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Uranium production and environmental restoration at the Priargunsky Centre, Russian Federation

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Abstract. State JSK "Priargunsky Mining-Chemical Production Association" (PPGHO) has been the only active uranium production centre in Russia during the last decade. Mining has operated since 1968, and derives from resources in 19 volcanic-type deposits of Streltsovsk U-ore region, which covers an area of 150 km^2. The average U grade is about 0.2%. Ten deposits have been brought into production: eight by underground mines and two by open pits. Milling and processing has been carried out since 1974 at the local hydrometallurgical plant by sulphuric acid leaching with subsequent recovery by a sorption-extraction ion exchange scheme. The high level of total production (over 100 000 mtU through 2000) marks it as one of the outstanding uranium production districts worldwide. Significant amounts of wastes have been accumulated. The main sources of the environmental contamination are: 30 piles of waste rocks and sub-grade ores, mine waters, milling and sulphuric acid plant tailings. The following activities are performed to decrease the negative impact on the environment: rehabilitation of waste rock dumps and open pits utilization of waste rock for industrial needs, heap and in situ leach mining of low-grade ores, construction of dams and intercepting wells below the tailings, hydrogeological monitoring and waste water treatment plant modernization. Environmental activities, including rehabilitation of the impacted territories and also waste utilization will be realized after final closure takes place.

1. SITE CHARACTERIZATION

State JSK "Priargunsky Mining-Chemical Production Association" (PPGHO) has been the only active uranium production centre in Russia during the last decade. It is located in Chita region of Russia, 10–20 km from the town Krasnokamensk with about 60 000 population. Priargunsky Association is an integrated facility including uranium (mines, processing plant, mill tailings) and non-uranium (power plant, coal and manganese open casts, workshops etc) units, all of which require environmental activities.

Principal historical dates:

- 1968 - mining started;
- 1969 - plant for effluents treatment was built;
- 1973 - construction of acid and milling plants;
- 1974 - U milling and production started;
- 1977 - environmental laboratory was organized;
- 1988 - environmental department was organized.

Mining operations include two open pits (both are depleted) and three underground mines (Fig. 1). Milling and processing has been carried out at the local hydrometallurgical plant by sulphuric acid leaching with subsequent recovery by a sorption-extraction ion exchange scheme. Since the late 80's some amount of low-grade ore has been processed by heap and underground in-place (or block) leaching. The high level of total U production (about 100 000 t) marks Priargunsky as one of the outstanding production centres worldwide [1].

The production from the Streltsovsk U-ore region is based on 19 volcanic-type deposits with an average U grade about 0.2%. The area covers about 150 km^2 [2]. Uranium mineralization occurs to a depth of 1100 m and lower.

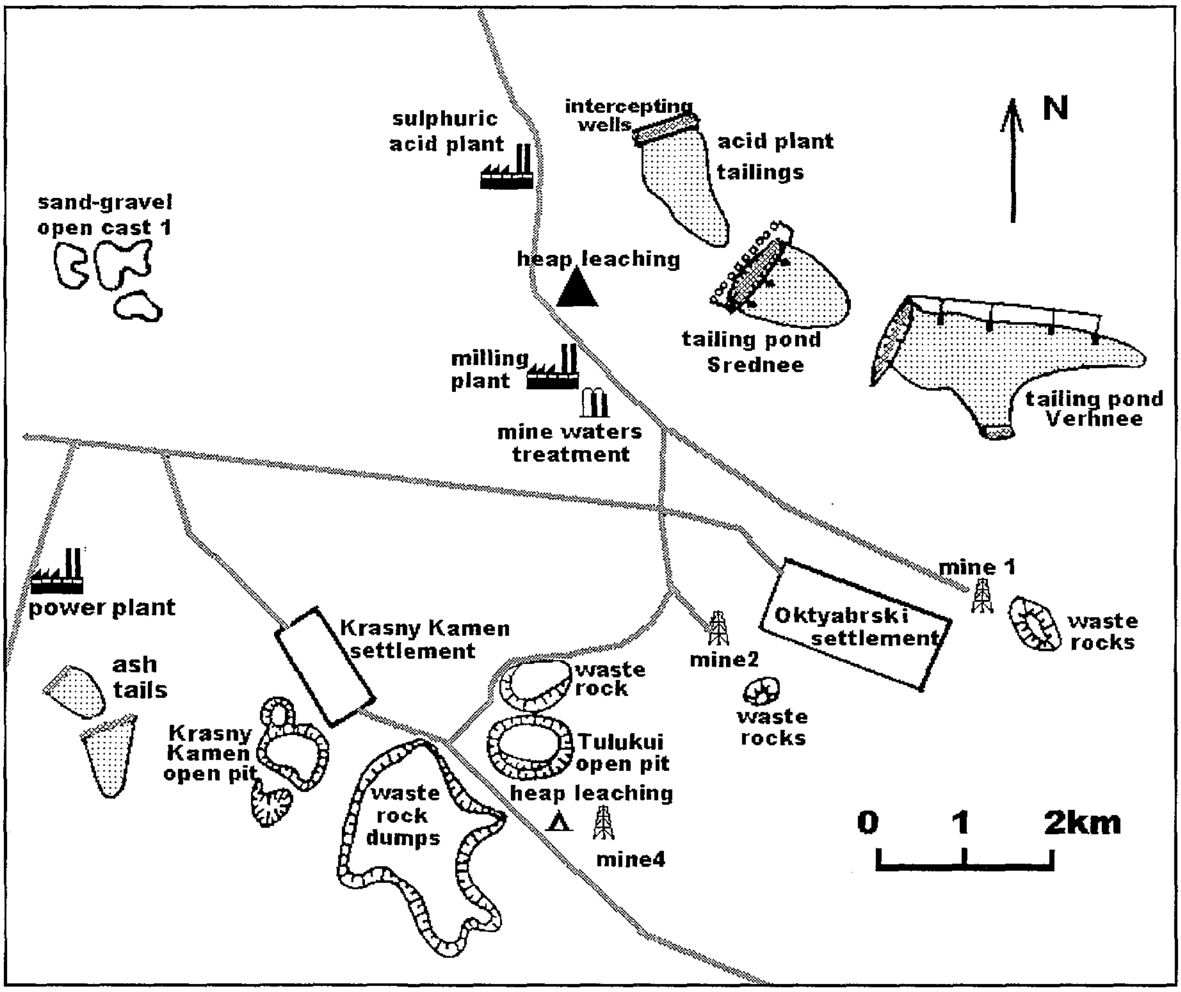

FIG. 1. Operation units of Priargunsky association.

Approximately 75% of the resources of the Streltsovsk district are in a depth interval from 200 to 600 m below surface where ore lodes are distributed at several levels in stratified sedimentary volcanogenic rocks. About 25% of the resources are situated at lower levels between 400 and 900 m deep. They are mainly contained in the two large and relatively high-grade deposits hosted by granite and with a marble basement.

Mineralization is largely controlled by structures reflected by predominantly vein and stockwork ore lodes. Monometallic uranium and polymetallic uranium-molybdenum ores are distinguishable. Since the discovery of the district in 1963, ten deposits have been brought into production, eight by underground mines and two by open pits.

Dominant production comes from underground mining of relatively high-grade ores (0.3 to 0.4% U). A limited amount of uranium (about 100 t U) is produced from the low-grade ores by heap leaching and in place (or block) leaching methods.

2. ENVIRONMENTAL IMPACT

Significant amounts of solid, liquid and gaseous wastes have been produced since 1968 (Table 1) [3, 4].

TABLE I. GENERAL CHARACTERISTICS OF WASTES

Type of waste	Area, ha	Amount, Mln. tn.	Volume, ths.m^3	U grade %	Radioactivity $\times 10^{-9}$ Ci/kg	Rn emanation $\times 10^{-3}$ Ci/m^2 y
Mill tailings	377		49 430	0.009	30-750	0.93-23.2
Acid plant wastes	125		6 180	Traces	30-250	-
Waste rock piles	340	153		0.002	27-80	0.84-2.50
Heap leaching sites		6		0.009	27-350	0.84-11.0

The aggregate area of radioactive contamination is 842 ha:

- 723 ha at the industrial site with the level 60 from to 240μR/hr,
- 119 ha in the sanitary protection and observation zones with the level below 60μR/hr.

The main risk for ground water contamination comes from the tailings of the hydrometallurgical operation and the sulphuric acid plants.

2.1. Mining waste piles

Mining activities produce the following contamination:

- emission of radioactive and blasting gases to the atmosphere;
- contaminated mine waters;
- waste and sub-grade waste rock accumulation.

Current uranium mining is carried out only by underground operations. About 0.2 to 0.4 tons of waste rock or sub-grade ore is generated for each ton of ore mined. Over 150 mln. tons of waste rocks and more than 2.7 mln. tons of sub-grade ores have accumulated in 30 waste rock dumps since 1968. Over 5.6 mln. tons of low and sub-grade ores have been placed for heap leaching. Total area of waste rock piles covers more than 340 hectares [5].

Waste rock dumps are generally not radioactive. Nevertheless, they can be a potential source for radionuclide migration to the atmosphere, soil and water. It is necessary to note that the radon and the long life alpha-nuclide concentration at 100 to 250 m from piles are close to background. The radioactivity decreases from 50–100 μR/h directly on a waste rock pile to 20–25 μR/h at a distance 200–250 m from it.

2.2. Mine waters

Mine waters are radioactive, bacterially infected and have a high dissolved mineral content. Their annual volume exceeds 8.5 mln·m^3. Since 1993, all mine and mill wastewater has been treated at the special water treatment plant. The flow sheet includes a precipitation circuit using chemical reagents (much of lime), a polyacrylamide as flocculent and green vitriol. The capacity is 1000 m^3/hour. The treatment process removes suspended matter, radionuclides, manganese, heavy metals and uranium. Effectiveness for U, Mn and radionuclides treatment is over 90% [5].

Normally, 5.4 mln·m^3 of treated mine water is used annually for milling plant needs and the remaining 2.6 mln·m^3 is discharged to the Umykei lakes. The water is also used to prepare the underground packing mix. The treated mine water, however, cannot as yet be used for other needs (agriculture, municipal services etc.).

2.3. Milling plant effluents

The milling plant, which processes up to 3500 tons of ore per day, produces significant amounts of solid, liquid and gaseous wastes. The plant consumes up to 3–4 m^3 of water per ton of ore leached. Only treated mine water is used in the milling operation.

Typically the concentrations of aerosols long life alpha nuclides, radon, its decay products and ore dust are low. More often the adverse environmental effect of non-radioactive harmful chemical substances such as ammonia and nitrogen oxides is more critical. The limits for each contaminant are established at the milling plant and controlled regularly.

2.4. Tailings

Two tailings impoundments enclose the milling plant wastes: Verhnee and Srednee (Table 2). During the past several years, the Verhnee tailing pond was the main impoundment, and Srednee was used only during pipelines repair. Table 2 shows tailing pond volumes [6]. Uranium grade in the solid mill wastes is about 0.010% U.

TABLE II. VOLUMES OF TAILINGS IMPOUNDMENT

Parameters	Mill tailing Verhnee	Mill tailing Srednee	Acid plant tailings
Upper level of embankment, m	706	660	648.8
Water table, m	697.8	656.7	642.3
Permitted level, m	698	658	646.1
Level of protection cover, m	699	659	347.7
Volume of impoundment, ths. m^3	46 055	3 377	6 179
Square of impoundment, ths. m^2	3 025	741	1 251
Square of liquid table, ths. m^2	1 775	384	1 021

Tailings impoundments are a significant source of potential environmental contamination. Milling tails contain appreciable amounts of radionuclides such as ^{226}Ra, ^{230}Th, ^{210}Po and ^{210}Pb. The principal emanation comes from ^{222}Rn and its short-life decay products as the result of beaches dusting.

Probable liquid waste seepage through tailing pond beds can affect underground waters and contaminate them. Continuous monitoring of observation wells shows that in 1997, after new intercepting wells were constructed, the water table decreased and contaminated aureole migration was stopped. However, high concentrations of sulphate-ion, manganese, copper and nitrate ion are noted in the wells located close to mill tailings.

3. WASTE MANAGEMENT

Waste management is carried out by an environmental survey organization according to the state laws and instructions. The environmental survey departments of PPGHO include the following:

- an environmental department to co-ordinate environmental activities of all services and divisions;
- environmental service facilities for controlling atmosphere pollution and harmful chemical substances concentrations in liquid wastes;
- a radiation and radiological safety service, for controlling industrial wastes and radioactive emissions to atmosphere, soil and water.

Annual limits for solid and liquid wastes at Priargunsky include: uranium sub-grade ores 150 000 tons/year; waste rocks 300 000 tons/year; treated mine water 2800 ths.cub.m/year; and a total wastewater discharge of 22 500 ths.cub.m/year.

The following activities are performed to decrease the negative influence of **waste rock** on the environment [5,7]:

- rehabilitation of waste rock piles;
- irrigation of dusty waste surfaces and roads;
- utilization of waste rock for industrial needs, i.e. for tailing pond dam, road and hydraulic engineering construction;
- development of heap leaching mining for low- grade ores.

The problem of waste rock utilization and dumps rehabilitation is urgent and requires immediate action. The project of Tulukui and Krasny Kamen open pits rehabilitation has been adopted.

One of the main environmental problems is **water supply**. All water sources (technical drains, power plant effluents, and treated mine waters) are confined to the system of Umykei inland lakes. Normally, 69% of the treated mine waters is used for milling and processing and remaining 31% is discharged to Umykei lake [5]. Further development of recycling water supply systems as well as clarification of mining and technical waters will allow the PPGHO to:

- stop completely technical water supply from Argun river and to preserve the storage pond;
- return the surplus of treated sanitary and technical waste waters to the Argun river;
- reduce waste water discharge to the Umykei lakes.

The **tailing pond** is considered as most dangerous unit, because of the large amount of accumulated radioactive wastes and possible overfilling. The potential threat of a dam accident together with waste seepage to Urulungui and Argun rivers exists at the mill tailings pond. Environmental activities [5,7] include:

- monitoring of the tails neutralization operation to reduce the toxic substance content in clarified tailing water;
- strengthening of dam bodies and building protective dams around the potable water wells;
- construction of new intercepting wells below the tailing pond dam and effective operation of existing wells;
- hydrogeological monitoring through special wells.

However, the construction of a special plant for liquid wastes treatment is considered to be the most desirable approach.

The following activities are performed to reduce **radionuclide emissions**:

- closure of old or stand by mine drifts, bore pits and ventilating shafts;
- isolation of underground mines by special crosspieces and concrete;
- complete water saturation of tailing ponds surfaces and beaches for dusting prevention;
- increasing efficiency of power plant filters to reduce ash emission in atmosphere.

4. MONITORING

Laboratories for radiation safety, waste testing and radiochemistry perform systematic monitoring [5,7].

4.1. Atmosphere

The integrated atmospheric protective zone exceeds 100 km^2. A number of permanent atmosphere monitoring stations are located within the zone to measure the concentration of most toxic chemical elements, ^{222}Rn, long life alpha nuclides, natural uranium, ^{226}Ra, ^{230}Th, ^{210}Po and ^{210}Pb. The emission of toxic substances must not exceed the limits that come from non-uranium facilities. Radiation monitoring of the personnel and the environment in mines and the mill show that the level of harmful factors (latent energy, radon emanation, alpha-contamination, dose rate etc.) generally meet the required standards.

Atmosphere monitoring is generally performed for sulphuric dioxide, nitrogen oxide, carbon dioxide, ammonia and dust content. Their amount varies from 9 to 74% of the estimated limits. The maximum concentrations of nitrogen oxide and sulphur dioxide are found in the effluents from the power plant and the sulphuric acid plant.

About 500 annual air samples from Krasnokamensk show that only minor ammonia and sulphur dioxide elevations are present.

The toxic substance contents (dust, NOx, NH_3, SO_2) are also monitored at the uranium heap leach sites, in the mill and in the sulphuric acid plant tailings. Toxic concentrations in the dust exceed the limits in only some samples.

Annual radiation doze rate for population does not exceed 1 msv. Environmental radiation and toxic chemical concentrations now basically meet the State regulators norms and requirements.

4.2. Ground waters

Monitoring for ground water quality is performed through a system of 111 wells and local monitoring wells around tailings, heap leaching sites, slag heaps etc. During 1998, 326 water samples were analysed for 7800 element-measurements. Portable water quality satisfies the regulatory norms except for the fluorine content, which is naturally present.

4.3. Solid wastes and soil

Monitoring of mill and acid plant tailings (42 observation points), power plants tailings (eight observation points) and waste rock piles is performed to prevent contamination in the protective zones. The principal activities include chemical composition and physical property measurements, estimation of the impoundment areas and volumes, etc. Special monitoring for soil and grass was performed in 1999 to evaluate the contamination in the protective zone near tailing ponds.

5. CONCLUSION

Significant amounts of uranium and wastes have been produced at Priargunsky for more than 30 years. The results of monitoring show that the impact of mining and milling on the environment is generally similar to that of other conventional uranium producing centres in the world, and it is minimized by proper environmental activities and waste management. Isolation of mill tailings, treatment of mill wastes, reclamation of mine waste rock piles and rehabilitation of closed mines – are the most important tasks for further activities and studies. The total rehabilitation of all impacted territories will be carried out after closure of the mining and milling operations.

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