RADIATION LEGACY OF THE USSR ENTERPRISES FOR MINING, MILLING AND PROCESSING OF URANIUM ORES: CONSERVATION, DECOMMISSIONING AND ENVIRONMENTAL REHABILITATION

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Abstract

The long-term operation of USSR uranium mining and milling enterprises produced a great volume of low level radioactive waste in the form of rock spoil heaps (181 million m^3), hydro-metallurgical plants tailings dumps (340 million m^3) and basins of mine waters (200 million m^3) with total activity of $25.1 \cdot 10^{15}$ Bq (670 kCi). The total area occupied by the dumps is about 180 km^2. The paper presents brief characteristics of the activities of uranium ore mining enterprises located at the CIS countries' territories, their wastes' status and describes measures for rehabilitation and restoration of territories of the Soviet uranium mining and metallurgical complex.

1. INTRODUCTION

The production complex of mining and processing enterprises of the former USSR included 8 uranium combines and a plant for uranium raw materials' processing now located at the territories of six independent countries:

- Russian Federation-Lermontov Industrial Association (LIA) "Almaz" (Caucasus Mineral Waters, Stavropol Land); Argun (Priargunskii) Industrial Mining and Chemical Association AMCA (Chita Region);
- Ukraine-Scientific and Industrial Association "Eastern Mining and Enrichment Combine" (Zholtye Vody); Industrial Association "Pridneprovskii Chemical Plant" (Dnieprodzerzhinsk);
- Kazakhstan-KASKOR Joint Stock Company (Aktau); Industrial Association "Tselinnyi Mining and Chemical Combine"-IA "Tselinnyi MCC" (Stepnogorsk);
- Tajikistan-Industrial Association "Eastern Combine for Rare-Earth Metals"-IA "Vostokredmet" (Khodgent);
- Uzbekistan-Navoi Mining and Metallurgical Combine (Navoi);
- Kyrghyzstan-Industrial Association "Southern Combine for Polymetals" (Kara-Balty).

The total area of lands spoilt by the ore mining and processing activities is about 0.5 thousand km^2, of which

- by ore mining objects-26.5% (133 km^2), about 81% of the area make quarries and rock spoil heaps;

- by ore processing objects–38% (190 km^2), about 92% of the area make tailings dumps;
- by auxiliary objects–8% (31 km^2);
- (146.5 km^2) are occupied by cities and settlements.

2. CHARACTERISTICS OF WASTES GENERATED AS A RESULT OF ACTIVITIES OF ORE MINING AND PROCESSING ENTERPRISES OF THE FORMER USSR

Over the period of activities of these enterprises a great volume of low level radioactive waste has been generated in the form of rock spoil heaps (181 million m^3), hydro-metallurgical plants tailings dumps (340 million m^3) and basins of mine waters (200 million m^3) with total activity of $25.1 \cdot 10^{15}$ Bq (670 kCi). The total area occupied by the dumps is about 180 km^2. Below a brief characteristics of the activities of uranium ore mining enterprises at the CIS countries' territories and their wastes' status is presented.

2.1 The Russian Federation

2.1.1 The Lermontov Industrial Association "Almaz" is located in the town of Lermontov, the Stavropol Region. The association was established in 1950 as an industrial uranium mining enterprise on the basis of the Beshtau and Byk deposits.

Sources of radioactive contamination of the environment have been left on the site of the enterprise after the completion of works on uranium ore mining and processing. These are dumps of unamenable ores and barren rocks as well as a pumped tailings dump. Their total area is 1366.7 thousand m^2. The actual volume of unamenable ores and barren rocks in three dumps is 3960.9 thousand m^3; the volume of the HMP tailings dump is 12031.6 thousand m^3 (Table 1).

TABLE 1. RADIOACTIVE WASTE ACCUMULATED AT THE IA "ALMAZ" AS OF JANUARY 1, 1993

Storage site	Area, $10^3 m^2$	Radwaste volume, $10^3 m^3$	Radwaste weight, $10^3 t$	Activity, Bq
Dumps of unamenable ores	570.0	3960.9	8403.7	1.40×10^{14}
HMP tailings dump	796.7	12031.6	14047.0	1.69×10^{15}
Total:	1366.7	15992.5	22450.7	1.83×10^{15}

The surfaces of unamenable ore and barren rock dumps were restored: covered with a clay and chernozem layer and afforestated. Some measures have been taken to diminish the environmental impact of the tailings dump. In particular, the beach of the embankment is isolated by non-radioactive waste phosphogypsum produced in the processing of apatite concentrate.

2.1.2 The Argun Industrial Mining & Chemical Association (AMCA) is located in the Krasnokamensk District, the Chita Region, 18 km north-east of the town of Krasnokamensk. The Association is engaged in mining, enrichment and processing of uranium-molybdenum ores. Uranium is mined in the Strel'tsovskii ore region in three underground mines and the Tulukui open pit.

Dusty dumps of amenable and unamenable ores, a uranium open pit, a tailings dump, the Urtui coal pit, a hydro-metallurgical plant (HMP) for enrichment of uranium and molybdenum, and the Krasnokamensk Heating and Power Plant (HPP) are sources of radioactive contamination for the surrounding territory. The tailings dump has been placed in a natural valley with an embankment and the excavated topsoil. The bed of the valley is paved with polyethylene film and a 0.5 m thick layer of inert ground. The HPP uses the Urtui coals with a high content of natural radionuclides (NRNs). In burning the coals, the NRNs are released in the atmosphere or discharged in an ash-disposal site. That is why the coals' burning is under control: only coals with uranium content not exceeding 0.006% are allowed to be used as a fuel. In such a way observation of permissible level of the NRN releases set by the NRB-76/87 Rules is ensured.

Mine waters of the AMCA, industrial sewage from the HPP and residential sewage are discharged through a collector in surface storage ponds and the local surface hydrologic system. The sewage from the HMP is discharged in the tailings dump. The total area of the storage ponds and the tailings dump is 4.264 km^2.

By using a multistage flow sheet developed at the association for radiometric enrichment of uranium ores the waste from a radiometric enrichment plant is divided into two classes:

- waste with sufficiently high uranium content to be used for heap leaching;
- waste with low uranium content comparable with that of a barren rock.

Barren rocks produced in mining and processing of uranium ores are kept in special dumps. The dumps of unamenable ores are used, as a rule, for heap leaching to extract an additional product. Waste from heap leaching is used, in turn, in the site to fill worked-out areas. The dumps of unamenable ores and barren rocks take a total area of 2.73 km^2 (see Table 2). Before forming a dump, the grading of an appropriate site is made, including topsoil excavation and filling of a 1-m-thick cushion course from barren rock.

TABLE 2. RADIOACTIVE WASTE PRODUCED AT THE AMCA AS OF JANUARY 1, 1993

Storage site	Area, $10^3 m^2$	Volume of radwaste, $10^3 m^3$	Quantity of radwaste, $10^3 t$	Activity, Bq
Dumps of unamenable ores	2730	104440	211260	16.7×10^{14}
HMP tailings dump	4264	109000	69170	29.0×10^{14}
Total:	6994	213440	280430	45.7×10^{14}

The total quantity of radioactive waste including that in the HPP ash-disposal site, the coal dump and a blending stockpile is 284.3 million tons with a total activity of 46.6×10^{14} Bq.

2.2 Ukraine

2.2.1 The Scientific & Industrial Association "Eastern Mining & Enrichment Combine" founded on the basis of the Pervomaiskii and Zheltorechenskii uranium-containing iron ore deposits in the Kirovograd ore region in the Ukraine. The mines simultaneously extracted uranium and iron. As of 1990, the enterprise stored 3770 thousand tons of unamenable ores and barren rocks in dumps with an area of 181.4 thousand m^2 (Table 3).

The bottom of the dumps is formed from loam's. Unamenable ores with a volume of 1960 thousand m^3 were buried in the cavities of an iron ore mine. This amounts to 8% of the design volume.

Since 1976 a tailings dump with a useful volume of 29200 thousand m^3 has been in service at a distance of 7 km from the HMP. As of 1990, it was 87% full, corresponding to 25404 thousand m^3 of waste in the form of pulp. The bottom of the tailings dump is water-proofed with compacted natural loam. The exposure dose rate (EDR) in a 950-m-radius observation zone varies within the range of $(1.7\text{-}2.5) \times 10^{-2}$ mR/h. Another tailings dump 400 m distant from the HMP has been taken out of service because it was completely filled (8400 thousand m^3). The tailings dump was constructed with no waterproofing course. The EDR within the observation zone limits does not exceed 2.5×10^{-2} mR/h.

The Association mined uranium by the *in-situ* leaching method in the Devladovo and Bratskoe deposits. At the sites restoration works have been carried out: 142.6 thousand m^3 of soil with total activity of $1.6 \cdot 10^{11}$ Bq were excavated following by their disposal into 2.8-3.5 m deep trenches.

TABLE 3. RADIOACTIVE WASTE ACCUMULATED IN THE SIA "EASTERN MEC" AS OF JANUARY 1, 1990

Storage site	Area, $10^3 m^2$	Radwaste volume, $10^3 m^3$	Radwaste weight, 10^3 t	Activity, Bq
Dumps of unamenable ores	181.4	-	3770	3.4×10^{13}
HMP tailings dumps	2859	37600	37750	2.1×10^{15}
Total:	3041.4		41520	2.1×10^{15}
In-situ leaching sites	2250	11235	-	$1.8 - 1.9 \times 10^{11}$

Currently the Association is engaged in uranium and iron ore mining, iron-ore and uranium concentrates and sulphuric acid production.

2.2.2 The Industrial Association "Pridnieprovskii Chemical Plant" started to process uranium-containing raw materials from iron ore deposits of the Krivorozhskii field in 1948. In

1948-1954 uncontrolled tailings dumps were created in natural clay pits within the sanitary & protective zone (SPZ) of the enterprise.

Throughout the enterprise's activities 13663 thousand m^3 of HMP tailings was accumulated in the tailings dumps (Table 4).

TABLE 4. RADIOACTIVE WASTE ACCUMULATED IN THE IA "PCP" AS OF JANUARY 1, 1990

Storage site	Area, $10^3 m^2$	Radwaste volume, $10^3 m^3$	Radwaste weight, $10^3 t$	Activity, Bq
HMP tailings dumps	3998	13663	52017	$2.7x10^{15}$

The tailings dumps have no protective barriers. Another tailings dump ("D") of the plain flooding type with a capacity of 10 million m^3 and an area of 76 ha was put into service in 1954 in the Dnieper flood lands to store radioactive waste from the hydro-metallurgical production of uranium. The tailings dump also has no waterproofing means. Its embankment is made of waste from a coke plant by-product, that is, of crushed stone, gravel and silty soils from coal, clay and mica shales. Since 1970 after compaction of its beaches the tailings dump had been filled with phospho-gypsum from processing of apatite.

The first section of a flooding-type tailings dump ("C") with a capacity of 8.7 million m^3 at a distance of 14 km from the city of Dneprodzerzhinsk was put into service in 1968. An asphalt-bitumen impervious blanket is used as an anti-seepage measure. The tailings dump was operated with the use of a circulating water supply without discharge of wastewater into the hydrosphere. The second section with a capacity of 19.2 million m^3 and anti-seepage protection was put into service in 1983 after the first section was completely filled. The reliability of the anti-seepage measures was confirmed by full-scale studies and regime observations.

A radioactive tailings dump (DP-6) is made in the form of a trench 54 x 121 m in size where the remains of a blast furnace melting uranium ores in 1948-1964 were buried. The trench was covered with solid rubble and a 1.5-2.0-m-thick chernozem layer as well as sowed with grass for turfing. The archival materials of the enterprise which are not complete were used to calculate the total activity of the tailings dumps. The survey work is under way now to determine reliable data on the activity of the tailings dumps.

2.3 The Republic of Uzbekistan

2.3.1 The Navoi Mining & Metallurgical Combine

Ore mining and processing enterprises of the Navoi Mining and Metallurgical Combine (Navoi MMC) are situated within the limits of the borders of the Republic of Uzbekistan. At present the Navoi MMC incorporates mines, open pits, HMPs, a sulphuric acid production plant, three mining departments (MDs), extracting uranium by the *in-situ* leaching method: the Northern MD, the Southern MD and the Central MD.

In the Northern MD 8 *in-situ* leaching sites with the total area of 3831 m^2 were decommissioned in 1975-89. After the implementation of environmental protection measures the surface exposure dose rate (EDR) within the SPZ (3520 thousand m^2) has not exceeded $2x10^{-2}$ mR/h. The volume of residual solutions in the depths is roughly 6782 thousand m^3.

On-site dumps of unamenable ores were built up for the operation period of a mine near the Nurabad settlement. The volume of rock and ore mass amounted to 166.7 thousand t. The EDR within the SPZ around the dumps is $1.7x10^{-2}$ mR/h.

After the Central MD site was rehabilitated, the EDR within the SPZ limits does not exceed $2.0x10^{-2}$ mR/h. The volume of residual process solutions in the productive underground horizon has amounted to 2344.6 thousand m^3.

An HMP flooding tailings dump located at a distance of 1 km from the settlement of Durmyan over an area of 6022 thousand m^2 has been in operation since 1964 (Table 5). This tailings dump is provided with a recycling water supply system and hydraulic feed of the HMP tailings when the fluid fraction of the pulp returns into the HMP. The tailings dump has accumulated 52800 thousand tons of waste containing uranium, radium and polonium. The EDR in the site does not exceed $3.0x10^{-2}$ mR/h. The SPZ area is 8360 thousand m^2.

TABLE 5. RADIOACTIVE WASTE ACCUMULATED IN THE NAVOI MMC AS OF JANUARY 1, 1990

Storage site	Area, $10^3 m^2$	Radwaste volume, $10^3 m^3$	Radwaste weight, $10^3 t$	Activity, Bq
Dumps of unamenable ores	55.2	-	166	$3.4x10^{12}$
HMP tailings dump	6022	47800	52800	$7.4x10^{15}$
In-situ leaching grounds	3831	9126.4	-	$2x10^{12}$

2.4 The Republic of Kyrghyzstan

2.4.1 The Industrial Association "Southern Combine for Polymetals" (IA "Yuzhpolimetall") was established on the basis of the Kyrghyz Mining Combine founded in the 60s. The Combine mined and processed uranium ores from the Southern Kazakhstan ore region.

Throughout the period of the Combine's activities 18 dumps of unamenable ores and barren rocks with a total volume of 55436 thousand m^3 and 4 tailings dumps containing a total of 35695 thousand m^3 of radioactive pulp were formed on its sites (Table 6). In the depths of two

depleted *in-situ* leaching grounds 2009 thousand m^3 of residual process solutions is left. The solutions contain natural radionuclides of the uranium series and high concentrations of chemical components. The dumps of unamenable ores and rocks are at a distance of up to 80 km from populated areas. All of the dumps had been taken out of operation by 1991. No data on the restoration of the areas occupied by the dumps is available. Three tailings dumps at a distance of 2-11 km from the settlement of Minkush were taken out of service within 1960-1969. A 0.5-m-thick layer of loam was filled and compacted on the surfaces of the tailings dumps as an environmental protection measure. The EDR within the SPZ is no more than 25-30 μR/h.

TABLE 6. RADIOACTIVE WASTE ACCUMULATED IN THE IA "YUZHPOLIMETALL" AS OF JANUARY 1, 1990

Storage site	Area, $10^3 m^2$	Radwaste volume, $10^3 m^3$	Radwaste mass, $10^3 t$	Activity, Bq
Dumps of unamenable ores	2144	55436	110873	6.0×10^{14}
HMP tailings dumps	2576	35695	34461	3.2×10^{15}
Total:	4720	91131	145344	3.8×10^{15}
In-situ leaching grounds	424	2009	-	3.3×10^{11}

An on-site tailings dump of the **Kara-Baltinskii Ore Mining Combine** (an independent industrial enterprise since 1992) has been in service since 1955 to the present time. The beach of its embankment is 65% formed from loam and 35% covered with polyethylene film. As of 1995, the tailings dump was filled to 54% of the design capacity. At present the tailings dump is used in reprocessing of molybdenum-tungsten-bearing raw materials and radioactive waste in an HMP.

2.5 The Republic of Kazakhstan

2.5.1 The Industrial Association "Tselinny Mining & Chemical Combine" was established on the basis of large uranium, uranium-molybdenum and uranium-phosphorus ore deposits in North Kazakhstan. The basic production facilities are located at a distance of 20 km from the town of Stepnogorsk. The uranium mining enterprises are located at distances of 120 to 500 km from the basic production facilities.

In the period of its activities the facilities of the association produced 66592 thousand m^3 of radwaste accumulated in a flooding HMP tailings dump and on-site dumps of unamenable ores in the mining enterprises (Table 7).

TABLE 7. RADIOACTIVE WASTE ACCUMULATED IN THE IA "TSELINNYI MCC" AS OF JANUARY 1, 1990

Storage site	Area, 10^3 m^2	Radwaste volume, 10^3 m^3	Radwaste weight, 10^3 t	Activity, Bq
Dumps of unamenable ores	823	14592	16200	$4.5x10^{14}$
HMP tailings dump	7220	52000	56600	$2.0x10^{15}$
Total:	8043	66592	72800	$2.4x10^{15}$

The flooding tailings dump occupies a space of 7220 m^2 and is located in the SPZ of the HMP. It was used in 1969-90 and filled to 90% of its design capacity. The bottom of the tailings dump is paved with polyethylene film. The tailings dump consists of two ponds. The surface of the one pond is isolated from the environment by polyethylene film. The second, evaporating pond has the non-isolated surface. The basic radioactive contaminants in the HMP pulp are the natural radionuclides of the ^{238}U and ^{232}Th series.

Solid radioactive waste from radiometric enrichment and heap leaching is stored in piles within the SPZ at a distance of 0.5-7.0 km from the enterprise. The piles are placed on a surface preliminarily compacted by rolling without implementation of special water-proofing measures. The EDR on the surface of the piles does not exceed 0.1 mR/h. The bottom under a 628000-m^3 heap leaching dump is covered with asphalt and film to facilitate the collection of productive solutions in sprinkling ore mass and to prevent contamination of the soil.

2.5.2 The KASKOR Joint Stock Company created in 1992 on the basis of the Caspian Mining and Metallurgical Combine is a large-scale ore mining and processing enterprise that incorporates 28 divisions. The Caspian MMC was established in 1959 on the basis of uranium-phosphorus deposits in the inhabited territory of the Mangyshlak Peninsula in the Republic of Kazakhstan.

One of the KASKOR divisions, a major chemical & hydro-metallurgical plant (CHMP) is a big enterprise for complex processing of local uranium-phosphorus ores and graphite concentrate. Its basic products are uranium concentrate, scandium oxide and fluoride, crystalline scandium, aluminium-scandium alloys as well as rare-earth concentrates of the light and medium-weight groups. From large-tonnage process waste the plant produces fodder dicalcium phosphate (precipitate), food dicalcium phosphate (dentaphos) and ammonium sulphate.

During the activities of the enterprise 210904 thousand m^3 of radioactive waste was accumulated in a CHMP tailings dump, a burial ground and a gypsum and rare-earth concentrate (GREC) storage facility (Table 8).

TABLE 8. RADIOACTIVE WASTE ACCUMULATED IN THE KASKOR JOINT STOCK COMPANY AS OF JANUARY 1, 1990

Storage site	Area, 10^3 m^2	Radwaste volume, 10^3 m^3	Radwaste weight, 10^3 t	Exposure dose rate, μR/h
Burial ground	100	1.8	6.0	40-60
CHMP tailings dump	85,000	210,000	360,000	15-20
GREC storage facility	90	904	-	250

The CHMP tailings is located 5 km north from the plant site in the natural Koshkarata hollow. During the 27-year operation of the tailings dump the total volume of waste in it had attained 210 thousand m^3, that is 70% of the design capacity of the dump. The CHMP pulp directed to the tailings dump contains radionuclides ^{226}Ra and ^{210}Bi. The radiometric survey of soils and ground and the upper aeration layer 0.3 m beneath the surface revealed no radionuclide contamination in the territory surrounding the tailings dump. An excess above the natural background is observed at the shore line of the tailings dump where the EDR ranges from 14 to 60 μR/h with the maximum value corresponding to the uncovered tailings sediments.

The burial ground is at a distance of 12 km from the town of Aktau and 6 km from the CHMP. The burial ground was in service for 25 years before filled. It accommodates 6000 tons of radioactive waste containing radionuclides ^{210}Po, ^{230}Th, ^{238}U and others. The surface and bottom of the burial ground are isolated from the environment by a compacted clay layer. The EDR at the surface of the burial ground and within its SPZ does not exceed 40-60 μR/h.

The GREC storage facility, 10 km away from the town, is waterproofed by iso-butylene and concrete. It has a design capacity of 29626 m^3 and holds 904 m^3 of solid radioactive waste containing ^{210}Pb, ^{227}Ac and ^{228}Ac. The EDR in the vicinity of the storage facility is 250 μR/h.

2.6 The Republic of Tajikistan

2.6.1 The Industrial Association "Eastern Combine for Rare Metals" (IA "Vostokredmet") was established on the basis of the Leninabad Mining and Chemical Combine which is situated in the western part of the Fergana Valley, one of the most picturesque areas of Central Asia.

The combine was established as a large-scale uranium mining enterprise on the basis of uranium deposits situated in Tajikistan, Kyrghyzstan and Uzbekistan. As the country's first raw materials base, the Combine incorporated seven mines and five plants, including plant V with a hydrometallurgical shop and the Tabashar, Adrasman, Mailisui, Uigur and Tyuya-Muyun mines.

Throughout the period of the Combine's activities 34907 thousand m^3 of low-level radioactive waste was accumulated in its territory. The waste are stored in 9 tailings dumps (a total area of 1741 thousand m^2) and 21 dumps of unamenable ores (a total area of 2241741 thousand m^2) in the mining and processing enterprises (Table 9).

TABLE 9. RADIOACTIVE WASTE ACCUMULATED IN THE IA "VOSTOKREDMET" AS OF JANUARY 1, 1990

Storage site	Area, 10^3 m^2	Radwaste volume, 10^3 m^3	Radwaste weight, 10^3 t	Activity, Bq
Dumps of unamenable ores	224	2678	1847	7.0×10^{12}
HMP tailings dumps	1741	32229	33684	2.5×10^{14}
In-situ leaching grounds	-	14754	-	4.0×10^{12}

In two mining departments which extracted uranium by the *in-situ* leaching method the volume of residual process solutions having an activity of 4.0×10^{12} Bq in the productive horizons occurring at a depth of 450-600 m amounted to 14754 thousand m^3.

The dumps of unamenable ores and barren rocks are disposed over the vast territory of the Combine. Twelve dumps of the mining department No.2 are arranged on the terraces of the Chauli-Sai river 0.3-6.5 km away from the city of Khodzhent. The quantity of radwaste accumulated within the period of operation of the dumps (1953-1980) whose area is 156.6 thousand m^2 and having the activity of 4×10^{12} Bq is 469.8 thousand tons. The EDR within the SPZ is 200-600 μR/h.

Eight dumps 1-10 km away from the settlement of Charkassar were formed within the operation period of the Adrasman mine in 1954-89. Their total area is 34 thousand m^2; the quantity of radwaste with a total activity of 5.4×10^{11} Bq is 292.1 thousand tons. The EDR within the SPZ varies from 70 to 100 μR/h. On the site of the mine at a distance of 50 m from the settlement there is a tailings dump of an ore mining enterprise. The tailings dump that occupies an area of 34 thousand m^2 was in operation in the period of 1949-1958. The volume of waste in it is 102 thousand m^2 with a total activity of 2.4×10^{12} Bq. The EDR within the SPZ is 50-60 μR/h.

A storage of barren ores with a volume of 1195 thousand m^3 and an activity of 2.5×10^{12} Bq remained in the site of the Tabashar mine 4 km distant from the settlement Tabashar after the 15-year operation of the mine (1950-1965). The EDR within the SPZ is 40-100 μR/h. Four tailings dumps with a total volume of 4547 thousand m^3 and a total area of 573.8 thousand m^2 were formed at different times during the operation of a pilot HMP (1949-1965). The total activity of waste in the tailings dumps is 3.6×10^{13} Bq. The EDR within the SPZ is 40-60 μR/h.

In the valley of the Maili-Su River 15 km away from the town of Mailisai a HMP tailings dump was in operation from 1947 to 1962. At present the surface of the tailings dump is isolated from the environment by a 0.5-m-high soil layer. The volume of waste in the tailings dump is 1340 thousand m^3; the activity is 1.9×10^{13} Bq. The EDR on the surface of the tailings dump is up to 30 μR/h.

A tailings dump for the waste of hydro-metallurgical processes (from the GMP-1 plant) has been in operation since 1963 in the Digmai cavity 4 km away from the town of Gafurov. The tailings dump occupies a space of 692 thousand m^2 and is filled with 19200 thousand m^3 of waste. The activity of the waste amounts to 1.56×10^{14} Bq. The EDR within a 1-km-radius SPZ varies from 40 to 250 μR/h.

Since 1949 to 1967 an HMP tailings dump with an area of 267 thousand m^2 at a distance of 2 km from the town of Gafurov was in operation. The volume of waste is 2600 thousand m^3; the activity of waste is 2.9×10^{13} Bq. A 0.5-m-high soil layer covers the surface of the tailings dump. The EDR in the vicinity of the tailings dump varies within 20-60 μR/h.

A tailings dump in the town of Gafurov was operated in 1945-1950. It was intended for a pilot plant for hydro-metallurgical processing of uranium ores. The tailings dump (an area of 39 thousand m^2) is disposed within the area of service and pilot production buildings. It was completely dried and in 1963 its surface was covered with a 1.0-m-thick layer of inert soil. The radon concentration in the air directly above the dump was 2-5 Bq/m^3; the release of radon to the atmosphere from the entire surface of the dump is about 2.96×10^{12} Bq/y. A decision on the on-site burial of the tailings dump was made in 1991. The most effective measures were chosen to ensure the reliable disposal of the tailings dump and the radiation cleanness of the surrounding areas. Under study is the choice of an appropriate material for the covering of the dump surface. The covering must reduce the release of radon from the surface down to 0.05-0.1 Bq/(m^2 s). It is suggested to use for this purpose loessial loam's with subsequent compacting. The height of the loam layer must be 1-2.5 m to ensure that the time of radon diffusion to the surface would be at least 30 days until the almost complete decay of the radon.

3. MEASURES FOR REHABILITATION AND RESTORATION OF TERRITORIES OF THE MINING & METALLURGICAL COMPLEX

The necessity of carrying out of rehabilitation and restoration works at the territories of enterprises of the mining & metallurgical complex is dictated by the currently going on processes of reduction of the uranium ore mining. This causes the necessity of liquidation (or laying up) and conversion of the ore mining and processing objects. If the areas of production zones of the enterprises with located there buildings and structures are passed to local authorities for further use, the radiation safety of the population and environment should be ensured. The same condition should be fulfilled in a case of conversion of uranium ore-mining enterprises – their transition to processing of gold-bearing or non-ferrous metals' ore processing, etc. In addition to the reduction in the activity of the corresponding radiation source, of extreme importance is reliable isolation of radioactive waste, especially its solid phase, from the environment. For this purpose, dumps of barren rocks, unamenable ores, radiometric enrichment tailings and heap leaching tailings as well as HMP tailings dumps must be reliably covered with a remediation layer of inert rocks. In so doing, the residual radon release must not exceed 1 Bq/(m^2s) for stand-by enterprises and 0.2 Bq/(m^2s) for abandoned enterprises. To meet standards for the residual radiation level (0.2 Bq/m^{-2} s^{-1}) the approximate depth of remediation layer for reliable isolation of the RW from the environment must be not less than 1.0-2.0 m for dumps of barren rocks and 2.5-3 m for tailings dumps.

The Federal Program on "Management of Radioactive Waste and Spent Nuclear Materials, Their Utilization and Disposal for 1996-2005" (named hereinafter the Program) was approved by the resolution of the RF Government in 1995 to solve, on the comprehensive basis, radwaste management problems as well as to construct long-term storage or disposal facilities for reliable isolation of radwaste from the biosphere. For uranium mining and processing facilities the Program envisages:

- a comprehensive study of the environmental impact of uranium mining facilities and the laying-up or, if necessary, disposal of decommissioned mines, open pits and tailings dumps;
- development of plants for decontamination and processing of liquid and solid radioactive waste produced in uranium ore mining and processing;
- development of plants for reprocessing of waste from enriched uranium production to extract useful elements and reduce the volume of the waste.

During the abandonment of and putting in a stand-by mode the uranium mining and processing enterprises their personnel and the population must be protected from the action of the factors of radiation hazard. Among the factors of highest significance are releases of mine waters and the liquid phase of the HMP ore pulp to the hydrosphere, releases of radon and products of its decay into the atmosphere, and dusts from dumps of unamenable ores, enrichment tailings and host rocks. For this purpose "Sanitary Regulations on Abandonment, Laying-up and Conversion of Radioactive Ore Mining and Processing Enterprises" have been worked out and approved. This document establishes the permissible residual levels of radiation contamination of the facilities to be abandoned or laid up. The standards worked out for the residual radiation contamination assure that the radiation risk to the personnel of these facilities and the population working or living in the neighbouring regions will be limited.

CONCLUSIONS

According to data of 1990 and 1993 radwaste inventorying, the main amount of radioactive waste resulted from uranium ore mining and processing at the territory of former USSR is concentrated in the form of rock and tailings dumps. The total area of lands under these structures is 121.2 km^2, of which 114.5 km^2 (94%) come to tailings dumps.

To ensure the radiation safety in the abandonment, stand-by mode and conversion of uranium mining and processing enterprises the following measures must be implemented:

- radiation-ecological survey of the actual state of the enterprises;
- research and development work involving the assessment of the environmental impact of the enterprases;
- development of abandonment (stand-by) projects including both the assessment of environmental damage and the feasibility study of planned environmental protection measures.

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