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# Problems of Uranium Waste and Radioecology in Mountainous Kyrgyzstan Conditions

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## 1. Introduction

It is known that uranium industry in the former Soviet Union was a centralized state management. Information flows related to the issues of uranium mining was strictly controlled and is in a vertical subordination of the structures of the Ministry of Medium Machine Building of the USSR. After the USSR collapse, the information about uranium mining and processing were not available in Kyrgyzstan, and all the data related to past uranium production, were in the Russian Federation in the archives of the successor of the former "Minsredmash".

The activity of the regulatory body in the field of radiation safety have been independent of the former USSR. The agency also was part of the "Minsredmash", which was responsible for the nuclear industry. Application of regulatory safety standards ("standards") with respect to exposure and control of emissions of radioactivity in the field of mining and processing was similar in all organizations of the uranium industry, making it easier for their administrative use.

The requirements of radiation safety often disappeared or were not fulfilled, because the task performance of production had priority at the expense of safety. The neglected environmental protection requirements and protection of human health in the process of extraction often the same reason and processing of uranium ores, and recycling. Environmental protection has not been determined as a priority, and have not been identified the relevant criteria of safe operations. While establishing the new mining and uranium ore processing units, the issues of the protection of the environment has been neglected, and the data collection which should become the basis for further evaluation and possible remediation of contaminated areas that make up the heritage of the industry, was not done.

Uranium mining in the country was launched in 1943 year. After Kyrgyzstan gained independence, the uranium tailings are preserved, but without the engineering and technical support outside of Russia and cooperation with other independent countries in the region. Since the early 90's uranium industry of Kyrgyzstan in the region was unexpectedly opened to the world market. A large number of mines in the region during the low

profitability of such production has stopped in the 70s of last century. Nowadays, some companies continue to pollute the surrounding areas polluted by dust from uncontrolled waste disposal sites of uranium production, although to a lesser extent than during the current production. The deterioration of the environment as a fact of many experts' associates with a significant economic slowdown in countries faced with serious social problems of local people. This particularly applies to facilities located in Kyrgyzstan, whose economy has suffered more than others in the region. The environmental situation in Kyrgyzstan is exacerbated economic problems, provoking people to predatory use of natural resources (deforestation, poaching, extensive use of arable land, neglect melioration and other measures), which leads, on the basis of the feedback to further environmental degradation.

Thus, the post-war (1941-1945) development of Kyrgyzstan has been closely linked with economic and military policies of the Soviet Union and known that Kyrgyzstan was the largest producer of uranium from 1946 to 1968 for the former Soviet Union. Huge amount of raw materials as a due to inefficient production and wasteful processing of minerals have in the territory of the Republic (747 220 000 m<sup>3</sup>) with high content of potentially dangerous chemicals stored in waste dumps and tailing. For storage of uranium waste additional waste were also imported from other friendly countries such as Germany, Czech Republic, Slovakia, Bulgaria, China and Tajikistan. The status of these dumps and storage facilities so bad, that radioactive waste, heavy metals and toxic chemicals pollute the environment (soil, air, water) and living organisms. They are involved in biogeochemical cycles in the formation of new biogeochemical provinces (5,6, 14).

In general, the territory of Kyrgyzstan is a large number of radioactive sources (1200). The radioactive sources are stored in premises built storages of primitive methods (overlap of the mountain gorge.) Many of the tailings were formed within settlements (Maili-Suu, Min-Kush, Kaji-Say, Ak-Tuz, Kahn and others) in the mountain valleys and along the river.

Interest in the use of a nuclear facility for peaceful purposes again increased in the early twenty-first century at the decision of the new strategic challenges in the world. For example, at this time (2011) in the country four companies have influenced right to operate at a uranium deposit and 12 companies have licensed right to search for uranium ore. However, it should be noted, after the case in the Japan with nuclear stations (2011), security, use of nuclear energy, require special importance and improvement processes for peaceful purposes.

Thus, in the republic issue of Radioecology and radio biogeochemistry took priority of rare and rare earth elements of the former uranium production (tailing and dumps). The most urgent is to find features radiobiogeochemical enriched uranium and other trace elements and evaluation of reaction areas of organisms in ecosystems of the high content of radionuclide and base metals.

During a long time of economic activities in the Kyrgyz Republic has accumulated a huge amount of industrial and municipal solid wastes containing radionuclide's, heavy metals and toxic substances (cyanide, acids, silicates, nitrates, sulfates, etc.), negatively affecting on the environment and human health. In this regard, the problem of waste management is becoming increasingly important, and some waste has a frontier character.

## 2. Materials and methods

Since 2005 integrated studies for evaluation of radio-ecological features and radio biogeochemical features in uranium tailings and dumps are carried out by us. The survey was carried out according to the modern techniques and methodologies at the territories of radiological, and eco-radio biogeochemical study of the various types of the biosphere(4, 8, 9,11, 13).

The equipment used in research, consists of a set - Dosimeter-radiometer DKS-96, Radiometer PPA-01M-01 with the sampling device POU-4, Photo-electro-colorimeter (SPECOL), liquid scintillation spectrometer,  $\lambda$  - spectrometer (CAMBERRA), radiometer UMF-2000, etc., a satellite instrument to determine the coordinates and a personal computer with data entry module. Distribution and data processing were performed on a personal computer using a special software package. Gamma-ray surveying carried out in accordance with the "Instruction on the ground survey of the radiation situation in the contaminated area" at a height of 0.1 and 1 meter above the ground. According to the technical manuals of dosimeters, at one point was carried out at least three measurements, the log recorded average

Measurements of gross alpha and beta - activity in the mass were performed in the laboratory. For measuring gross alpha and beta - activity in the mass was performed prior to digestion. For that, each sample weighing was carried out separately, and determined their actual weight. They then converted into porcelain crucibles and placed in a cold muffle furnace. Digestion was performed for one hour at 450°C, and then the temperature was raised to 550°C and after three hours muffle furnace turned off. The resulting ash was weighed and ground in a porcelain mortar and homogenized to the state from counting samples were collected weight 0.4 grams for the measurement of alpha and beta - irradiation on radiometer UMF-2000. Volumetric total alpha activity in the sample (Bq/kg) was calculated using the formula:

$$A = (A\alpha / M) \times (M_1 / m)$$

where  $A\alpha$  - gross alpha-activity of radionuclide in the counting sample (Bq)

$M$  - mass of the original sample (kg)

$M_1$  and  $m$  - mass of the ash samples and aliquots of cell mass (mass of sample countable) (g), respectively.

The total volume of beta activity calculated similarly.

*Determination of the isotopic forms of radionuclide* samples of soil and plants were dried after harvest, soil samples were ground further in a mortar and pestle and sieved through a 2.0 mm diameter, 1.0 mm, 0.25 mm., Plant samples were cut with scissors and prepared at the machine for grinding plant samples. Further sample tests of soil and plants were burnt in a muffle furnace at 400°C, after burning  $^{90}\text{Sr}$  stood by oxalate and antimony- $^{137}\text{Cs}$  iodine on relevant techniques. Shortchanging the final draft of  $^{90}\text{Sr}$  was carried out on the radiometer UMF-2000, by  $^{90}\text{Sr}$  by instrumental gamma-ray spectrometry. As a model of a radioactive source used a set of solid sources,  $^{90}\text{Sr} + \text{It}^{90}$  activity of 50 Bq in the angle  $4\pi$  and 26 Bq in the angle  $2\pi$ , with an area of active spot 4 cm<sup>2</sup>. Cut-off screen for  $^{90}\text{Sr}$  was an aluminum filter with a surface density of 150 mg/cm<sup>2</sup>, such a filter reduces the effects of  $^{90}\text{Sr}$  in 128 times, and activity  $\text{It}^{90}$  two times (2, 4).





Toxic chemicals and radionuclide (As, S, Pb, Hg, Sb, U, etc.) in the waste dumps and tailings are found in both soluble and insoluble forms. The most dangerous of them are mobile forms compounds that are primarily involved in the chain: soil, water, vegetation, animals, people. Special problem of waste accumulation (more than 15 million m<sup>3</sup>) of overburden dumps, tailings and ore-balance, holding large areas near the settlements in the mountains, drainage basin, etc. The greatest threat of contamination remains uranium waste in cross-border areas on the slopes of the Fergana mountain frame and Chui valleys (near Maili-Suu city, settlements Shekaftar, Ak-Tuz and others).

After independence (1991), Kyrgyzstan began to collaborate with many international organizations on this issue, such as the UN, the IAEA, EU, UNESCO, UNDP, IMF and others. The following areas have been designated as priorities for Kyrgyzstan in conclusion with experts of the TC IAEA for the intermediate term period.

### 3.1 Rehabilitation of the effects of uranium mining and processing activities

Kyrgyzstan is facing serious environmental problems associated with uranium mining and processing activities in country. Due to natural disasters such as earthquake, landslide, mudflow and erosion processes increases the threat of further contamination by radioactive substances. As a result of natural processes a number of uranium tailings had been damaged. Most of the tailings storage facilities are in disrepair and poorly controlled.

*The following actions require immediate attention:*

- to develop and confirm the national program of radiating monitoring (at present is not present national the program on radiation monitoring);
- to give radio ecological and radio biogeochemical estimation;
- to estimate and begin rehabilitation works by a priorities;
- to develop correspond uniform regulating infrastructure on the radiating and nuclear safety, capable to operate a situation for the long-term period (till now there is no uniform regulating state structure).

### 3.2 Health: Improved diagnostics and nuclear services radiotherapy

The use of methods based on radiation for the prevention, early detection and treatment of cancer is one of the main priorities of the government in the health sector.

It is known that the use of obsolete equipment in radiotherapy for cancer treatment greatly reduces the chances of survival, and jeopardizes the health of staff. Moreover, the operating costs of equipment, lack of parts and skilled technicians make things worse.

Therefore, the planned improvement of radiotherapy services was an important component of the IAEA TC for the country over the medium term:

- the urgent need to upgrade radiotherapy equipment at the National Center of Oncology, KR;
- modernization of nuclear medicine and diagnostic services through appropriate programs;
- modernization of tomography and diagnostic equipment;

- The need to focus efforts on training of medical staff, as well as the introduction of modern diagnostic techniques.

### 3.3 Knowledge management and rational use of nuclear technology

In 2005, Kyrgyz Republic became a member of the International Nuclear Information System IAEA (INIS). How to create a network of analytical and calibration laboratories.

Kyrgyzstan has received significant assistance through projects of various international organizations such as the World Bank, IAEA, UNDP, IMF, EU and bilateral assistance provided by the governments of Austria, Japan, Netherlands, Sweden, Switzerland and the USA.

By the IAEA in the country, a modern radiology laboratory at the Institute of Biology and Pedology National Academy of Sciences, industry laboratories under the Department of State Sanitary and Epidemiology, Health Ministry of KR and Kara-Balta Environmental Laboratory.

In the framework of national and regional projects of IAEA - agency offers: the expertise, scientific visits, seminars and training courses on various aspects of radiation safety. Kyrgyzstan also has acquired the necessary modern dosimeter and analytical equipment for monitoring and analysis.

#### Legal and regulatory framework

The main basic Law of the KR, which regulates the handling of sources of radiation, is the "Law on Radiation Safety KR" as amended on February 28, 2003 # 48 and August 1, 2003 # 168. This law defines the legal relationship in the field of radiation safety and protection of the environment from the harmful effects of ionizing radiation. The law defines the main concepts, in particular, the term - "contamination" as the presence of radionuclide of technogenic origin in the environment, which may lead to additional exposure in an individual dose of more than 10  $\mu\text{Sv}$  year. Additional exposure below this level is negligible and should not be taken into account.

In accordance with the Act in 2005 Kyrgyz Republic, a special representative governing body for radiation protection, regulatory activities with radiation hazardous technologies and sources of radiation under the Ministry of Ecology and Emergency Situations. Since 2006, this Ministry was reorganized into two - "The Ministry for the Protection of natural and forest resources" and "The Ministry of Emergencies." The regulatory role belongs to the Ministry of Health, in particular the Office of the State Sanitary and Epidemiological Surveillance.

The main regulations in the Kyrgyz Republic have been adapted previously developed in the Russian Federation NRB-99 and Sanitary Regulation of Radioactive Waste Management (SRRM-2002). In particular, as the principal dose limit for the staff of the existing enterprises whose activities are related to the practice of radioactive waste management is set at 20  $\mu\text{Sv}$  per year, while the limit dose for the population in areas where uranium companies is set at 1  $\mu\text{Sv}$  per year. A clear recommendation for establishing intervention levels and regulatory criteria for the study of remediation activities at the former uranium companies has not been established yet.

Till present time establishes the recommendations for remediation of former uranium companies "Sanitary rules of liquidation, and conversion mining of conservation and processing of radioactive ores" (SLCP - 91). "The existing law "On the tailings and dumps" (2001) is a specific document relating to governance and uranium tailings and rock dumps. Earlier as a noted, some of these documents were developed during the former USSR and some are adapted to the Russian Federation, but they must be revised and adapted. These activities are carried out by the Ministry of Emergency Situations and the Agency for Environmental Protection and Forestry of the Kyrgyz Republic.

It should also be noted that the IAEA report ("Radiation and Waste Safety Infrastructure Profile (RWSIP) Kyrgyzstan Part A, 2005), most legal documents in the Kyrgyz Republic of related issues justify rehabilitation, are not available and require development yet.

4. Brief description of the major uranium tailings and dumps

4.1 Maili-Suu technogenic uranium province

Uranium deposit district in Maili-Suu practiced from 1946 to 1967. Currently, the former enterprise, including in the urban areas are 23 tailings and 13 mining dumps. The total amount of uranium waste, pending in the tailings is approximately 199 000 000 m<sup>3</sup> and occupies an area of 432 000 m<sup>2</sup>. The tailings were conserved in the 1966-1973 years, according to existing regulations. Heaps with a volume of 939 300 m<sup>3</sup> and occupied area about 114 700 m<sup>2</sup> were not re-cultured (Fig. 2), (1, 3, 5).

For a long time working on repair and maintenance of tailings were sporadic and insufficient. At the present time, the average exposure dose of gamma radiation (gamma-background) on the surface of the tailings is 30-60 mR/h, at some local anomalous areas have greater than 1000 mR/h.

However the science analysts' estimate that extraction from the original rock has been reach up to 90-95% of the uranium, and in the tails is only 5 to 10% or so in today's tails makes great background progeny of the uranium series. In table 1 the structure of original ore and a tail material of the Maili-Suu field are resulted. Elevated levels of Mn and Ca in the tails, as compared with the ore is associated with the use of compounds as a reagent and auxiliary substances in the ore processing and extraction of uranium, and high levels of lead, usually associated with the addition of radiogenic lead, is in the ore.

Components%	Original ore	Tailings
Ca	10-20	30
Si	20	6-10
Fe	2-3	0,4-1,0
Pb	1,5-2,0	2,0-3,2
Cr	4,5-6,0	2-3
Mn	-	50-200
V	1,0	0,4-0,6
Ni	3-5	2

Table 1. The average maintenance of separate components in ores and tailings of Maili-Suu



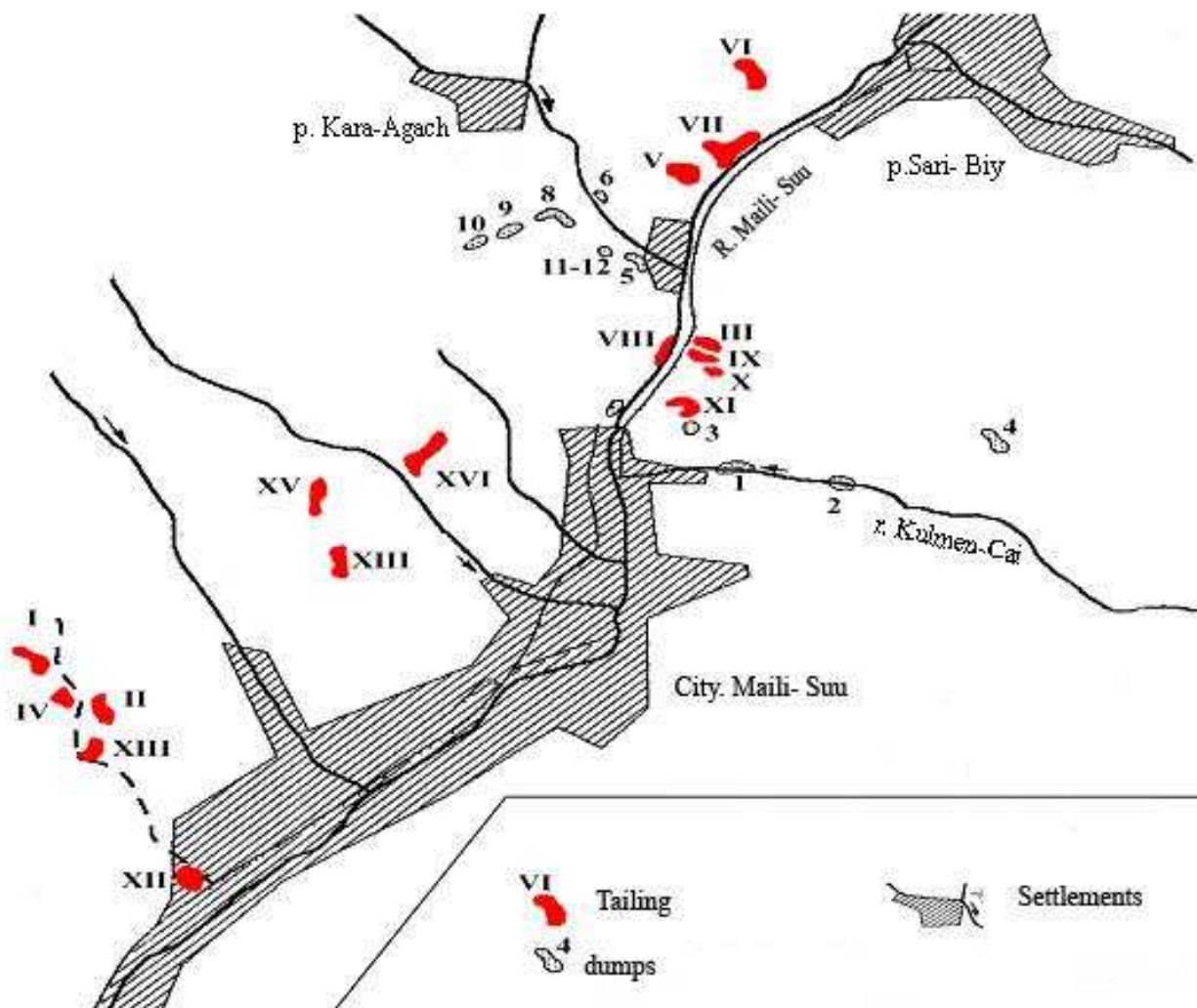


Fig. 2. The scheme of arrangement of tailings and waste dumps in anthropogenic provinces Maili-Suu.

From 1997 to 2003 special rehabilitation work in the country have been done, if they were sporadic. Starting from 2003 to 2007 in the country sharply intensified geomorphologic processes (landslides and floods), and therefore became acutely the question of preservation and rehabilitation of tailings and dumps (Fig.3-4). Upsurge in landslides, mudflows, erosion phenomena on the slopes adjacent to the tailings, the lack of funds for maintenance and repair and maintenance work has created a situation in some of the tailings in which may cause an ecological catastrophe. It should be noted that the destruction of tailings lead to removal of the tail material, not only in to the Maili-Suu river valley, but also into the densely populated Ferghana valley, and further to the basin of Syrdaria river. Fig. 5-6 shows the effect of surface re-vegetation of tailings in the period 1997-2003 compared to 1961. It clear from this scheme that the final completion of the re-cultivation work has far prospective.

The soil cover in the basin area downstream of the river - a typical gray soil, in the middle course - a dark gray soil, and then start mining-brown soil. General characteristics of the soil is as follows: pH 8.2 - 8.8, nitrate - 13.2 - 25 mg/kg of dry matter, chlorides - 25 - 47 mg/kg sulfate - 240 -895 mg/kg and petroleum products - 18 - 128 mg/kg of dry matter. Physical



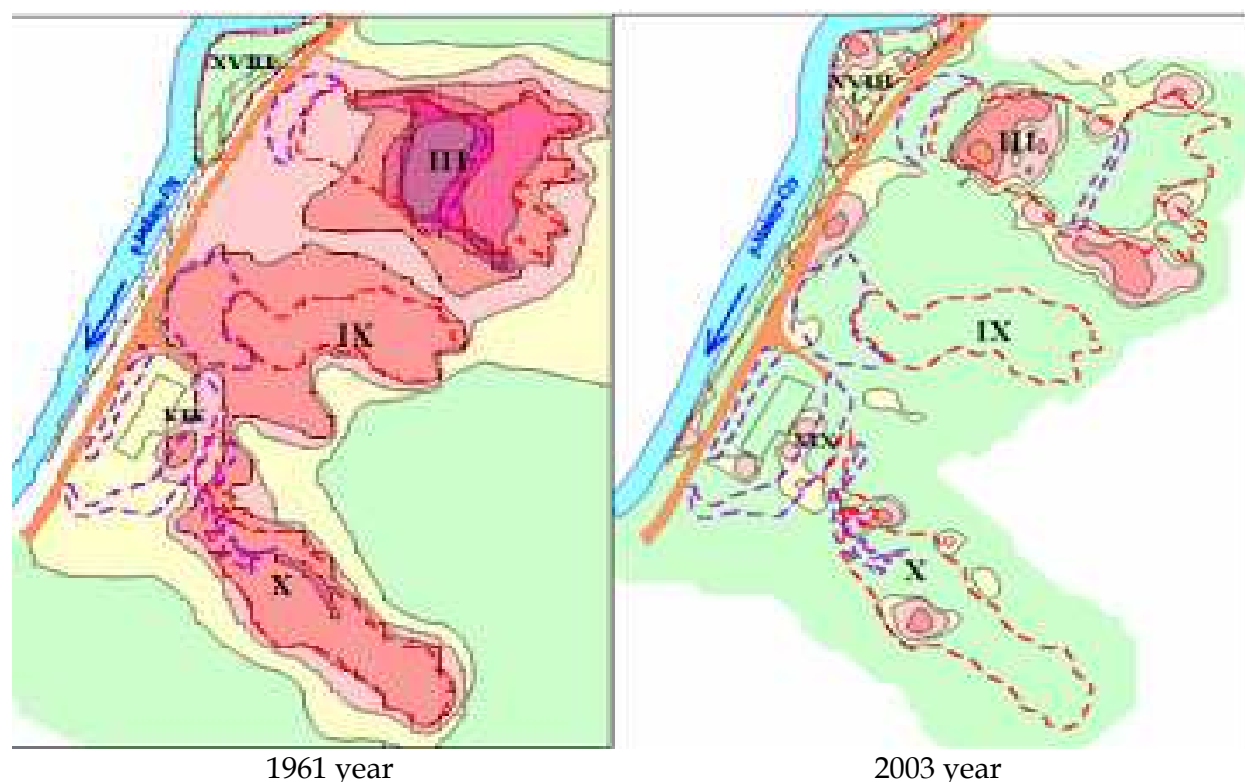
Fig. 3. Location uranium production Maili-Suu



Fig. 4. The current state of tailings (# 8,9)

and chemical properties of soil cover, the Maili-Suu (except for the area of man-made sites), according to Sanitary and Epidemiology norm (SanEpidN) are in conformity or below the MPC (Maximum Permitted Concentration). More detailed study showed that not all the indicators correspond to the standard level, especially the level of trace elements.

Studies suggest a relatively low level of contamination of the soil cover micronutrients in relation to the background and the MPC. Found a slight increase in the concentration: Al, Mn, Se and U (2 - 3 times) in the autumn and spring, and Zn up to 6 times, the background of U in sub-region in more than 10 times than MPC.



\* Red indicates the areas exceeded MPC ( $100 \text{ mR/h}^{-1}$ ), green area marked with MPC, complying with local natural background

Fig. 5. and Fig. 6. The effect of surface re-vegetation of tailings in the period 1997-2003.

The vegetation (collection) in the basin Maili-Suu content of most trace elements studied at the level of control areas or slightly higher. Compared with the background sites, content: Al, Ba, Be, Fe, Mn, and Zn 2-times higher; As, Hg, Ni, Pb, Se and U - to 5 times; Mo, Co, Cd - 10-15 times. Increasing concentrations of trace elements observed in the middle and lower reaches of rivers. At some level of background regions is different from the minerals MPC. For example: U, Fe and Co more than a factor of 2, Hg - 10 times higher.

In an average sample of plants in the upper section (conditionally pure), the level of key micronutrients studied is relatively low, except for certain items, such as - Al in the Fergana wormwood (*Artemisia ferganensis*) - 2.5 times; Cu, Se and V in the astragalus (*Astragalus lasiosemius*) - 2 - 2.5 times; Ni in astragalus (*Astragalus lasiosemius*) and *Artemisia Fergana* (*Artemisia ferganensis*) - 10 times more compared to the background of other areas of the country.

According to our research water of Maili-Suu r. is not suitable for drinking. In some parts of the river water are found the highest concentrations - Se, exceeding the MPC in 23 times. Fe - concentration exceeds the MPC by 6 times or more, especially in the 2 and 5 points. The content - Cd, Al, Hg, Mn and Pb higher than normal in 2 times. The data obtained by: Ba, Fe, Co, Ni and Zn were not statistically significant (Table 2).

It should be noted that the destruction of tailings lead to removal of the tail material, not only in the valley r. Maili-Suu, but in the densely populated Ferghana valley, then - in the basin r. Syrdaria. In the zone of influence of the tailings of the former enterprise Maili-Suu in

Elements	MPC	Sampling point (the river) and the mean values					
		1	2	3	4	5	Σ
1. Al	0,5	0,55±0,09	1,076±0,15	0,94±0,031	1,026±0,13	1,086±0,13	0,935±0,22
2. Ba	4,0	0,068±0,01	0,009±0,001	0,024±0,003	0,088±0,012	0,102±0,012	0,074±0,068
3. Co	1,0	0,005±0,002	0,0073±0,001	0,005±0,001	0,006±0,001	0,005±0,001	0,005±0,001
4. Cu	1,0	0,004±0,001	0,007±0,002	0,005±0,001	0,008±0,002	0,008±0,001	0,006±0,001
5. Fe	0,5	0,248±0,025	0,46±0,062	0,34±0,025	2,54±0,42	3,209±0,54	2,601±1,01
6. Hg	0,005	0,01±0,003	0,01±0,001	0,01±0,002	0,01±0,002	0,01±0,002	0,01±0,001
7. Mn	0,1	0,07±0,012	0,225±0,013	0,081±0,012	0,181±0,032	0,192±0,016	0,101±0,03
8. Co	0,5	0,005±0,001	0,004±0,001	0,010±0,002	0,003±0,001	0,010±0,002	0,006±0,004
9. Ni	0,1	0,026±0,006	0,032±0,001	0,025±0,003	0,028±0,004	0,025±0,004	0,22±0,14
10. Pb	0,1	0,02±0,001	0,035±0,001	0,02±0,003	0,02±0,003	0,02±0,003	0,023±0,002
11. Se	0,001	0,023±0,005	0,02±0,003	0,023±0,02	0,02±0,004	0,023±0,005	0,021±0,001
12. V	0,1	0,007±0,001	0,011±0,002	0,006±0,001	0,008±0,001	0,006±0,001	0,007±0,001
13. Zn	1,0	0,005±0,001	0,011±0,002	0,003±0,001	0,142±0,023	0,077±0,011	0,047±0,023
14. U	0,037	0,004±0,001	0,04±0,002	0,19±0,021	0,04±0,005	0,04±0,005	0,04±0,01
15. Cd	0,001	0,002±0,001	0,002±0,000	0,002±0,001	0,002±0,000	0,002±0,000	0,002±0,0002

Table 2. Trace element composition of water in the r. Maili-Suu (average annual mg/kg)

Kyrgyzstan, home to 26 000 people, and Uzbekistan - to 2 400 000, Tajikistan - about 700 000, Kazakhstan - about 900 000 long-term contamination of radionuclides will be subjected to extensive areas Uzbekistan, Kazakhstan, Tajikistan, most of which are in the area of irrigated agriculture. Exposed to infection by rivers and streams, including such major rivers as the Kara-Darya, Syr-Darya. Water supply of drinking water is from rivers and canals, taking them from the beginning. Even if the water supply from groundwater wells may be contaminated with radioactive elements.

It should be noted that the collapse of tailings lead to removal of the tail material, not only in the valley of the Maili-Suu river, but in the densely populated in Fergana Valley, then - in the basin of Syr Darya river. In the zone of tailings influence in Maili-Suu the former enterprise in Kyrgyzstan, lives about 26 thousand people, Uzbekistan - to 2.4 million, Tajikistan - around 0.7 million, Kazakhstan - about 0.9 million. Extensive areas in Uzbekistan, Kazakhstan, and Tajikistan, most of which are in the area of irrigated agriculture, are exposed to long-term contamination with radionuclides. The major sources for public exposure are the rivers and streams, including such major rivers as the Kara-Darya and Syr Darya. Water supply of drinking water is from rivers and canals, taking them from the beginning. Even if the water supply from groundwater wells may be contaminated with radioactive elements.

As a whole the soil-vegetative cover near the rivers Majli-Suu according to obtained data is satisfactory. There are no changes revealed of level of the studied elements in a soil-vegetative cover for several years. Naturally, the land covers in the tailings is not suitable for agricultural purposes and require special guidelines for local residents.

Currently, the safe storage of uranium waste in the town of Maili-Suu, has the following problems: disposal facilities are located less than 200 meters from residential city limits, the waste stockpiled near the river bed Maili-Suu. In order to reduce radon load to an acceptable level of sanitary protection zone in the city should be more than 3 km. Tailings dams require constancy of preventive measures in case of catastrophic floods and mud streams.



In the geotechnical investigations and tailings design was not taken into account susceptibility to landslides in the region involving the violation of rock massifs in the development of oil fields. In recent years, large-scale response of the slopes on the mountain of work is expressed in the mass development of landslides in the entire field. They provoke the probability of failure of some tailings. With landslides in the valley may be formed landslide lakes and catastrophic floods. In the flood zone may be tailing located along the river Maili-Suu river, as well as homes and other facilities of the city.

Lack of waterproofing the bottom of the tailings may lead to contamination of groundwater with radionuclide. Studies on the content of radionuclide in ground water and other contaminants have been conducted, as disposal facilities were not equipped with monitoring wells. The situation is complicated by the fact that after the cessation of uranium mining and the collapse of the Soviet Union and tailings dumps were abandoned for a long time in the state. Until 1998, there were only occasional maintenance and repair work. Environmental emergency calls for speedy implementation of measures for rehabilitation of tailings and dumps, to ensure long-term stability and prevent the threat of ecological catastrophe, the consequences of which could cause political complications and also in Central Asia.

Since 2007, the province implemented the project "Prevention of emergency situations", funded by the World Bank, worth 10 950 000 US dollars. The project provides for the identification and prevention of the most significant risks of radioactive tailings in the town of Maili-Suu, hazards of natural origin (landslides) and the improvement of emergency management. Work carried out by VISUTEK (Germany). Earlier, district repeatedly visited various expert missions to the IAEA, the World Bank, ADB, and the Russian Federation and other international organizations. As indicated from the conducted studies, tailing number 3 can impose high risk, so this tailing has been transferred to tailing number 16.

#### **4.2 Issyk-Kul province of natural uranium (uranium-technogenic Kadji-Say)**

Issyk-Kul province of natural uranium is located on the south shore of the lake Issyk-Kul, in Ton district, at an altitude of 1980 m above sea level. Mining Enterprise of the Ministry of Average Machine Building of USSR for processing uranium ore there was in operation from 1948 to 1969, and was subsequently converted into the electrical engineering plant. The uranium oxide at this site is generated from the ashes of brown coals uraniferous sogutin filed as a by product for the electricity production from coal (5, 15)

Waste and industrial equipment have been buried, forming a tailings pond, with a total volume of uranium waste 400 000 m<sup>3</sup>, an area of 10 800 m<sup>2</sup>. Tailings from uranium waste is located 2.5 km east of the residential village, but due to natural factors (rain, groundwater, landslides and mudflows) is an environmental threat to lake Issyk-Kul (1.5 km from the lake) and the nearest towns located on slopes up to 30-45° between the mountains. For 50 years there has been intense uplifting coastal area near the industrial site. A small part of the radioactive ash reached the lake Issyk-Kul.

According to Kovalsky V.V., Vorotnitskaya I.E. and Lekareva V.S. (10), the amount of uranium in the waters of rivers - Ton, Ak- Suu, Issyk-Kul is  $5,6 \cdot 10^{-6}$  g/l. According to Kovalsky V.V element content in the river Jergalan varies, depending on season and room selection, from  $2,8 \cdot 10^{-6}$  to  $1 \cdot 10^{-5}$  g/l. Key water wells and rivers of the Issyk-Kul basin



contain 10, in some cases - 100 times more uranium than water areas and non-black earth black earth zone of Russia. Table 3 shows the results of our analysis of natural radionuclides in the water of rivers and tributaries of the lake Issyk-Kul, and the ratio of  $^{234}\text{U}/^{238}\text{U}$ . According to scientific estimates of researchers in the lake holds about 100 tons of uranium.

Location of sampling	Uranium (total) Bq1 <sup>-1</sup>	$^{234}\text{U}/^{238}\text{U}$	Gross alpha Bq1 <sup>-1</sup>	$^{226}\text{Ra}$ Bq1 <sup>-1</sup>
Issyk-Kul lake , Kara Oi v.	1,79±0,18	1,13±0,05	1,80	0,013
r. Bulan-Sogotu	0,09±0,01	-	0,10	0,002
r. Kichi Ak-Su	0,17±0,02	-	0,20	0,009
r. Tuip	0,23±0,02	-	0,23	0,016
r. Kara-Kol	0,21±0,02	-	0,25	0,005
Issyk-Kul lake , Ak-Terek v.	0,56±0,06	-	0,60	0,02
Kadji-Say v. a stream number 1 before the rain	4,21±0,42	1,49±0,05	4,5	0,007
Kadji-Say v. a stream number 2 before the rain	10,2±1,02	1,30±0,05	10,0	0,005
Issyk-Kul, v. Kadji-Sai river mouth	1,69±0,17	1,52±0,05	1,67	0,015

Table 3. Natural radionuclides in the water of rivers and tributaries of the lake Issyk-Kul

As Table 4 shows, for comparison, the ratio  $^{234}\text{U}/^{238}\text{U}$  at different times and the average content of uranium, this has the same level with slight variations.

Location of testing	$\gamma = ^{234}\text{U}/^{238}\text{U}$		Contents Uranium 10 <sup>-6</sup> g/l (9)
	1966-1990 (1-6)	2003-2004 (12)	
r. Toruaygyr	-	1,49±0,01	11,0-19,0
r.Chon-Aksu	1,39±0,01	1,42±0,01	6,7-10,7
r. Tup	1,43±0,01	1,34±0,08	2,6-8,7
r. Jergalan	1,23±0,01	1,20±0,02	4,7-13,0
r.Chon-Kyzylsuu	1,23±0,01	1,20±0,02	4,3-11,2
r. Barskaun	1,14±0,01	1,08±0,07	7,2-2,7
r. Ak-Terek	1,23±0,01	1,24±0,02	0,42-47,0
r. Tamga	1,22±0,01	1,22±0,06	15,1-21,6
Spring in the alluvial fan of r.Orukty	1,51±0,02	1,62±0,02	2,6
Borehole 3 v. Dzhergalan	1,20±0,02	1,32±0,06	0,6-15,6

Table 4. Comparison of uranium-isotope data from the test 1966-1970 and 2003-2004 (12)

From radiometric survey we found that radiation levels in the Issyk-Kul basin, and the village itself Kadji-Say and the adjacent territory is relatively low. However, this basin is the natural uranium province, in some areas there is increased radiation background. We found that the beach areas near the southern coast of v. Dzhenish and v. Ak-Terek (placer - Thorium sands) the exposure dose is 30 to 60 mR/h, at least at some points reaches up to 420 mR/h (Table 5, Fig. 7-8).

Background areas were studied by measuring alpha-active isotopes in soils around Lake Issyk-Kul. The level of background radiation on the surface of the industrial zone and the tail short, in a residential area above the 2 time compared with the norms.

On isotopic composition of the soil (Bq/kg), extremely high levels of activity were detected. In the area of the settlement v. Kara-Oy, the content of U238 and Pb210 were found to be 2 – 2.5 times higher in the upper (0-5 cm) soil layers. In the area of the settlements Ak-Terek and Jenish, it was found that for all the thorium (Th) isotopes the level of radiation are higher than any other studied locations by 2 to 10 order of magnitude (Table 6; Fig.9-10).

Sampling location	T° of water	pH	Gamma background	
			on the soil surface	at a height of 1 m
Kara-Oi v.	18,5 °C	8,5	150-200 mSv / h	100 mSv / h
Cholpon-Ata t.	18,8 °C	8,6	200 mSv / h	150 - 220 mSv / h
Bulan-Sogotu v.	17,5 °C	8,15	150 mSv / h	100 mSv / h
Kichi Ak-Suu r.	13,2 °C	7,94	160 mSv / h	150-170 mSv / h
Tuip r.	18,8 °C	8,12	170 mSv / h	140 mSv / h
Kara-kol r.	15,8 °C	8,05	180 mSv / h	150-210 mSv / h
Ak-Terek v.	17,5 °C	8,24	470 mSv / h	420 mSv / h

Table 5. The level of exposure dose in the Issyk-Kul basin



Fig. 7. Tailing after the rain



Fig. 8. The tailings from the bottom

Sampling location	Layer cm	Activity of soils by isotope, Bq / kg									
		U-238		Ra-226		Pb-210		Th-228		Ra-228	
			+/-		+/-		+/-		+/-		+/-
Kara-Oi	0-5	71,8	12,7	35,1	3,9	147,4	13,0	39,5	2,2	35,2	8,8
	5-10	50,8	7,3	37,7	3,4	64,6	11,4	49,0	1,9	60,1	7,5
	10-15	44,0	1,7	35,1	3,2	50,1	7,2	45,6	1,8	52,3	3,5
	15-20	51,7	7,4	46,1	3,5	50,2	7,7	49,9	1,9	53,6	7,7
Kichi-Ak-suu	0-6	71,5	14,3	51,0	3,4	88,5	18,4	69,1	3,6	72,4	7,2
	6-11	52,1	6,5	43,2	3,1	71,7	10,2	43,2	3,3	59,2	19,7
	11-20	54,9	7,3	45,4	3,5	68,6	7,6	64,3	3,8	64,1	7,5
Ak-Terek sand	0-5	260,0	30,0	103,0	8,0	169,0	30,0	915,0	57	846,0	70,0

Table 6. Background values for alpha-active isotopes in soils around Lake. Issyk-Kul and thorium sands

Soil and ground tailings - in the upper layer of soil bulk (0-20 cm) of uranium from 1.1 to 2,6 • 10<sup>-6</sup> g/g, with the depth of the element increases - up to 3,0 • 10<sup>-6</sup> g/g. Most of the uranium concentration was noted in the central zone of tailings: in the upper layer of soil - 4,2 • 10<sup>-6</sup> g/g in the bottom (at depths of 40-60 cm) - 35,0 • 10<sup>-6</sup> g/g, which is 8.3 times more than in the upper horizons.

**The vegetation** is characterized by the province following associations: xerophytic shrub-, sagebrush-efimerovymi deserts, thorny (Akantalimon alatavsky, bindweed tragacanth). The vegetation cover is sparse, the project covering ranges from 5 to 10% and only in some areas





Fig. 9. Dosimeter research.



Fig. 10. Local cattle pastured

up to 50%. The uranium content in different types of wormwood (*Artemisia*) in the tailings relatively high in relation to the region as a whole -  $0,03-0,04 \cdot 10^{-6}\text{g/g}$ . Representatives of the legume (*Salicaceae*) - *Astragalus* (*Astragalus*) and sweet clover (*Melilotus*) contain up to  $0,09 \cdot 10^{-6}\text{g/g}$ , while the grass (*Poaceae*) - a fire roofing (*Bromus tectorum*) uranium contained in twice to  $0,17 \cdot 10^{-6}\text{g/g}$ . According Bykovchenko J.G. (3) these types of plants can serve as a land-improving plant for reobiletation tailings. According to the results of our studies the percentage of uranium in the province of plants Kaji-Sai is from 0,17 to  $4.0 \cdot 10^{-4}\%$ .

Consequently there is reason to say that most of the plants Kaji-Says region have high uranium content in comparison with other territories in the region. Growth of plants in an environment with high concentrations of uranium is not only accompanied by changes in their biological productivity, but also causes morphological variability in particular: the splitting of *Astragalus* leaf blade, *Peganum garmaly* instead of the usual five petals it was noted 6-7 and part of their split, and the black grate observed significant morphological changes - low-growing form with branched inflorescences instead of straight single arrows (5, 10, 13) (Fig.11-12).



Fig. 11. Straight from the top of the tailings



Fig. 12. Color mosaic of plant leaves *Iris* family (Iridaceae) species-*Iris songarica* Schrenk



Currently, surface water eroded slopes adjacent to the tailing of relief, ground ash dump, the protective coating surface of the tailings piles and rocks. Diversion of surface water systems tailings are partially destroyed preserved, due to changes in drainage conditions due to existing buildings and structures do not provide normal drainage of surface water. Fences tailings destroyed, the network of groundwater monitoring is absent.

4.3 Uranium deposits of settlement

**Min-Kush** (Tura-Kavak) are at an altitude of about 2000 m in the basin of the r. Min-Kush. The population of urban settlement. Min-Kush at present is 4760 persons. In this region there are 4 tailing of radioactive materials - the volume of 1.15 thousand m<sup>3</sup>, an area of 196.5 thousand m<sup>2</sup>, and 4 mountain dams (substandard ore, there is no data on the volume) and the whole tail is a flat, land located on slopes up to 25-40° between the mountains. Ore complex operated from 1963 to 1969. After closing all the tailings of the uranium production was inhibited.

Currently, because of the timing of repairs and maintenance, there is a destruction of individual defenses and surface areas. The most dangerous are tailing "Tuyuc-Suu" and "Taldy-Bulak." Tailings "Tuyuc-Suu" is located in line with the same river. The total volume of reclaimed tailings - 450 000 m<sup>3</sup>, their area - 3,2 hectares. According to the results of radiometric survey the exposure dose at the surface of the tailings - 25-35 mR/h, locally - 150 mR/h. The total radio activity of nuclides in the disposal of the tail material - 1555 Ci.

To skip the reinforced concrete built river bypass channel is now part of ferro-concrete bypass channel structures destroyed, there was differential settlement surface tailings, formed locally closed injury, do not provide a flow of surface waters: a protective coating in some places broken excavation, fences and signs forbidding destroyed. The tailings are located in an area prone to mudslides. Possible violation of the water drainage and destruction of the tailings with the removal of the tail of material in the river Kokomeren and Naryn, then - in Toktogul and the Fergana valley. There has been a movement of an ancient landslide threat of overlap Tuyuk-Suu river and the destruction of the road to tailing (Fig. 13-14).

The radiometric survey of the exposure dose of gamma radiation at various sites of uranium tailings Min-Kush, showed from 27 to 60 mR/h, but at some points is high. For example the tailing Taldy-Bulak - 554 - 662 mR/h (Table 7). In general, the soils of Min-Kush geochemical province largely enriched by uranium, as far as concentration of uranium in them is 5-6 times higher than in other soils of Kyrgyzstan.

Name of areas	Radiation background in mR/h
Min-Kush village	27,0-28,0
Tailings Tuyuk-Suu gate	27,5-28,0 60,0-61,0
The site- 21(where miners lived)	32,0-32,5
Tailings Taldy-Bulak	554 - 662
Water from the tunnels	61,0-61,5
Hotel Rudnik	60,0-61,0

Table 7. The level of background radiation in a uranium province of Min-Kush



Fig. 13. Arrangement of uranium tailings storage Tuyuk-Suu in the village of Min-Kush



Fig. 14. A landslide in the lower portions of tailing

The soil cover neighborhoods Min-Kush presented, as indicated above, sub-alpine soils of steppe and meadows. The uranium content here, in the middle of the profile ranges - from  $3,3$  to  $17,5 \cdot 10^{-6}$  g/g is relatively high. Moderate pollution (great danger) in the area located above the processing plant where the uranium content in the soil reaches the surface -  $30-35 \cdot 10^{-6}$  g / g, indicating that the local pollution of this area.

In all soil profiles high concentration of uranium observed in the horizon of 20-40 cm ( $15-20,0 \cdot 10^{-6}$  g/g). In the adjacent - Kochkor valley where the soils are mountain-valley light brown the uranium content in the range  $3,0-5,0 \cdot 10^{-6}$  g/g. Humus to a certain extent helps to perpetuate the uranium in the soil apparently is in the process of sorption of uranium by organic matter of soil and the formation of uranyl humates.

We have also studied the radiation background in some village homes'. V. Min-Kush (Table 8) and measurement results showed that in homes, compared to the MPC, the background radiation slightly increased (2 times) and therefore requires specific measures to reduce. The main reasons for the slight increase in background radiation provided cases of using waste ashes from the local coal for the construction needs.

Gamma-ray background: in the attic	
0,97mcZv/h ± 22%	0,78 mcZv/h ± 20%
0,88 mcZv/h ± 20%	0,73 mcZv/h ± 20%
Inside appartment 6, in the hall	
Bedroom - - the floor	Kitchen floor
0,76 mcZv/h ± 20%	0,63 mcZv/h ± 20%
0,65 mcZv/h ± 20%	0,69 mcZv/h ± 20%0,
0,75 mcZv/h ± 20%	69 mcZv/h ± 20%
Bedroom - the ceiling	Kitchen ceiling
0,72 м mcZv/h ± 20	0,57 mcZv/h ± 10%
0,66 mcZv/h ± 22%	0,80 mcZv/h ± 10%
0,79 mcZv/h ± 22%	0,71 mcZv/h ± 10%

Table 8. The level of radiation background in the residential of v. Min-Kush (17 Square, st. Zhusup, Building 10, Apt. 6)

Considered several options for security of stored waste:

- Dismantling and transport the tailings to a safer place;
- Repair of hydraulic structures and constant maintenance of their working condition over a long period of use (thousands of years);
- Conducting sanitation radioecological studies and measures to reduce the exposure dose in dwellings.

4.4 Uranium-technogenic provinces Shekaftar

The mine operated from 1946 to 1957 year at this area and also 8 dumps located here. In the dumps warehousing about 700 000 m³ of low-level radioactive rocks and ores substandard.

In the immediate vicinity are houses with gardens. The main pollutants are elements of the uranium series. The average gamma-ray background is 60-100 mR/h on the anomalous areas - up to 300 mR/h. All damp are not re-cultured (Fig. 15).

The material of which is used by local people for household needs. Damp number 5 located on the bank of river Sumsar intense urged by its waters. The lack of vegetation on the surface contributes to the development of wind erosion and surface runoff material stockpiles and distribute them not only to the territory Shekaftar item, but also in adjacent territories of Fergana valley.

A more extensive destruction of stockpiles fall down cross-border contamination of the territory of Uzbekistan and Tajikistan.





Fig. 15. The not re-cultured dumps in the region of Shakaftar

Bringing the dumps in a safe condition requires the following emergency operations:

- strengthening the river banks Sumsar;
- re-culturing of land dumps;
- restoration of fences,
- the installation of warning signs.

#### 4.5 Ak-Tuz technogenic provinces of rare and radioactive metals

Ak-Tuz technogenic provinces of rare and radioactive metals are located in the Chui region of KR in the upper part valley river Kichi-Kemin and river basin Chu. The terrain - a complex, mountainous. Absolute altitude exceeds 2000 m above sea level.

The ore field of the region is characterized by an extremely complex structure, and covers about 30 occurrences of lead and rare metals. It is widely developed within a multiplicative and disjunctive offenses manifested repeatedly throughout geological history, ranging from the Precambrian. Within the deposit an oxidized sulfide ores of metals were developed. In industrial concentrations established the presence of: Pd, Zn, Sn, Mn, Cu.

In the region of the Ak-Tuz are 4 tailings. Stored 3900 000 m<sup>3</sup> of waste ores, which occupy 117 000 m<sup>2</sup>, the average gamma-ray background is 60-100 mR/h in the abnormal areas of up to 1000 mR/h (Fig.16-17).

From 1995 to 1999. work to maintain the waterworks were not conducted. In 2000 activities were conducted waterworks tailings number 1 and 3. There is intense erosion of the protective layer tail number 1 and wind erosion surface tailings number 3 with the destruction of the surrounding areas.



Fig. 16. Tailings number 2



Fig. 17. Territory after the development

According to the radiometric measurements the average exposure dose of gamma radiation in part of Ak-Tuz is 21,3 – 33,0 mR/h and around the village within radius of 1 km – 28.8 mR/h. The gamma-ray background in the processing plant is 73,3 mR/h in the sump - 720-740 (in places up to 900) mR/h and near the mines (career) - 50,0-72,0 mR/h. Natural gamma-ray background in the canyons of the Kichi-Kemin is 30,0 mR/h.

The soil cover of the province is typical for middle mountain areas of Kyrgyzstan. Ak-Tuz mining and metallurgical combine mountain-meadow black earth subalpine soil. The texture of the soil has medium and high clay content character. Humus in the upper levels are between 4-8%. Soil reaction (pH) ranges from neutral to slightly acidic and is 6,5-6,8 to 7-7,0. Humus horizon of these soils are rich in potassium (2.2 to 2.6 %.) Contains of 0.35% nitrogen and 0.15-0.30% phosphorus. In the sump pH close to neutral medium (pH = 7)



above and below the sump level is the same. Eh - in the region settling tank is moderately increased (210), below the sump decreases.

Results of the analysis of the upper soil layer (up to 0 - 20 cm) are presented in Table 9. The table shows that the maximum concentration of lead found in the area of 500 m below the lagoon ( $3108,4 \pm 415$  mg/kg), followed by factories in the area of 1 km ( $2686,1 \pm 287,7$  mg/kg) and 4 tailing ( $1937,0 \pm 325,4$  mg/kg), which is increased to 10 times compared to other sites, and in relation to the MPC to 200 times.

Zinc concentration increased to 10 times compared to other sites, as compared with up to 15 times MPC. For example, in the factory up to 1 km ( $720,62 \pm 59$  mg/kg), the tail region of 3 ( $818,90 \pm 26$  mg/kg), 4 tail ( $756,20 \pm 57$  mg/kg) and 2 tail ( $652,70 \pm 87,1$  mg/kg).

#	Sampling locations	Pb mg/kg	Zn mg/kg
1	1 km upstream from v.Ak-Tuz (the right bank of the river from the road 60 m)	621,14±17,82	104,83±17,82
2	Ak Tuz v. (center, from a point-600 m)	2057,5±339,4	678,79±30,3
3	In the area of the factory up to 1 km	2686,1±287,7	720,62±59
4	In the area of weight	398,2±38,2	128,3±11,3
5	200 m from the factory (above)	436,7±45	76,83±5,3
6	In the area of tank	453,2 ±37,3	631,16±70
7	500 m below the lagoon from the factory	3108,4±415	91,68±33
8	In the region of 2 tailings	370,0±39	652,70±87,1
9	In the region of 3 tailing	331,0±34	818,90±26
10	In the region of 4 tailings from the road above 450-500 m	1937,0±325,4	756,20±57

Table 9. The average content of heavy metals in the soil cover Ak-Tuz polymetallic province

Thus we can say that in the village of Ak-Tuz and its surroundings the level of gamma-ray background is almost within the natural. Near the mine (quarry) and in the processing plant, where the extraction and processing of ore containing rare earth metals and radioactive thorium, the average exposure dose of gamma radiation exceeds the natural rate of several times, especially Pb and Zn. In unfenced and located near the settlement of the sump in the tens or hundreds of times, which adversely affects of the ecology region. These objects are contained except for radioactive thorium, heavy metal salts. In the event of failure of tailings can take away the tail of material in the basin of Chui river and pollution across national boundaries.

4.6 Kara-Balta mining ore plant for production of oxide, oxide of uranium

The plant's capacity to 2,000 tons of uranium a year, in operation since 1955. Tailings mining and metallurgical plant the plain type is located 1,5 km from the town of Kara-Balta, 2380 000 m² area, maximum height of 35 m. The net capacity 63,5 million m³ is filled with 54.4%. Currently 32,5 million m³ of waste stored, AC power is 84600 Ci.

The main polluting components - uranium series elements. Damp height to 12 m. Completed closed drainage to the production and wells to 35% of the stacked protective plastic film, the rest of the shield consists of loam and clay. There is a technical device abstraction to capture contaminated groundwater from five wells. There is a regular monitoring of groundwater. In the area of tailings maximum contamination up to 3-4 g/l outside the sanitary protection zone at the MPC. In conducting radiometric survey we found that in the tailings level 1 and 2 background radiation is much increased (from 4 to 20 times) compared to the other points. The radiation background at the tail KGRK and surrounding areas from our data is 25 mR/h (the town of Kara-Balta, 200 m from the SPZ) to 550 mR/h (at the base of tail).

## 5. Conclusion

In the complex environmental problems in the country first place put forward the problem of safely storing large quantities of waste mining. The accumulation of significant amounts of radioactive waste resulted from the activities of mining and processing enterprises of the uranium industry 40-70s. Storage in open dumps, tailings and not enough trained squares leads to an intense weathering of toxic substances into the atmosphere, their penetration into the groundwater, soil, surface water and adverse impact on the environment and human health.

Many of the tailings and dumps, radioactive waste disposal in the border areas are in critical condition and cause a risk of contamination and radiation exposure in the territory of Kyrgyzstan, as well as possibly other Central Asian republics. The main causes of environmental stress in the region due to bad choice of storage sites and storage facilities, short-term considerations of economic gain, a low level of geological engineering survey and design lack of foresight and taking into account the effects of technological impacts on the stability of fragile mountain ecosystems. Many of the tailings were formed within settlements.

With the recent surge in industrial and natural catastrophic events, landslides, mudflows, erosion, the threat of radioactive pollution of the environment increases significantly. There is a threat to the health of people living near areas with high levels of radiation and radioactivity in the environment. On many dangerous areas, lack of basic information on the radioactivity content of tailings is not being monitored due to lack of funding and related equipment on the ground.

The main radiological concern in the country is the restoration of plant-soil (gardening) and the bare heaps tailing, protection from the intense erosion of the protective layer of tailings. Thus the uranium tailings are poorly protected and poorly understood features of life in different organisms (biological response to the increased content of radionuclide, the state of microbial complex and human).

Estimated cost of MES KR (approximate) of the reclamation and rehabilitation work only on the tailings will be more than - \$ 40 million dollars USA, including:

1. v. Maili-Suu tail. Landslides - 16.8 million USA
2. v. Min-Kush tail. - 4.6 million dollars USA
3. v. Ak-Tuz tail. - 1.6 million USA

4. v. Kaji-Say tail. - 3.6 million USA
5. v. Sumsar tail. - 5.0 million USD
6. v. Shekaftar tail. - 1.5 million USA
7. v. Soviet tail tail. - 2.0 million USA
8. v. Orlovka - 3.0 million USA
9. etc.

Therefore, the Government and the President of the KR pay special attention to these problems and made some steps in this direction. In 2009 the President appealed to the UN Secretary-General, in 2010, the European Union with a request to provide financial and technological support in addressing this issue in Kyrgyzstan and the region.

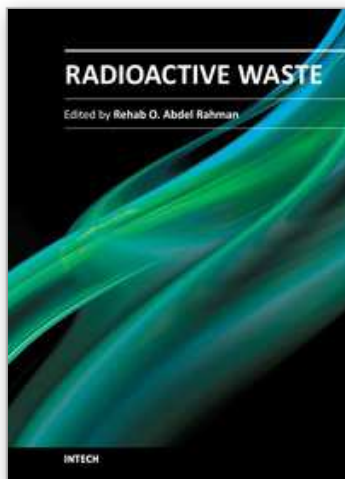
1. In general, the overall level of external radiation background in Kyrgyzstan is normal except for some man-made and natural areas.
2. Increased radioactive anomaly in the man-made sites marked by three types:
  - Natural radioactivity anomalies associated with layers of loose deposits of radioactive brown coal of Jurassic age.
  - Man-made anomalies, hundreds of times higher than background, are confined to fenced concrete wall piles of gray fine-grained material.
  - Activity of man-made anomalies in the landfill is ten times higher than background.
3. Growth of plants in an environment with high concentrations of uranium is not only accompanied by changes in their biological productivity, but also causes morphological variability - *Astragalus borodinii*, *Peganum garmala*, *Potentilla argentea*
4. It is important to educate the population.

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## **Radioactive Waste**

Edited by Dr. Rehab Abdel Rahman

ISBN 978-953-51-0551-0

Hard cover, 502 pages

**Publisher** InTech

**Published online** 25, April, 2012

**Published in print edition** April, 2012

The safe management of nuclear and radioactive wastes is a subject that has recently received considerable recognition due to the huge volume of accumulative wastes and the increased public awareness of the hazards of these wastes. This book aims to cover the practice and research efforts that are currently conducted to deal with the technical difficulties in different radioactive waste management activities and to introduce to the non-technical factors that can affect the management practice. The collective contribution of esteemed international experts has covered the science and technology of different management activities. The authors have introduced to the management system, illustrate how old management practices and radioactive accident can affect the environment and summarize the knowledge gained from current management practice and results of research efforts for using some innovative technologies in both pre-disposal and disposal activities.

### **How to reference**

In order to correctly reference this scholarly work, feel free to copy and paste the following:

B. M. Djenbaev, B. K. Kaldybaev and B. T. Zholboldiev (2012). Problems of Uranium Waste and Radioecology in Mountainous Kyrgyzstan Conditions, Radioactive Waste, Dr. Rehab Abdel Rahman (Ed.), ISBN: 978-953-51-0551-0, InTech, Available from: <http://www.intechopen.com/books/radioactive-waste/the-problem-of-uranium-tailings-and-radioecology-in-mountainous-kyrgyzstan>

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