The Environmental Conditions and Health of Workers at the Russian Uranium Mining and Milling Facility - 11525

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ABSTRACT

The goal of this study is to carry out comprehensive environmental and hygienic examination of the Health Protection Zone and the location area of the the Priargunskiy production mining and chemical association and to assess health conditions of miners. The media under examination were: common air, soil, vegetation, and water. Contents of natural radionuclides - U-238, Th-232, Ra-226, Po-210, and Pb-210 have been determined. Concentrations of other chemicals have also been determined in common air. Radionuclide migration levels and accumulation coefficients of uranium series have been determined. Medical and dose information has been collected and verified to evaluate health conditions of miners.

INTRODUCTION

Uranium depositions in Chita region were revealed in 1963. The Priargunsky industrial mining chemical association (PPGHO) has started industrial uranium mining since 1972. This association is the largest one in Russia and one of five largest uranium mining facilities over the world. The PPGHO is multi-branch ore mining facility. In addition to underground mining of uranium ores it is involved in milling of such ores using hydrometallurgical method with production of the natural uranium oxide concentrate; lignite mining; sulphuric acid production for the reprocessing manufacture; electric power production and warm power supply of industry and municipal formations. The PPGHO is a township-forming enterprise. Krasnokamensk city, with the population of about 60 thousands, is situated in 18 km to the southwest from the PPGHO. The long-term and perspective plans of the facility envisage the uranium ore mining and milling to be continuously increased. Increasing potential of the facility can result in unhealthy consequences for the environment and population living and working nearby the PPGHO. Today, there are parts with local radioactive contamination on-site, so some adequate remedial measures are necessary there. The radiation situation is hard in Octyabrsky village. This village fell in the health protection zone of the facility during its operation and development and it is located close to the ore processing complex facility[1].
The goal of this work was to carry out comprehensive radio-ecological inspection of the PPGHO site and to evaluate the public and miners'health in Octyabrsky village.

EXPERIMENTAL PART

The radio-ecological situation on-site has been assessed using measurements both of gamma dose rate in-situ and activities of natural radionuclides Ra-226, Th-230, Po-210 and Pb-210 in soil, water and vegetation. Radon and thoron progeny EEC has been determined in air in- and out-doors. Soil, vegetation and water sampling has been carried out according to the requirements of "Methodical recommendations for sanitary control of radioactive substance contents in the environmental media" [2]. Activities of natural radionuclides U-238, Th-232, Ra-226, and K-40 in the soil and vegetation samples were being measured using the "ORTEK" semiconductor spectrometer. Radionuclides Pb-210 Bi-210 and Po-210 were being determined using the radiochemical method of electrolytic deposition. Measurements were being performed using the low background radiometer UMF-2000. The radon and thoron EEC were being determined using the alpha radiometer (RAA-3-01 alpha aero) out-doors in the places of soil sampling and gamma dose rate measurement, as well as in dwellings and workshops within the Health Protection Zone (HPZ).
The epidemiological method was used to identify the morbidity structure of the population in Octyabrsky village and miners of the PPGHO. This method was based on the assessment of the public health according to data of the reported medical statistics.

Results

The structural organization of the radio-ecological monitoring system on-site the PPGHO is implemented in the follow manner: the PPGHO division of independent radiation safety service is responsible for monitoring of radiation and chemical situation; RM 107 and CH&E 107 under the FMBA of Russia are responsible for independent regulatory sanitary-and-hygienic supervision; the Burnasyan FMBC implements scientific and methodical support of operations relating to the regulatory supervision and arrangements of remedial measures aimed at assurance of radiation protection of the population and the PPGHO workers. The radio-ecological situation

monitoring covers the PPGHO HPZ and the adjacent settlements – Krasnokamensk village situated on the outer border of the HPZ and Krasnokamensk city. Soktuj village has been selected as the background region because of it's the most favorite wind diagram in sanitary aspects.
The main sources of radiation and chemical exposure to the environment are the uranium ore mines and facilities for the mine waste storage (mines, heap leaching sites, spent ore dumps); facilities for ore milling and milling waste storage (hydro-metallurgical plant (HMP), tailing dumps of the ore milling complex facility, the sulphate plant (SP), cinder/calcine storage facilities). The nature of distribution and accumulation of natural radionuclides in the environmental media at the area under inspection depends on: dust transfer from the rock dumps from the HMP tailing facility site and from the central ore stockyard; ore mass spills along motor ways; spillage of the uranium containing pulp and mine water from the mine pump station basin. Moreover, dumps of non-commercial ores are under natural leaching caused by the rains, so the radionuclides penetrate to the hydrographic network. The shafts and air holes, as well as the TPP pipes release the radionuclide mixtures of U, Rn-222, Po-218, Pb-214, Bi-214, Th-232 and K-40 into the atmosphere. This makes the significant contribution into the external gamma dose rate.

Gamma Dose Rate at the Area of the PPGHO HPZ
The gamma dose rate within the HPZ of the industrial units of the facility varies over the wide range, depending upon direction and farness from the objects under inspection, and the upper border of this index exceeds significantly the background values typical for the area of the Territory (Table 1). Maximum dose rate values are registered near the cinder/calcine storage facility at the west direction (1.12÷2.15 μSv/h**),** due to high soil contamination (A_{eff} varies over the range 851-7838 Bq/kg). Over the recent 4 years (2005-2009), the radiation situation near the HMP and TPP is specified by the permanent small exceeding of the background dose rate values typical for the uranium containing areas [3]. The east and southeast directions are exclusions: the gamma background value reaches there 0.41 and 0.57 μSv/h, respectively. Analysis of gamma dose rate change dynamics at the spent ore processing and storage facilities (HMP and tailing dump) over 2005-2009 showed that regardless the remaining high non-uniform territorial distribution of this index, the dose rate range removed to the area of lower values (Fig.1). *Gamma dose rate* at the area of Octyabrsky village situated within the HPZ of the facility, varies over the range 0.1–2.5 μSv/h, this is higher than in Soktuj village (0.12 – 0.16 μSv/h) and at other areas within the 100 – km PPGHO zone (Krasnokamensk village – 0.26 – 0.42 μSv/h, Krasnokamensk city 0.20– 0.35 μSv/h). This is due to the fact that filling and above-mine complexes are located in close proximity to the village involved in the uranium ore loading. The emergency air holes and pump station of the mine water are also located there. The air hole for the mine air removal from the underground mines is located directly at the residence area of the village. The technological road from the uranium mines passes near the village.

Table 1 − Gamma dose rate in the HPZ of the PPGHO industrial units

Area	Dose rate range, μSv/h
Within the PPGHO HPZ	
Above-mine buildings	0.33-3.5
Hydro-metallurgical plant (300-1200 m)	0.18-2.1
Tailing dump at 300-800 m distance	0.11-1.48
Sulphate plant	0.19-0.57
cinder/calcine storage facility (300-800 m)	0.14-2.8
TPP	0.12-0.45
Octyabrsky village	0. 1-2.5
Beyond the PPGHO HPZ	
Krasnokamensk village	0.28-0.47
Krasnokamensk city	0.20-0.35
Soktuj village	0.14-0.16

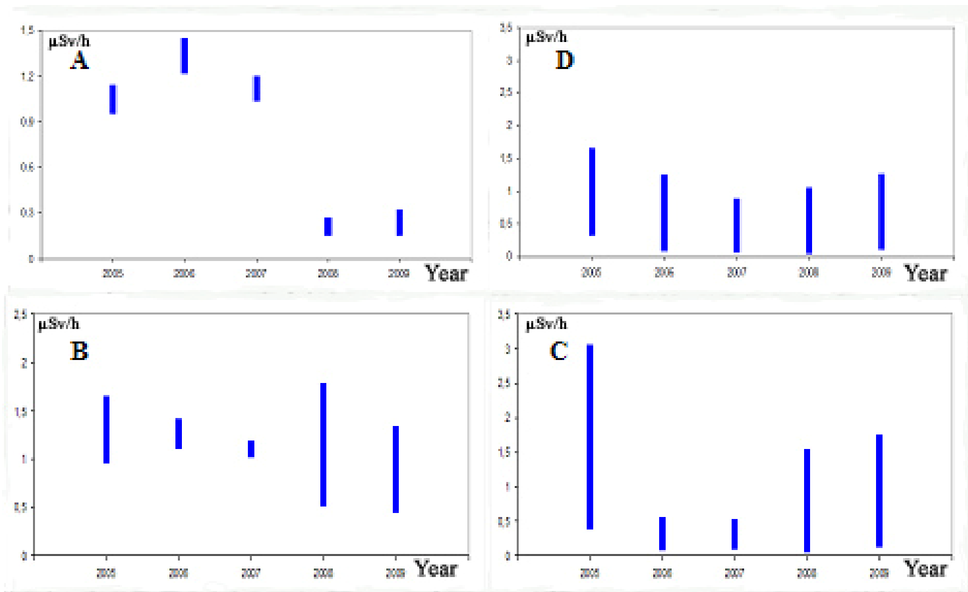

Figure 1 – Dose rate monitoring at the HPZ area of the the Priargunskiy production mining (µSv/h)

A. HMP 300 m
B. HMP 1200 m
C. Tailing dump 300 m
D. Tailing dump 1200 m

Activity Concentration of the Radon and Thoron Progenies in Air

Within the HPZ of the PPGHO industrial units, the radon equilibrium equivalent concentration (EEC) outdoors varies over the wide range of concentrations - from 3 to 48 Bq/m^3. Beyond the HPZ, the highest dispersion of values has been registered in Krasnokamensk city (3-17 Bq/m^3), while in other settlements this index was not higher 7 Bq/m^3 (Krasnokamensk village, Soktuj village) [4]. The thoron EEC outdoors over the areas inspected was not higher 3 Bq/m^3. The measured radon EEC values over the above-land serviced rooms within the HPZ vary mainly over the range from 10 to 70 Bq/m^3. Maximum radon EEC values have been registered inside the technological transport establishment, about 180 Bq/m^3. The radon EEC outdoors the Octyabrsky village varies over the range from 3 to 10 Bq/m^3 . The highest concern is caused by high radon levels being found in the cottage type dwellings – for 39% of the residential area, the radon EEC exceeds the authorized level, 200 Bq/m^3. Today, some protective/preventive measures are being taken to reduce level of radioactive gas in dwellings.

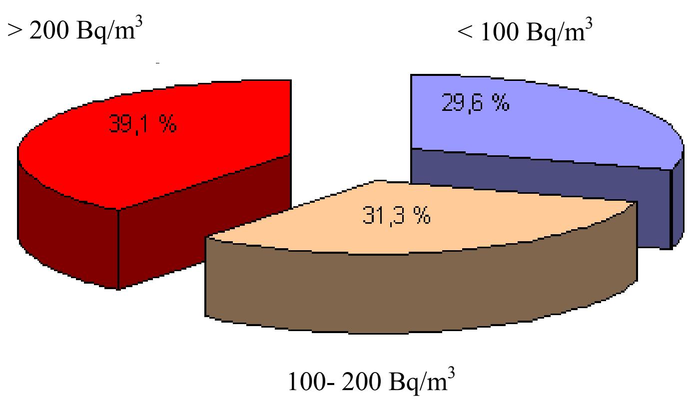

Figure 2 – The flat distribution in Octyabrsky village by the radon EEC levels in air indoors, %

Contents of Natural Radionuclides in Soil and Vegetation

Enter of natural radionuclides into the environment due to the technological processes results in some disposition of natural isotope ratios of the uranium-radium series typical for mineral raw materials. Analysis of activity ratios Ra-226/Th-232, Ra-226/K-40 , Th-232/K-40 enables to identify the man-made radioactive contamination of areas by natural radionuclides.

Table 2 – Ratio between the specific activities of the natural radionuclides in soils of the PPGHO HPZ

Place of sampling	Ratio between the specific activities		
	Ra-226/Th-232	Ra-226/K-40	Th-232/K-40
Above-mine building 8K-9K directions west 300 m and east 300 m	25.4	0.44	0.017
Above-mine building 3R directions south 300 m and north 300 m	750	15	0.019
Above-mine building 5B directions north 300 m and east 300 m	9.3	0.325	0.035
Above-mine building 3B directions east 300 m and north 300 m	16	0.40	0.025
Trench «Eastern» directions west 300 m and south 300 m	1.5	0.074	0.05
Tailing dump All directions 300 m	3.3	0.15	0.043
Soktuj village	0.32	0.054	0.17
Krasnoyarsk Territory	0.67±0.07	0.090±0.018	0.15±0.04

As this table shows, the activity ratios of the prime radionuclides of the uranium-radium series in soils of the controlled settlement Soktuj and in soils with clark NRN of the Krasnoyarsk Territory are values of the same order, i.e., contents of these radionuclides correspond to the natural background. While the activity ratios of these radionuclides in soils under above-mine buildings and tailing dump differ significantly from the activity ratios of the prime natural radionuclides at the background areas. The data obtained confirm the presence of the parts of the areas with un-uniformed man-made changed content of the natural radionuclides in soil [5].

The terrestrial vegetation plays an important role in determination of the migration level and the radionuclide re-distribution in the system soil-vegetation-human. The accumulation coefficient (K_n) is the quantitative characteristic of radionuclide intake from the soil into vegetation and serves as an index of biogenic migration. This coefficient is determined as a ratio between the radionuclide specific activity in vegetation (Bq/kg) and its specific activity in soil (Bq/kg). Table 3 shows the calculated accumulation coefficients of the NRN in vegetation in the HPZ and the background region[3].

Table 3 – The radionuclide accumulation coefficients in the system vegetation-soil, Bq/kg / Bq/kg

Sampling place	Accumulation coefficients vegetation/soil, Bq/kg					
	Ra-226	U-238	Th-232	K-40	Pb-210	Po-210
Above-mine building 8K-9K direction Eastern 300 m	0.26	0.002	–	0.20	0.12	0.062

Above-mine building 3P direction Southern 300 m	0.24	0.003	0.053	0.21	0.098	0.027
Above-mine building 3B direction Eastern 300 m	0.17	0.002	0.117	0.15	0.076	0.047
Above-mine building 3B direction Northern 300 m	0.20	0.004	0.063	0.09	0.10	0.041
Trench «Eastern» direction Southern 300 m	0.11	0.009	0.038	0.27	0.098	0.029
Tailing dump direction Northern 300 m	0.14	0.007	0.04	0.09	0.053	0.029
Tailing dump direction Southern 300 m	0.12	0.007	0.015	0.17	0.16	0.085
Mean value	**0.18**	**0.005**	**0.05**	**0.17**	**0.1**	**0.05**
Soktuj village	0.22	0.015	0.007	0.16	0.14	0.097

Analysis of data obtained shows that the radionuclide migration potential decreases in the series: Ra-226, K-40, Pb-210, Po-210, Th-232, U-238. In the soil-vegetation system, Ra-226 and K-40 have the highest biological mobility. U-238 is specified by the lowest migration potential[6].

Radionuclide Contents in the Drinking Water, Water from Open Reservoirs and Ground Water
The domestic effluents of Krasnokamensk city and the PPGHO industrial units are being purified in the local purification facilities, mixed with in TPP industrial effluents and released into accumulating lakes – into the system of Umykey lakes. With the purpose of the radionuclide enter into the water system via sewage and filtration water, the NRN content levels have been determined in sewage and mine water, ground water and drinking water (Table 4).

Table 4 – Radionuclide contents in sewage water, water from the observation boreholes, mine water and drinking water, Bq/kg

Place of sampling	Sample characteristic	Activity concentration, Bq/l						$\sum(A_i/IL_i)$
		U-238	Th-232	K-40	Ra-226	Sr-90	Cs-137	
Umykey lakes at the effluent point	Sewage water	0.9	0.23	7.4	0.75	0.38	0.15	1.8
Pump station	Mine water	0.2	0.04	1.5	0.5	0.21	0.09	1.26
Umykey lakes	Lake water	1.0	0.15	5.5	0.35	0.20	0.08	1.14
Observation borehole No 77207	Ground water	0.2	0.03	0.8	0.04	0.03	0.02	0.20
Observation borehole No 8016	Ground water	0.4	0.06	2.0	0.12	0.05	0.06	0.48
Octyabrsky village	Drinking water	0.1	0.15	5.5	0.30	0.03	0.09	0.89

On the base of data obtained, compliance with the intervention level (IL) has been checked under condition of joint presence of several radionuclides in water (Table 4) [7]. The IL exceeding can credibly be confirmed only in sewage water being released into Umykey lakes, and in mine water being released into the tailing dump. This is explained by their high ^{226}Ra content, for which IL = 0.5 Bq/l. In water from the observation boreholes and in drinking water, this ratio is less than 1, i.e., no measures are necessary to be taken to reduce its radioactivity in this case, because the resulting effective dose will not be higher than 0.1 mSv per year (quota for water is 10%) [7].

Health Assessment of the Public and the PPGHO Workers

Having in mind more than 40-year period of the human living under conditions of the uranium containing province and the radon anomaly region, the health assessment of the population in Octyabrsky village can be considered as one of the criteria of the current environmental conditions on the PPGHO site.[9] The following factors define the medium- and long-term radiological risk for the residents of the allocation region of the retired uranium mining and milling facilities:

- Radon exhalation from the surface of dumps and tailing dump;
- Application of radioactive materials in building operations;
- Contamination of superficial water flows and aquifers being used for drinking water supplying;
- Contamination of open reservoirs being used for fish farming and fishing;
- Contamination of foods produced at the area of the tailing dump.

The inspection performed have demonstrated that the main medical and demographic indexes – birth rate and mortality – of the residents of Octyabrsky village was practically the same as the mean regional (Chita region), and similar indexes over Krasnokamensk city. The morbidity dynamic analysis of the adult residents demonstrated that for the main disease classes, including the malignant neoplasms, the higher indexes were being registered among the residents of Octyabrsky village in comparison with the urban citizens of Krasnokamensk. So, the cancer morbidity, by 2005, became 42 % higher in comparison with the similar index over 2001. The similar trend has been noted in respect to the death rates caused by malignant neoplasms. Analysis of infant (0-14 years old) and teenager (15-17) morbidity dynamics has revealed much higher indexes in Octyabrsky village in comparison with Krasnokamensk city. Practically all nosological forms of diseases (including common morbidity index) in Octyabrsky is 5 times higher than the similar index for Krasnokamensk.

The structure of the occupational morbidity of the PPGHO workers has been analyzed. Over the whole period of observation, since 1969, at the facilities under MSCh 107 service and RM 107 control 446 cases of the occupational diseases have been registered: PPGHO – 422, GRE-324 – 24. The main producer of the occupational diseases is the Uranium Mine Management «PPGHO». The first place in the structure of occupational morbidity fills sensorineural deafness. 151 cases have been registered (34.0% of all revealed occupational morbidity). The majority of occupational patients work under underground conditions (83% of the registered cases): facemen (miners), drift miners (tunnellers), drillers, timber men, underground locksmiths. Generally (94%), the occupational dust bronchitis of the underground group of workers is registered. Over the period 2000-2009, only 3 cases of the occupational dust bronchitis and 1 case of the bronchial asthma have been registered. Occupational cancers of lung and upper airways fill the third place in the structure (16.9 %). These diseases have been registered of the underground workers. Before 1981, 2 cases have been registered; over the period 1982-1994 – 14 cases; over 1995-2005 – 59 cases. Increasing of amount of the registered cases of the occupational cancers is explained by: increasing number of the training personnel, improved quality of diagnostics and the early disease revelation, as well as the existence of «latent time period» between radiation exposure and development of the neoplastic process, which is 15-20 years on average.

Identification of relationship between the industrial factors making exposure to miners during their mining work and a role of these factors in the aetiopathogenesis of early and late (stochastic) consequences for the worker health is very important. With this purpose, today, the medical and dose register for miners is under development to accumulated, store and verify the retrospective personal information on work conditions, doses, life status and health of workers.

CONCLUSIONS

1. Comprehensive assessment of the current radio-ecological situation on the PPGHO site has been carried out.
2. It was shown that gamma dose rate at the PPGHO HPZ varies over the wide range (0.14-3.15 μSv/h) within the HPZ of the industrial units. At the areas adjacent to the HPZ, gamma dose rate is at the level of the background values typical for these areas [8].
3. Data on the radionuclide contents in soil have been obtained. This data confirms the presence of some parts of these areas with man-made changed contents of the natural radionuclides in soil. The NRN distribution within the HPZ is very un-uniformed with dominant radium and its decay products (Ra-226 – $1.31*10^4$ Bq/kg, Po-210 – 7755 Bq/kg and Po-210 – 5074 Bq/kg). The high migration potential of radium has been demonstrated in the system soil-vegetation, which was being determined on the base of the NRN accumulation coefficients calculated.

4. High radon levels have been registered in the cottage-type dwellings of Octyabrsky village, which is located within the HPZ of the facility. The radon EEC exceeds the authorized level, 200 Bq/m^3, in 39% of the residential area.

5. The unhealthy current radiation and ecological situation at the PPGHO HPZ reflects in the morbidity indexes of the basic quota of workers and population living in the places of the facility sitting. Analysis of the morbidity dynamics for different age groups of population revealed much higher cancer indexes and diseases of the main nosological groups in Octyabrsky village in comparison with Krasnokamensk city.
6. The structure of the occupational morbidity of the PPGHO workers has been analyzed. At the early stage of medical information collection, a large proportion of the lung cancer should be noted in morbidity with malignant neoplasms and their induced deaths of miners. Such diagnoses are exactly confirmed by the morphological studies. Plans of the further stages include continuation of medical and dose information accumulation and verification and its analysis over the miner group being employed at the Priargunsky production mining and chemical association earlier.

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