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Improvement of Environmental Safety of Population in Uranium-Mining Regions Ukraine

V. Lyaschenko1*, V. Stus2, T. Lisova3

[1] *Head of the research department – academic secretary, Ukrainian Research and Design Institute for Industrial Technology, Zhovti Vody, Ukraine*

[2] *Department of Urology, State Institution Dnipropetrovsk Medical Academy of the Ministry of Health of Ukraine, Dnipro*

[3] *PJSC VITAMINS, Uman, Ukraine*

* Responsible author: e-mail vilyashenko2017@gmail.com tel. +380565229064

Abstract

Objective is to increase ecological safety of population in uranium mining regions on

the basis of scientific substantiation, development and introduction of rehabilitation measures for minimization of negative effects on the environment and human health from the influence of radiation factors.

Methods. Radio methods (measurement of exposure dose and intensity of *γ*-radiation,

measurement of radioactivity of γ– and β-radiation, measurement of the exposure dose rate of γ-radiation, determination of the power of absorbed dose of γ-radiation in air, analysis of natural radionuclides); statistical and mathematical methods of research using integrated system approaches were applied. Radioecological studies included measurement of the exposure dose rate of γ-radiation over the network of 100x100 m and 20x10 m (pedestrian gammagraph) in the volume of 40 km2; soil analysis on radionuclide content; sampling of water for the contents of radium and uranium; determination of the total α– and β-activity of the soil; determination of radon concentration in residential properties.

Results. *Radiation protection.* All sources (3973 units) of ionizing radiation with a total activity of more than 15 thousand curies were removed from the city's territory. The most polluted parts of the city with an area of more than 6 hectares were remediated. Anti-radon activities were conducted in nine schools (100%), one orphan asylum (100%) and in 11 pre-school institutions (100%) on a total area of almost 3000 m^2. Three microdistricts of the city were landscaped with a total area of almost 85 hectares. The pond in the children park was cleaned and 24 thousand m^3 of radioactively contaminated soil were removed. A new modern solid domestic waste landfill was built and commissioned and other measures were taken.

Social protection. Every year, almost 3,000 children receive improved nutrition in

schools and pre-school institutions and 150 children are rehabilitated outside the city and in local camps. Hospitalized patients are provided with additional food. A part of the cost of medicines is refunded for more than 9 thousand requests from seriously ill patients. Dental prosthetics have been provided for 1.8 thousand people who have been working for more than 10 years at uranium mining enterprises, as well as to handicapables, labor veterans and other privileged categories.

Scientific novelty. Rehabilitation measures for minimizing the negative effects for

the environment and human health from the influence of radiation factors were scientifically substantiated, developed and implemented.

Practical significance. It has been shown that still we have a rare positive experience in increasing the radiation and social protection of the population of Zhovti Vody, Ukraine, who live in the area of influence of uranium industry facilities.

Key words: ecological safety, population, uranium-mining regions, state program,

nature protection measures

1. Introduction

Uranium was first found in the Czech Republic, later in Africa and the northwestern part of Canada. Until 1940, its mining was mainly concentrated in these countries. Currently, more than 200 uranium deposits have been discovered, which are located in 40 countries of the world [1, 20]. According to the World Nuclear Association (WNA), the main uranium deposits (96.5%) are concentrated in 15 countries of the world such as Australia (explored reserves of 466 thous. tons, which is about 20% of the world deposits), Kazakhstan (18%), Canada (12%), Uzbekistan (7.5%), Brazil (7%), Nigeria (7%), South Africa (6.5%), USA (5%), Namibia (3%), Ukraine (3%), India (2%) [2, 3, 9].

Mining of uranium ores in the USSR was developed in Tajikistan in 1926, when the Tabosharskoye deposit was discovered. Uzbekistan, Kyrgyzstan, Kazakhstan, Ukraine, Russian Federation and Bulgaria were also engaged in that. Nowadays a significant number of uranium deposits in these regions have been worked out, but environmental problems related to the legacy of the uranium industry remain. This is due to the fact that the main uranium production facilities (mines, pits, industrial sites of mining and chemical plants, hydrometallurgical plants, tailing dumps, etc.) were located in the territories which were subjected to technogenic pollution. For such territories, it is highly relevant to bring them into an ecologically safe state. However, the practical solution of these tasks is hampered by the lack of experience in planning and implementing environmental restoration projects and the lack of financial resources for the implementation of long-term rehabilitation programs [6, 12].

Research objection is improving the environmental safety of the population in the uranium mining regions of Ukraine on the basis of scientific substantiation, development and implementation of rehabilitation measures to minimize negative effects on the environment and human health from of radiation factors.

1.1. Research methods and adopted terms

The authors used radiometric methods (measurement of the exposure dose and γ-radiation intensity, measurement of the radioactivity of γ – and β – radiation, measurement of the exposure dose rate of γ – radiation, determination of the absorbed dose of the γ – radiation in the air, natural radionuclides analysis); statistical and mathematical research methods using integrated systems approaches. Radioecological studies included measurement of the exposure dose rate (EDR) of γ – radiation beyond the network of 100x100 m and 20x10 m (pedestrian gammagraph) in a volume of 40 km^2; soil analysis for radionuclide content; water sampling for radium and uranium content; determination of total α– and β – soil activity; determination of radon concentration in residential premises [5, 7];

Radiation safety is a set of measures ensuring the safety of work with radioactive substances and other sources of ionizing radiation. The radiation safety system solves two functional tasks, namely, creating an effective radiation monitoring system and reducing the irradiation level to regulated borders (based on a set of design, technical, medical, sanitary, and hygienic measures).

1.2. Instrumentation

The following instruments and equipment checked by state bodies of metrology and standardization of Ukraine were applied to perform radiation survey of the territory and residential premises in Zhovti Vody: dosimeter DBG–06T, radiometers SRP–88N and IRM, gamma-spectrometer SGS (LP – 4900B), AlphaGUARDPQ2000 radon monitor, a set of measuring instruments KSIRA – 2010Z, etc. manufactured by M/s Positron GmbH and M/s Tetra (Zhovti Vody, Ukraine) together with M/s Genitron GmbH, (Frankfurt am Main, Germany) and others [8].

2. Discussion and evaluation of research results

On the territory of the regions located in the zone of influence of six CIS countries (Russian Federation, Kazakhstan, Ukraine, Uzbekistan, Tajikistan and Kyrgyzstan), there are eight mining and metallurgical plants for the mining and processing of uranium ores, including:

In Russian Federation. First of all, these are the housing estates of Chita Region located in the zone of influence of the Priargunsky Industrial Mining and Chemical Union (PJSC PIMCU, enterprise of ARMZ Uranium Holding, Krasnokamensk) established in 1968, which today is the largest uranium mining enterprise of Russia; Lermontov Production Association “Almaz” (LPO Almaz, the North Caucasus); Zabaikalsky GOK (Pervomaisk), which is one of the largest mining enterprises in eastern Russia for mining, processing and concentration of antimony ore and obtaining the antimony metal (oxide); separate towns of Chelyabinsk, Tomsk, Novosibirsk and Krasnoyarsk regions, etc. [4].

In the Republic of Kazakhstan. Primary, this is the JSC Tselinny Mining and Chemical Plant (JSC TMCC, Northern Kazakhstan), the Caspian Mining and Processing Plant Production Association (CMPP Production Association), separate enterprises of Ust–Kamennogorsk (East Kazakhstan), Akchatau village, Karaganda region, etc.

In the Republic of Uzbekistan. Here one can single out housing estates in the zone of influence from the Navoi Mining and Metallurgical Combinat (“NMMC”) with the center in Navoi.

In the Republic of Tajikistan. Housing estates in the zone of influence from the production association Vostokredmet (PA Vostokredmet) should be mentioned.

In the Republic of Kyrgyzstan. Villages in the zone of influence from the production association Yuzhpolimetal (PA Yuzhpolymetal) are interesting for this study.

In recent years, the IAEA's international technical cooperation programs (projects KEK/0986 and KEK/30Sh), UNDP, EurAsEC, etc. aimed at assisting for the implementation of rehabilitation projects have been actively developing at the uranium production facilities of EU countries. Some activities are also carried out within the framework of the World Bank programs (Mailuu-Suu, Kyrgyzstan), ISTC (Kaji-Sai, Kyrgyzstan), OSCE (Taboshar, Tajikistan), TACIS (Lermontovo, North Ossetia-Alania, Russian Federation). The effectiveness of their implementation depends largely on the availability of relevant national environmental safety strategies, standard requirements and regulatory mechanisms, as well as experience in managing such projects in accordance with international standards.

In the EU countries, all rehabilitation projects assumed that landscapes at the site of the former uranium facilities should be partially restored to a socially acceptable level of comfort for the population living in the adjacent territories. For example, during the remediation of the facilities of the Wismut enterprise in Germany, the task was not only to bring the uranium production waste to a safe condition, close old mines and clean up the territories, but also to fully restore all industrially damaged landscapes [6]. Today, this program launched in 1990 is almost complete. According to various estimates, €3-5 bln. was invested in it and a significant amount of funds was spent on social transfers and the restoration of the environment well fitting into the landscape of the adjacent territories (Fig. 1).

2.1. Development of the uranium industry in Ukraine

First uranium ore mining began at the Pervomaiskoe deposit in 1948 by the Leninruda Trust (Pervomaiskoe Mine Administration of the Krivbassruda Production Association, Severnaya Mine) and the Zheltorechensk deposit of Zhovti Vody (1951). Olkhovskaya, Severnaya-Drenazhnaya, Kapitalnaya, Novaya, Novaya-Glubokaya, Yuzhnaya-Ventialiacionnaya mines, the uranium raw material processing plant (GMZ), the sulfuric acid plant (SAP) and a number of miscellaneous facilities are located in Zhovti Vody. Since the Zheltorechensk deposit started to operate, two open-pit mines, namely, Gabaevsky and Veseloivanovsky, four tailing dumps such as a worked out limonite pit (LP); gullies – Shcherbakovskaya (Fig.2), Razberi and Ternovskaya, as well as the collapse sinkhole have been appeared as a result of underground mining of iron ore deposits with systems including forced caving of ores and host rocks. The mining of ores in mines and pits has led to the formation of dumps of waste rocks and ores, which are out of balance, according to the content of the useful component, and disturbance of fertile lands, which today are partially reclaimed, in particular, KBZH (Fig.3), dumps of Olkhovskaya, Severnaya-Drenage, Kapitalnaya, Novaya mines, etc. [7, 9].

The uranium industry of Ukraine is concentrated mainly in the Dnipropetrovsk and Kirovograd regions and is represented by three operating mines of SE VostGOK (Ingulskaya (Fig. 4), Smolinskaya and Novokonstantinovskaya). These regions are located on the Ukrainian crystalline shield, the geochemical composition of which throughout the massif has a high content of natural radionuclides (NRN) of the uranium-radium and thorium series. When conducting mining and primary technological processing of uranium raw materials, they adversely affect the environment and people [15].

One of the first enterprises in the former USSR for processing of uranium raw materials was PA Pridneprovsk Chemical Plant (hereinafter PA PCP) in Kamenskoe, which was commissioned in 1947 and since 1991 has ceased uranium production. Tailing dumps of uranium production were left: on the territory of the plant – Zapadnoye, Tsentralny Yar and Yugo-Vostochnoe; outside the plant territory – Dniprovskoye, Sukhachevskoe with sections 1 and 2; storage Baza C (Fig.5). During the liquidation of the plant, a number of hazardous facilities contaminated with radiation were destroyed, looted and partially dismantled and not all tailing dumps were brought into an environmentally safe state in accordance with the current regulatory and legal requirements for the diversion of the former uranium production facilities [6]. This led to the creation of radioactive contamination zones within a large area of the Kamensk industrial-urban agglomeration (Table 1) [5, 8].

2.2. Radiation situation in the initial period of the uranium deposit development

The problem is that due to lack of knowledge, absence of reliable radiometric equipment, effective radiation monitoring instruments and systems, the legal framework for handling radioactive wastes. Some rocks containing radioactive materials were illegally used in the construction of roads, sidewalks, houses and other social infrastructure facilities (preschool institutions, secondary schools, Zhovti Vody Industrial College, etc.). Such radioactive materials were found in most of the surveyed domestic buildings and courtyards of the town sector in the form of spots (in foundations, bedding inside and outside the premises). Moreover, in many cases, materials used in mines and GMP such as wood, metal, etc. were applied during construction (Fig. 6) [7, 9, 13, 14].

Table 1. Characteristics of main tailing dumps PA "Pavlograd chemical plant"

Facility	Operation period	Area, ha	Waste weight, mln. t	Amount of waste, mln.m^3	Total activity, thous. Bq
Tailing dump: Западное	1949–1954	6,0	0,77	0,35	180
Tsentralnyi Yar	1951–1954	2.4	0.22	0.10	104
Yugo-Vostochnoe	1956–1980	3.6	0.33	0.15	67
Dneprovskoe (D)	1954–1968	73.0	12.0	5.9	1400
Lanthanium fraction	1965–1988	0.06	0.0066	0.0033	130
Sukhachevskoe: Section 1	1968–1983	90.0	19.0	8.6	710
Section 2	1983–1992	70.0	9.6	4.4	270
Storage: Blast Furnace No 6	1978–1982	0.2	0.04	0.02	330
Base C (former storage of uranium ore)	1960–1991	25.0	0.3	0.15	440

The technogenic γ-background for Zhovti Vody is 1.7-44 μSv/hour (from 200 to 5000 μR/hour), with background levels of 0.03 μSv/hour (3.5 μR/hour) and with radon activity in residential premises up to 1600 Bq/m^3, which is 16 times higher than the standard and 3.5% of the population only due to external γ-radiation obtain an annual radiation dose of 4.5 to 30.7 mSv, while a standard is 1 mSv/year. Such an external exposure determines a high ($p < 0.05$) specific activity of uranium isotopes (234U, 238U) in the kidneys of citizens (17.1 ± 10.7 and 13.5 ± 9.6 mBq/sample).

A separate problem is caused by radon, which is a radioactive, inert, odorless and colorless gas generated during the decay of radium-226 containing in the uranium series. Depending on the nature of its generation, this element has a different half-life period: radon-222 – 3.8 days, and radon-220 (Toron) – 55 s. The dependence of the volumetric activity of radon in the air on the distance for the tailing dump of the Shcherbakovskaya gully Zhovti Vody industrial site is shown in Fig. 7 [5].

Radon spreads through the pores (cracks) of the soil, rocks or ores and can penetrate into the air of residential premises or the atmosphere. The main source of radon in the air of the premises is the soil under the building and construction materials mined in the deposits (crushed stone, gravel, sand, rubble and sawn stone, cement and brick materials), industrial by-products, as well as industrial wastes used for their production (ash, slag, etc.). Experts confirm that today the main contribution to the population exposure dose is made by natural radionuclides of the uranium and thorium series, besides, radon and its decay products, the presence of which can be detected only with the help of special devices, play a decisive role. Radon can be accumulated in the premises of domestic buildings, schools, offices and other buildings, as well as in the mine openings. It easily passes through a layer of soil, penetrates into buildings and structures through cracks and cavities in the floors and lower parts of the walls. In hermetically-sealed, unventilated premises, radon concentration can reach significant values and pose a potential hazard to human health.

Thus, when choosing protective measures in existing buildings, two factors should be taken into account. ***First,*** the possibility of reducing the radon activity in the air of the building to standardized values. ***Second,*** the cost of carrying out anti-radon measures should be single [12].

2.3. Radiation and social protection of the city population

Considering the national importance of the production of uranium raw materials, Ukrainian Government adopted a number of special regulations. In particular, in 1995, the basic "State Program of Measures for Radiation and Social Protection of the Population of Zhovti Vody, Dnipropetrovsk Region" was adopted, which was for ***1996-2005*** (hereinafter ***the Program***: Resolution of the Cabinet of Ministers of Ukraine ***dtd. June 8, 1995 No. 400***), which was most fully cited in [7–9, 13–15]. It consists of two sections. *The first is radiation protection of the population* provides activities that have a long-term nature, namely, creation of a local diagnostic and rehabilitation center (LDRC), rehabilitation of city residents, procurement of necessary medical equipment and medicines, construction of new houses for people displaced from radiation-contaminated areas and the implementation of anti-radiation measures, landscape gardening, clearing the estuary of the Zheltaya River within the city area, assessment of the pollution impact on the health of residents taking into account the long-turn effects, creation and implementation of an environmental system including radiation monitoring in Zhovti Vody. *The second* is *social protection of the population*, which provides measures for the social protection of the population, the provision of compensation and benefits to certain categories of citizens including children.

2.4. Measures to reduce gamma-radiation and radon concentrations in premises

According to the current Sanitary Rules for the Liquidation, Conservation and Re-engineering of Enterprises for the Mining and Processing of Radioactive Ores (SRLCR – 91), the dose rate of external gamma radiation at a height of 1 m above the surface of the reclaimed (decontaminated) site should not exceed 20 μR/h above the natural background. With assumed background level of 20 μR/h, the exposure dose rate (EDR) of the decontaminated areas should not exceed 40 and on the ways – more than 60 μR/h. Contaminated soil, which is located in residential premises, is removed to a depth of 0.2 m. Sections of vehicle driveways with an increased background are dug out to the underlying soils and then removed (asphalt concrete pavement and bases). Spotted local anomalies are taken away and transported to the burial site (tailing dumps). All works are carried out with mandatory dosimetry control by a special building organization that has the means of small-scale mechanization. Disturbed areas are restored by replacing soil and road surfaces and then landscaped.

Reducing the concentration of radon in the air of the premises provides the development of each house based on its space-planning and design solutions, radon concentration and carried out after the removal of anomalous inclusions from their structural elements. These works are divided into three types: ventilation, insulation and combined.

The anti-radon measures were carried out in separate premises of the Zhovti Vody Industrial College, the Scientific and Technical Center for Decontamination and Integrated Management of Radioactive Wastes and Ionizing Radiation Sources (STC IMRW), the reconstructed house on Parkovaya Street, 18 for residential and individual kindergartens of the city (Zhovti Vody, Ukraine). As an example, we can consider anti-radon measures taken in one of the office premises, where the radon volumic activity measured during 2 days on weekends ranged from 650 to 700 Bq/m^3. The source of radon entry into the room was the heat network duct (pit with dimensions of 1.5x1.5x1.5 m). The anti-radon measures were as follows: filling the bottom of the heat network duct from the outside of the building with a layer of clay to a depth of about 1 m and its further compaction; sealing the heat network input through the building foundation; concreting the bottom of the pit. As a result of the implementation of these measures, the radon volumic activity in the building was reduced by 5–6 times and amounted to 110–120 Bq/m^3.

Measurements of volumic activity of radon – 222 in the rooms of the building were carried out by the method of passive sorption of activated carbon. 2-3 capsules with activated carbon were placed at different points in the inspected premises, the doorways of which were previously covered with plastic wrap at a distance of at least 1–3 m from possible sources of radon inflow (walls, floor, ceiling, soil, etc.). Capsules were preliminary annealed and the background values were measured with radiometer IRM–1. The exposure time of the capsules in the premises was at least 2 days. After ending this period, these capsules were removed, sealed, and after holding for 3 hours to achieve radioactive equilibrium, their radon – 222 volumic activity was measured by using radiometer IRM–1 having a scintillation detection unit with 80 x 80 mm crystal placed in lead protection with a wall thickness of 5-7 cm.

2.5. Social and welfare directions of city area remediation

This landscaping of the city's territory is supposed to be carried out by planting trees and bushes resistant to increased gas pollution and dustiness, which are natural radionuclide sorbents (chestnut, ash-leaved maple, lombardy poplar, large-leaved linden, oak, warty birch and shrubs, namely, lilac, smoke-tree, Bumalda spirea, honeysuckle and ornamental plants such as rose, spruce, etc). Simultaneously with the landscaping of the city's territory, it is planned to create protective forest belts in sanitary protection zones of environmentally hazardous industrial facilities.

3. Execution of works

Radiation Protection. The radiation situation in the city has been improved and citizens living in radiation-dangerous apartments and houses have been provided with housing. A house with 79 apartments for migrants from radiation-contaminated areas of the city was built and commissioned. All sources (3973 units) of ionizing radiation with a total activity of more than 15 thousand curies were removed from the city's territory. The most polluted parts of the city with an area of more than 6 hectares were remediated. Anti-radon activities were conducted in nine schools (100%), one orphan asylum (100%) and in 11 pre-school institutions (100%) on a total area of almost 3000 m^2. Three microdistricts of the city were landscaped with a total area of almost 85 hectares. The pond in the play park was cleaned and 24 thousand m^3 of radioactively contaminated soil were removed. A new modern solid domestic waste landfill was built and commissioned as well as other measures were taken.

Social protection. Every year, almost 3,000 children have improved nutrition in schools and preschool institutions and 150 children are rehabilitated outside the city and in local camps. Hospitalized patients are provided with additional food. A part of the cost of medicines is refunded for more than 9 thousand requests from seriously ill patients. Dental prosthetics have been provided for 1.8 thousand people who have been working for more than 10 years at uranium mining enterprises, as well as to handicapables, labor veterans and other privileged categories. Financial aid have been given for the treatment of 8.5 thousand citizens. In the local treatment and rehabilitation center, about 800 residents (average per year) are recovering and undergoing rehabilitation after illness. 123 units of complex medical equipment were bought and funding for medicines was increased to a total amount of almost 5 million UAH. The project was developed and the reconstruction of the building of the modern diagnostic department and the department of rehabilitation treatment was started, as well as other activities were performed.

4. Development of the program for radiation and social protection of the city population

Due to insufficient budgetary financing, the Government of Ukraine has extended the above ***Program*** twice with the relevant resolutions of the Cabinet of Ministers dtd. May 5, 2003 No. 656– for 2003–2012 and dtd. June 25, 2012 No. 579 — for 2013–2022. Increasing the radiation and social protection of the population envisages the solution of the following main tasks with general budget financing of more than 200 million UAH:

– ***Create and ensure*** the functioning of continuous environmental and radiation monitoring system of the city. To provide this, it is planned to build, equip and commission a special laboratory;

– ***Bring*** the radiation background in residential, administrative buildings and structures to the level determined by "Radiation Safety Standards of Ukraine" (**RSSU-97**). To this end, 160 houses and facilities are planned to be examined for the radon content;

– ***To carry out*** a complex of works on the remediation of the polluted area of the city in order to reduce the radiation dose effect to the population. To this end, about 23 hectares of disturbed and polluted lands will be reclaimed until the end of 2017. Until 2022, anti-radon measures will be carried out in the city buildings on an area of 13.4 thousand square meters and 30 hectares of protective forest belts will be planted. In addition, by 2022 it is planned to clear the bed of the Zhovta River;

– ***To increase*** the social protection of the population living in areas with high radiation background. For this, annual compensation for the cost of: feeding more than 6 thousand of children of preschool and school age; part of the cost of feeding patients who are hospitalized to the city medical institutions; part of the cost for feeding of children up to 1 year old; provision of food in infant-feeding center for children under 1 year old; part of the cost of medicines bought as per doctor prescription for children of preschool and school age, pregnant women, women in labor, handicapable groups, labor veterans and other preferential categories; free dental prosthetics for preferential categories, as well as for people whose work experience in enterprises for the extraction and processing of uranium raw materials is more than 10 years; partial compensation for medical care provided outside the city and region (up to 12 people annually) are is provided. Providing financial aid to citizens for treatment and rehabilitation because of the increased radioactive background of the city (annually up to 430 people). Improving the quality of social services for 180 disabled citizens. In total, the budget for this activity is 700 thousand UAH;

– **To bring** the department of functional diagnostics and the of rehabilitation treatment department in line with modern requirements. For this purpose, it is planned to carry out the reconstruction of the functional diagnostics department (1.2 thousand square meters), and the reconstruction of the rehabilitation treatment department shall be provided by 2022 (3.5 thousand square meters);

– ***To improve the health*** of citizens in the department of rehabilitation treatment. To this end, annually 900 citizens are envisaged to recover here;

– **To provide** medical equipment and medicines for its total functioning. To do this, it is planned to purchase 377 units of medical equipment until 2022.

5. Evaluation of the results obtained.

Enterprises for the mining and processing of uranium ores have a radiative effect on the environment (radon and short-lived by-products of its decay, gamma radiation, long-lived alpha nuclides, aerosols, etc.), they require carrying out of organizational, technical, and special activities to reduce the negative impact on the environment and people, radiation and social protection of the population living in the zone of impact of radiation-hazardous objects. To perform this, the State Enterprise UkrNIPIpromtekhnologii developed and implemented the sectorial "Program for improving the radiation condition of uranium industry facilities and their regions", which have been approved by the Ministry of Fuel and Energy of Ukraine, as well as

the Program for Zhovti Vody. Together with Ukrainian Research Institute for Environmental Problems, Kharkov, Ukraine, priority measures were developed and implemented in accordance with the State Program for the Liquidation of Hazardous Facilities of Production Association Pridneprovsk Chemical Plant for the period of 2005–2014 (Resolution of the Cabinet of Ministers of Ukraine, November 26, 2003; No. 1846), which, due to insufficient budget financing has not been fully implemented yet. In cooperation with the Institute for Environmental Management and Ecology of the National Academy of Sciences of Ukraine, Dnipro, Ukraine (research supervisor, corresponding member of the National Academy of Sciences of Ukraine A. G. Shapar), priority activities were developed according to the State Program for Sustainable Development of the Region of Uranium Mining and Primary Processing for the period of 2006–2030 (Resolution of the Cabinet of Ministers of Ukraine dated December 16, 2004, No. 1691), which, also because of insufficient budget financing, was not fully implemented and was canceled by a decision of the Government in 2011 [7–9, 11].

6. Direction of further research

Radiation impact on the environment and people was assessed according to the research program of the Department of Ecology and Environmental Protection of the Central Ukrainian National Technical University (state registration No. 0108U008325 "Research and assessment of the level of radiation pollution of the environment in the area of impact of the uranium mining industry (on the example Ingulskaya mine of SE VostGOK). In particular, on the area of the sanitary protection zone (SPZ) of this mine (Kropyvnytskyi, Ukraine), dosimetric measurement of EDR of radiation was carried out around the perimeter of each waste dump and off-balance ores at the daylight surface near its base at a distance of 2 –3 m from the dump (see. Fig. 4, b). On the site where surface run-off is observed, the background radiation averages to 0.3 µSv/h and in some places reaches a level from 1.07 to 1.59 µSv/h, which is 8–13 times higher than the allowable and reference level (Table 2). This indicates the radiation contamination of the area at the dump bottom and the impossibility to use this area in other economic purposes. In addition, there is a danger of spreading of radioactive dust from the dumps by natural (wind, rain and melt waters) and man-made (vehicle) factors. To confirm the above arguments, a dosimetric study of the Ingul River bank, the boundaries of the sanitary protection zone (SPZ) with the adjacent territories, road haulage and roads of the closely located settlement were carried out. A dosimetric study of the riverbank was performed in order to detect the radioactive contamination by surface run-off of rain and melt water infiltrated through the dump containing natural radioactive nuclides (NRN). EDR measurement was made on the left bank at a distance of 1–2 m from the river downstream. The part of the river flowing through the territory of SPZ of the indicated mine was investigated [16–18].

Table 2. EDR near the dumps of Ingulskaya mine

No of dump	Base area of dump, m^2	Volume, thous. m^3	EDR value, µSv/hour		
			Maxi-mum	Average	Mini-mum
1	23688	315	4.7	1.05	0.13
2	26324	448	3.87	1.12	0.17
3	15525	160	4.16	0.66	0.11
4	16715	132	10.83	0.93	0.2
5	19283	410	12.53	1.26	0.19
6	15341	250	2.16	0.94	0.15
7	40513	600	11.00	1.04	0.21
8	1540	250	6.99	1.08	0.29

Thus, the analysis shows that the effectiveness of the implementation of rehabilitation measures largely depends on the availability of relevant national environmental safety strategies, regulatory requirements and mechanisms, as well as experience in managing such projects in accordance with international standards [19-21].

7. Conclusion.

1. ***It is shown*** that nuclear industry enterprises have a radioecological impact on the environment and population. To prevent the harmful effects of radiation pollution on the human body, it is necessary to establish systematic sanitary inspection of NRN and heavy metals content in food and edible products.

2. ***It was noted*** that with the help of IAEA projects and bilateral cooperation with Norway, Sweden and the USA in Ukraine, Russian Federation, Central Asian countries, measures are being taken to harmonize and improve regulatory requirements and criteria aimed at supporting the preparatory phase of planning and implementation of rehabilitation programs.

3. ***It has been established*** that the excess of the standard level of equivalent equilibrium radon activity (50 Bq/m3) in certain premises is due to its emission from the underground space and the input channel of the external heat and water supply network, internal distribution ducts of the heating network. Backfilling of the heat network duct from the outside of the building with a clay layer to a depth of 1 m and its compaction, sealing the heat and water supply network through the building foundation and

pouring the pit reduce the radon volumic activity in the room by 5–6 times. Complete sealing of the floor with plastic wrap or other materials or isolation of individual slots and places for supply lines, as well as isolation of the soil surface with a concrete coating together with plastic wrap or just concrete reduce the radon activity in the air up to two times.

4. The system of radiation monitoring of uranium facilities on the basis of instruments and automated systems of the new generation is ***recommended***: radiometer RKS–02 "Kordon"; radiometer "RUG – 2001"; multichannel installation "Puls–1m"; radiometer RZBA – 06; radon monitor "AlphaGUARD"; complex "KSIRA – 2010Z"; autonomous system "SkyLINK"; gamma monitor "GammaTRACER", etc. The radiation monitoring system includes four observation posts on the Zheltaya and Zelenaya rivers, observation wells on GMP territory, which allows specifying the area of groundwater pollution and the distribution of water-bearing layers.

The work was prepared with the assistance of specialists from leading research institutes and centers of Ukraine, the city community, local government authorities (heads of city administration of different election periods), deputies of the city and regional councils, Dnipropetrovsk and Kirovograd regional state administrations, people's deputies of Ukraine, ministries, departments, Cabinet of Ministers Ukraine and others.

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