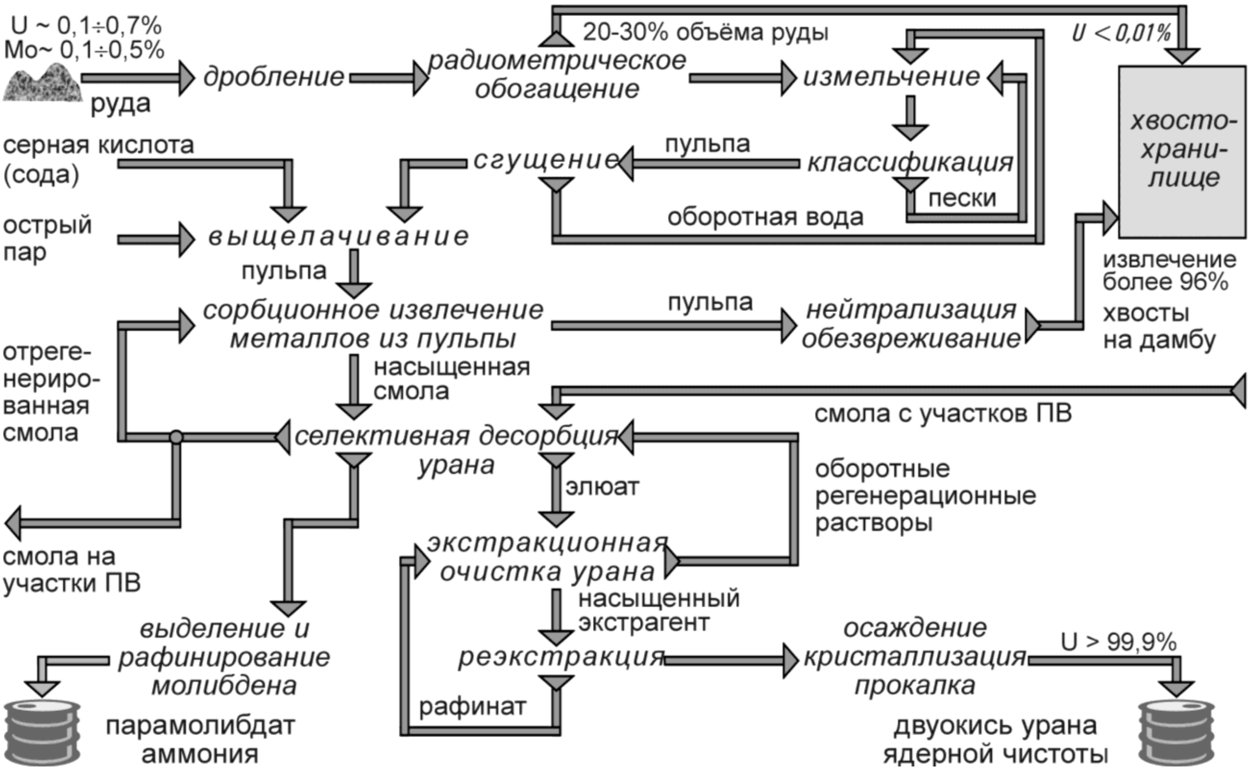

Figure 2. Hydrometallurgical production of nuclear purity uranium.

[руда means ore; дробление means crushing; радиометрическое обогащение means radiometric enrichment; объёма руды means of ore volume; измельчение means pulverization; классификация means classification; хвостохранилище means tailings dam; пульпа means pulp; пески means sand; оборотная вода means recycle water; сгущение means condensation; выщелачивание means leaching; острый пар means direct steam; сорбционное извлечение металлов из пульпы means sorption extraction of metals from pulp; насыщенная смола means saturated resin; нейтрализация means neutralization; обезвреживание means deactivation; извлечение более 96% means more than 96% extraction; хвосты на дамбу means tails to dam; смола с участков ПВ means pitch from PV sites; селективная десорбция урана means selective desorption of uranium; элюат means eluate; отрегенерированная смола means regenerated pitch; смола на участки ПВ means pitch to PV sites; выделение и рафинирование молибдена means molybdenum isolation and refinement; парамолибдат аммония means ammonium paramolybdate; экстракционная очистка урана means extractive purification of uranium; насыщенный экстрагент means saturated extragent; реэкстракция means reextraction; рафинат means raffinate; осаждение means precipitation; кристаллизация means crystallization; прокалка means calcination; двуокись урана ядерной чистоты means uranium dioxide of nuclear purity]

At the ore pretreatment stage including crushing, radiometric enrichment and pulverization in mills with classification, pulp is prepared for acid leaching. A part of ultralow activity ore (up to 30%) goes to the tailings dam for strengthening of the protecting dam and of the retaining prism of the construction. After air cleaning, radon and its short-living decay products isolated in the crushing and pulverization processes are discarded to the air.

Uranium and thorium isotopes are transferred in the technological process of leaching into the liquid phase of the pulp. Radium and products of its decay remain in the solid phase, because radium is not leached by sulfuric acid. Natural uranium isotopes are extracted from the pulp in a series of uranium sorption pachukas (Figure 3) [6, 8, 9].

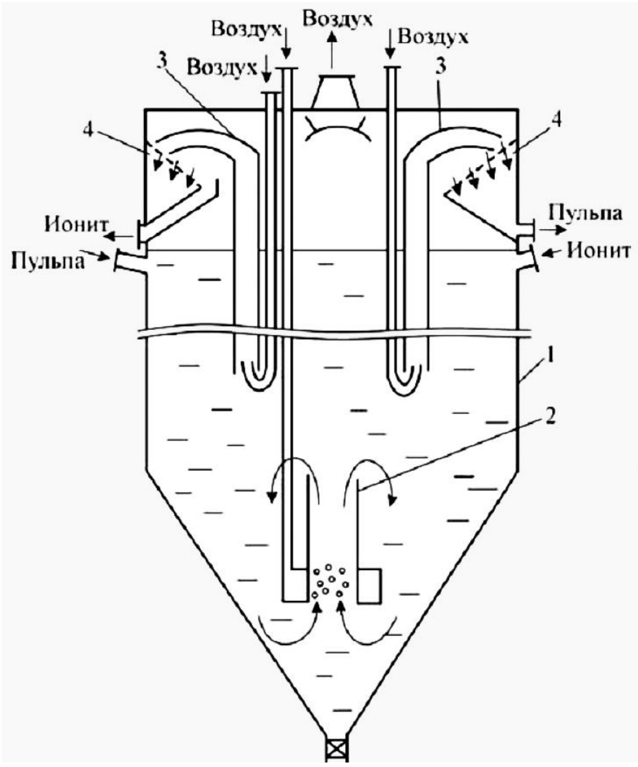

Figure 3. Pachuka for uranium sorption from pulp:
1 – case, 2 – deflector, 3 – airlifts, 4 – screening machine.
[Воздух means Air; Ионит means Ionite; Пульпа means Pulp]

The pachuka (an apparatus with air mixing) shown in Figure 3 was designed by professor N.N. Tokarev under the leadership of academician B.N. Laskorin in VNIIHT in the early 1960-ies. It was used at all uranium plants of the USSR and many other countries. Applying sorption from pulps increased the plants productivity 3–5-fold. Energy, water and reagents consumption was enormously reduced.

After leaching, the pulp containing ions of many metals in the liquid phase including uranium comes to the apparatus. The ionite (sorption resin selectively extracting only uranium) comes through the other tube. The technology for synthesizing various ionites was also created in B.N. Laskorin's department. The air coming to the bottom of the apparatus mixes the complex mixture of the liquid and solid phases of the pulp and creates a fluidized ionite bed in the pulp. Uranium is intensively extracted in this mode from the pulp onto the sorbent phase. The system of screening machines enables easily solving the problem of the pulp separation from the ionite.

The ionite saturated with uranium goes to the stage of desorption and further to uranium refining. After neutralization by lime milk and deactivation the pulp containing radioactive waste goes through the slurry pipeline to the tailings dam (Figure 4).

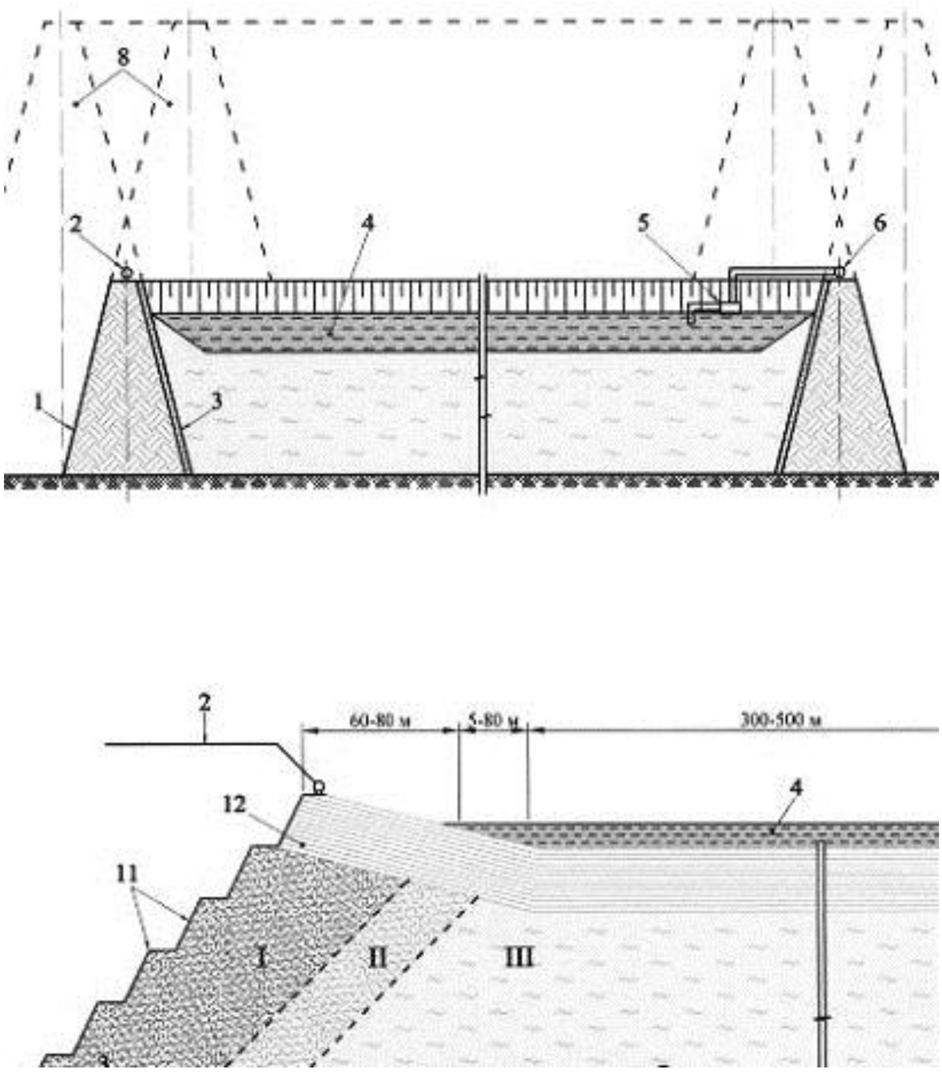

Figure 4. Tailings dam scheme:
I – retaining prism; II – transition zone; III – central zone. 1 – protecting dam;
2 – slurry pipeline; 3 –screen of polymeric materials or clayey soil;
4 – pool; 5 – floating pump station for recycling water supply; 6 – conduit of recycle water;
7 – deposits of tail material; 8 – options of protecting dam buildup; 9 – starter dam of career soil;
10 – drainage; 11 – alluvium circle; 12 – alluvium layer.
[м means m]

At large HMP’s the annual amount of radioactive waste discarded as the pulp solid phase is up to 5–6 million tons. As for the liquid phase, it makes the basis of HMP water cycle. It is from the tailings dam surface where a special pump station (No. 5 in Figure 4) takes technical water for the HMP operation. The group of developers led by B.N. Laskorin was awarded the 1st degree Lenin award “For successful completion of an important task of the Soviet Government” for developing the scheme of sorption extraction of uranium with closed water recirculation, which allowed increasing uranium production 3–5-fold and enormously reduced many expenses.

Over 40–50 years of operation hundreds of million tons of solid radioactive waste are accumulated in the tailings dam of a large HMP. This waste mostly consists of long-living radionuclides: thorium-230, radium-226, lead-210 and polonium-210. Its general activity is higher than the activity of produced uranium approximately by a factor of 4.

Radiation load of the environment in the course of uranium ores production and processing is caused, first of all, by the emission of radon-222 and thorium-230. After extraction of uranium the content of uranium in dumps and tails is 0.001 – 0.02%. The content of Ra^{226} (half-life period 1600 years) in the waste remains practically at the level of 80 – 95% of its initial equilibrium content in the ores. As a rule, the rate of radon-222 emission from dumps and waste is 2 – 6 Bq/sq.m · cm, and it is also considered to be a constant during 10 thousand years.

Recultivation of territories polluted as a result of the activity of uranium mining enterprises should provide actions for deactivation or burial of all buildings and constructions, elimination of superficial pollution of territories, prevention of dusting of dumps and tailings dams, stabilization of dumps and tailings dams, prevention of surface and underground water pollution.

Conclusions

Taking into account the huge amount of solid radioactive waste (hundreds of millions of tons) accumulated in tailings dams, the long period of their high activity (tens of thousands of years) before making technological and organizational decisions for the elimination of tailings dams that still should be found, stability, hydrological control, minimal entry of contaminated water into purifying installations, termination of radon entry into the atmosphere, and also continuous radiation monitoring of the natural environment should be provided.

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