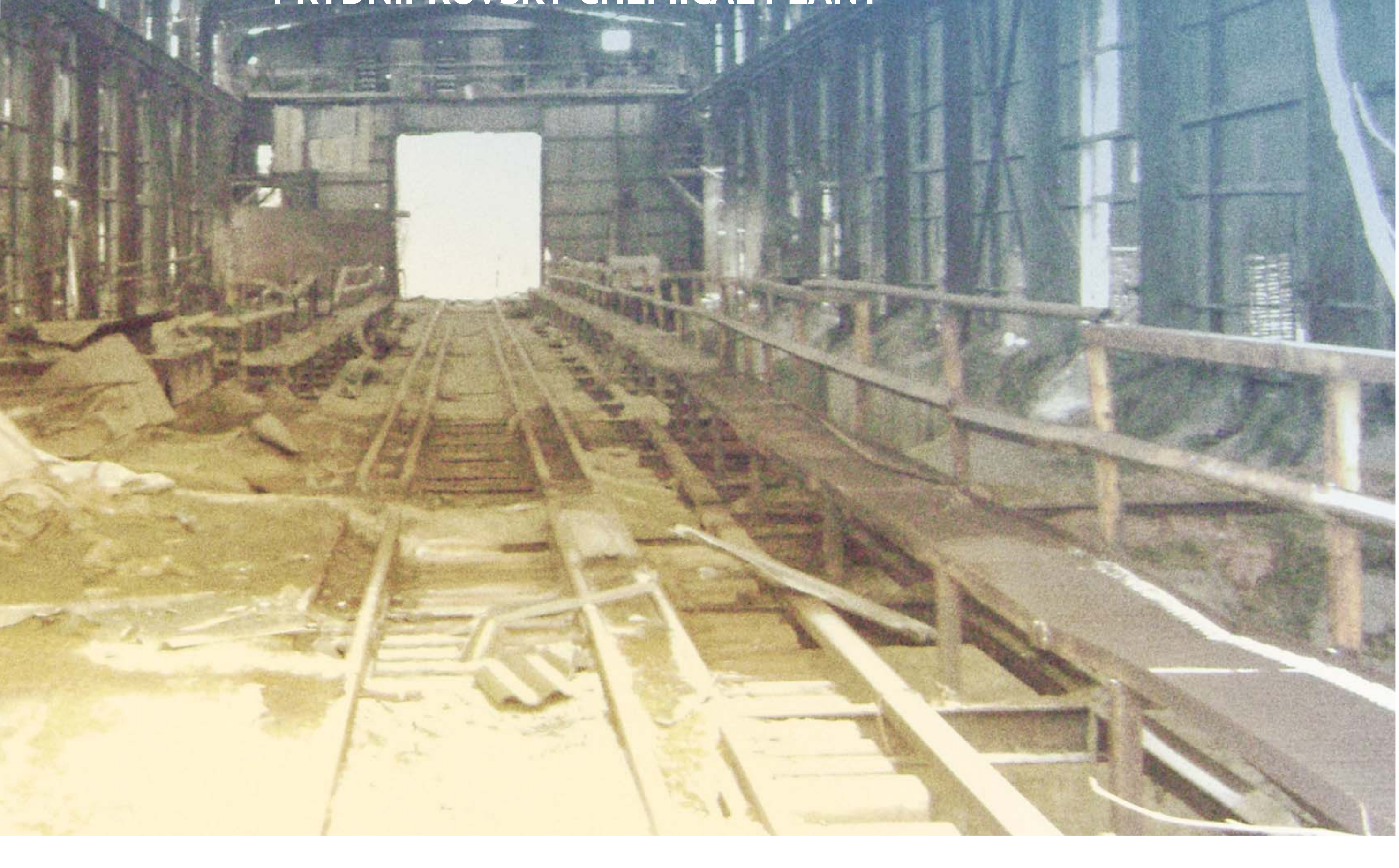
BELLONA

THE PRYDNIPROVSKY CHEMICAL PLANT – UKRAINE'S URANIUM HERITAGE

2020

SURVEY REPORT ON THE ACTIVITY HISTORY AND THE MODERN STATE OF THE FORMER PRODUCTION ASSOCIATION "PRYDNIPROVSKY CHEMICAL PLANT"



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CONTENT

LIST OF ABBREVIATIONS AND DESIGNATIONS

GDP	— gross domestic product
HEI	— higher education institution
PA PCP, PCP	— production association ”Prydniprovsky Chemical Plant”
ESW	— engineering staff worker
HEPS	— hydroelectric power plant
MPC	— the maximum permissible concentration
SC	— state company
BFR-6	— Blast furnace repository No 6
SC ”38th MITU”	— State company ”38th military engineering and technical unit”
EC	— The European Commission
IAEA	— International atomic energy agency
SRSU-97	— Standards of radiation safety of Ukraine (1997 р.)
BSRU-2005	— Basic Sanitary Rules for Ensuring Radiation Safety of Ukraine (2005)
PJSC DCCP	— Public Joint Stock Company ”Coke and Chemicals Plant”
PJSC DMC	— Public Joint Stock Company ”Dniprovskyi Metallurgical Combine”
GRI	— gamma-radiation intensity
SPZ	— sanitary protection zone
USSR	— Union of Soviet Socialist Republics
USTC	— Ukrainian Science and Technology Center
FSBI SSC FMBC named after A.I.Burnazian	— Federal State Budgetary Institution “State Scientific Center Federal Medical Biophysical Center named after A.I. Burnazyan ", Federal Medical and Biological Agency of Russia
BMU	— Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit (Federal Ministry for the Environment, Nature and Nuclear Safety, Federal Republic of Germany)
IAEA	— International Atomic Energy Agency
JSO	— Joint Support Office in Kiev
MSK-64	— 12-point scale of earthquake intensity of Medvedev – Sponheuer – Kárník
PC_B^{inhal}	— permissible concentration of radionuclides in the air for category B (population)
PC_B^{ingest}	— permissible concentration of radionuclides in drinking water for category B (population)
SWOT, SWOT-analysis	— Strengths; Weaknesses; Opportunities ; Threats

FOREWORD

This review, entitled "THE PRYDNIPROVSKY CHEMICAL PLANT – UKRAINE'S URANIUM HERITAGE OF UKRAINE", which was prepared by Ukrainian experts in cooperating with Bellona, an international environmental association.

The main activity at the production association "Prydniprovsky Chemical Plant" (Dniprodzerzhynsk, from 2016, Kamianske) between 1949 to 1991 was the processing of uranium raw materials for the purposes of obtaining a concentrate of natural uranium for use in the military-industrial complex of the former USSR. Due to the collapse of the Soviet Union and the subsequent decentralization processes, the "Prydniprovsky Chemical Plant" (PA PCP) stopped operating without complying with the requirements to liquidation, conservation or its conversion as a uranium object.

In conditions of insolvency of PA PCP, a restructuring procedure for the plant was introduced. It took place against the background of its bankruptcy, with the subsequent privatization of individual objects and their commercialization. In some radiation-contaminated territories and in the former plant workshops, various economic activities were introduced, which were not typical for the uranium object and production or commercial activities were carried out without observing the basic requirements to radiation safety. The decommissioning of the main facilities of the former uranium cycle by means of dismantling of the most valuable equipment and decontamination of some buildings and territories was largely motivated by economic interests, without due regard to compliance with radiation safety requirements of employees and environment.

In addition, separate state-owned enterprises, such as 'Zirconii', 'Smoly', 'Amofos', 'Nitrofos', were established. The compliance with radiation safety requirements of employees and environment in these enterprises was entrusted to their management bodies.

In 2000, a specialized state-owned company 'Barrier' was established to ensure the safety of activities in the territory and facilities of the former PA PCP. Such uranium facilities, as 5 tailing storage facilities with uranium ore processing wastes and some most polluted industrial buildings (workshops) used in the uranium production chain were signed off to this company.

Bellona, a non-governmental organization with pragmatic goals, is constantly searching the ways to prevent radiation and nuclear threats. The organization places special emphasis on helping contain the nuclear and radiation heritage left by the Soviet Union. Of particular interest to the organization are nuclear and radioactive waste repositories, as well as nuclear power plants that have run for their engineered lifespans, which have not yet been decommissioned. Major problems have arisen in industrial territories that have yet to be rehabilitated.

The aim of this report is to draw attention of the national and international institutions to one of the most problematic objects of the Soviet Union's nuclear heritage in Ukraine;. WE here analyze the situation and suggest proposals for a roadmap toward eliminating hazardous objects at the Prydniprovsky Chemical Plant and rehabilitating all the enterprise's territory.

Preparation of the review involved the wide use of materials from technical reports on the European Commission project U4.01/10G "Development of a method (strategy, technology) of rehabilitation of the areas affected by uranium production of the former uranium object 'Prydniprovsky Chemical Plant'" and project U4.02 16B1 "Implementation of urgent measures on Prydniprovsky chemical plant". The materials were used with the permission of the state-owned company 'Barrier' as the beneficiary of the projects.

1. BRIEF HISTORICAL REFERENCE OF PA PCP

1.1. BRIEF HISTORICAL REFERENCE OF PA PCP

Former production association "Prydniprovsky Chemical Plant" was established in accordance with the Decree of the USSR Council of Ministers No 2800-890 of August 8, 1947 and the Order No. 906 of the First General Directorate (FGD) of the USSR Council of Ministers of 14.08.1947.

According to the Decree of the Council of Ministers of the USSR No. 5744-2162 of December 27, 1949, the plant was transferred from the FGD to the Second General Directorate (SGD) of the Council of Ministers of the USSR. According to the decision of the Special Committee (Minutes No. 73 of February 18, 1949), plant No. 906 was given the open name 'Prydniprovskyi office of Glavgorstroy', as well as 'Slag Fertilizer Plant of the Ministry of Chemical Industry (for local organizations). Later, the production of natural uranium concentrate was carried out under the names: Prydniprovsky Hydrometallurgical Plant and Production Association "Prydniprovsky Chemical Plant" (1966).

REFERENCE:

First General Directorate *(FGD) under the Council of Ministers of the USSR (1945-1953) – the authority of the USSR, which was entrusted with the question of securing the Soviet nuclear project. In fact, the FGD was a special branch of the defence industry. In 1953 enterprises and apparatus were transformed into the Ministry of Medium Mechanical Engineering of the USSR.*

Second General Directorate *(SGD) under the Council of Ministers of the USSR (1950-1953) – the authority of the USSR, which solved the problem of the creation of missile technology [2]. The SGD's task was to create a carrier rocket to transport nuclear charges to a target in the territory of a potential adversary.*

Special Committee of the Council of Ministers of the USSR*, informally called the Special Committee on the Use of Atomic Energy. It was a body established in the USSR 14 days after the atomic bombing of Hiroshima by order of the State Defence Committee No. 9887ss/op of 08/20/1945 in order to develop i short time nuclear weapons to maintain parity between the USSR and the US.*

The Ministry of Medium Mechanical Engineering of the USSR *(USSR MMME) is the central government body of the USSR, which was responsible for managing the nuclear sector of industry and providing for the development and production of nuclear warheads. It was formed on 26.06.1953 by the Decree of the Presidium of the Supreme Council of the USSR.*

The site for the plant was chosen based on the following conditions:

- availability of Pervomaysk and Zhovtorichensk deposits of uranium-iron ores at a distance of 100 km (discovered in 1927);
- availability of a metallurgical industrial complex for smelting uranium iron ores to produce iron and uranium enriched slag in the city of Dniprodzerzhynsk (the present name of the city – Kamianske);
- availability of a nitric-fertilizer plant that produced nitric acid and other reagents needed to obtain uranium concentrate in the city of Dniprodzerzhynsk;
- availability of specialists who know chemical technologies;
- availability of an extensive transport network.

PA "Prydniprovsky Chemical Plant" used to be a multidisciplinary processing plant in which:

- from 1948 to 1991 the processing of uranium ore and production of concentrates took place, in particular of uranium blast furnace slag (up to 1981);
- processing of uranium ore and production of concentrates was performed;
- since 1965 ion-exchange resins have been manufactured
- from 1974 to 1990 apatite processing was carried out to obtain rare earth elements and mineral fertilizers;
- Since 1982 zirconium-containing raw materials have been processed to obtain pure zirconium and hafnium compounds;
- Since 1991 North African phosphorus-containing raw materials have been processed for obtaining mineral fertilizers.

As of January 1, 1992, the number of industrial-production staff amounted to 7200 people, including about 1,000 people at uranium facilities.

Uranium ore processing was ceased in 1991 after the collapse of the Soviet Union.

According to the memories of the veteran of the nuclear industry A.P. Mukhachev, chairman of the Joint Council of Veterans of the PCP, a laureate of the State Prize of Ukraine, the choice of location for the construction of the uranium plant was determined based on the geography of the city location, availability of a nitrogen plant alongside (now PJSC "Dniproazot"), that produced the necessary chemical reagents.

The general view of the beginning of construction of the first stage of the plant can be seen in Fig. 1.

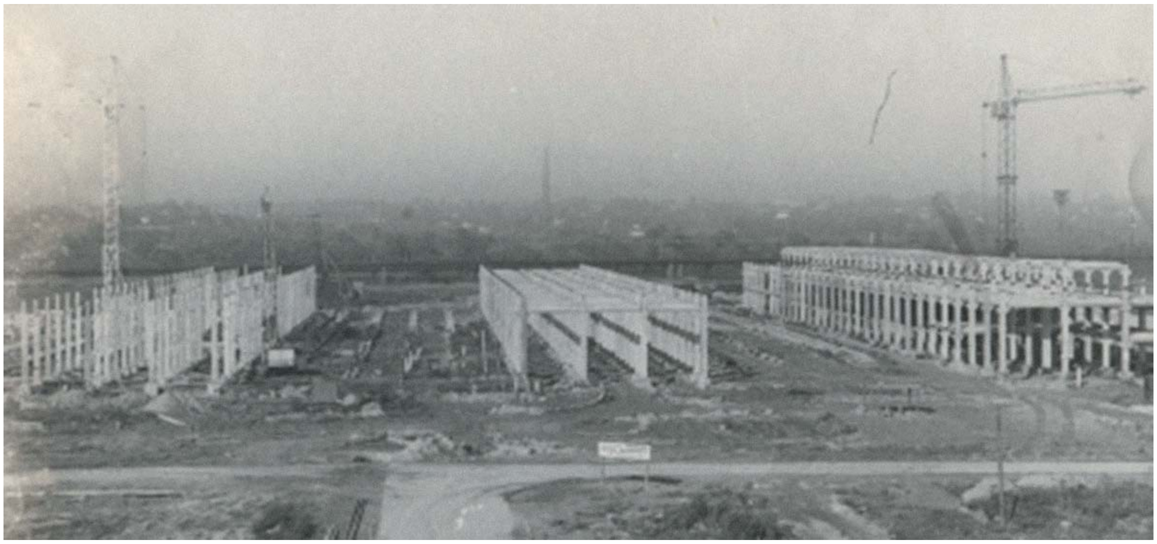

Fig. 1. Beginning of construction of PCP workshops (photo from the article 'Plant No. 906', newspaper 'Atomnik of Ukraine' № 36 (875) from 07/09/2017 by A.P. Mukhachev)

The following is a quote from the article.

“Uranium ore was discovered in 1946 in the Dnipropetrovsk region, in Kryvyi Rig at the mines 'Zhovta richka' and 'Imeny pershogo travnia', composed of rich iron ores. The construction of the plant was supposed to be finished by August 1948, that is, only in a year after the adoption of the Resolution of the USSR Council of Ministers. Initial capacity was determined at 50 tonnes of 40% of natural uranium concentrate per year with a further increase of up to 100 tonnes. All plans were based on real uranium ore reserves in the country. The plant was built in order to create nuclear weapons, that is, to use uranium for military purposes, because after nuclear bombs were dropped in Japan, the US monopoly has become threatening. On May 15, 1946, a special train arrived at Bagley Station, which brought 300 builders from the Ural. The builders were led by an engineer – major M.B. Oziransky. This event was the beginning of the history of the Prydniprovsky PCP Construction Department that played certain role in the establishment of the country's largest uranium industrial complex. Initially, the builders began the restoration of a nitrogen- mineral fertilizer pant destroyed during the occupation, the construction of the housing industry base. The number of construction workers reached 15,000 people, including prisoners and captured Germans.

The first raw material for uranium was slag smelted at the blast furnace of Dnipro metallurgical plant No.6 with a content of uranium from 0.5 to 1.5%. Construction of the plant was carried out from 1947 to 1954 in four stages, after which the reconstruction and expansion of production began.

The first product was released in December 1948, the first pilot batch -in February 1949, only 1,5 years after the beginning of construction. The plan of 1949 was successfully implemented! In terms of uranium production, there were also related products – nitrogen fertilizers, radium sulphate – for medical purposes and ammonia alum. The first technological scheme was nitric acid filtration scheme, proposed by the branch institute.

The slag processing scheme was time consuming, periodic, with large number of press filters. Uranium specialists were not trained at the HEI at that time, but ESW trainees were the first to work, the first workers were graduates of craft schools from Poltava and Lysychansk. They were the children of the frontline soldiers, they worked enthusiastically. No one knew at the time what radioactivity was, its dangers, and how to protect from it. This experience came later when medicine started treating sick staff.

In the shops of the second stage in 1951 processing (530 tons per day) of local and imported ores was started according to the acid-soda scheme, with the production of nitrous oxide and sodium nitrate, which became a permanent production of the plant. This made it possible to utilize nitric acid and prevent nitrates from flowing into Dnipro River. The first nitrate solutions were transferred to the nitrogen-fertilizer plant, where nitrogen fertilizers were produced from them."

1.2. Technologies for processing uranium raw materials and other chemical products on former PCPs

The production cycle of processing uranium raw materials and other types of hydrometallurgical and chemical products at the former PCP was multifunctional and very complex. It envisaged the use of over 150 buildings and industrial facilities located both in the southern and northern parts of the industrial site

About 30 PCP facilities (buildings, overhead utilities, pipelines, radiochemical facilities, tailings (tailing storage facilities) were used in the complex of uranium processing (ore transportation, temporary storage, wet and dry grinding, pipelines for the hydro transport of crushed materials between different buildings, the separation of radium and thorium, the production of uranium concentrate and the production of uranium oxide and industrial waste management).

Processes of uranium ores processing of by PCP were characteristic of technologies used in the former USSR, including grinding, hydrometallurgical processing, sorption, radiochemical separation, and purification of uranium concentrate from radium and thorium. Different types of uranium ores were processed. The scheme of uranium processing is shown in Fig. 2.

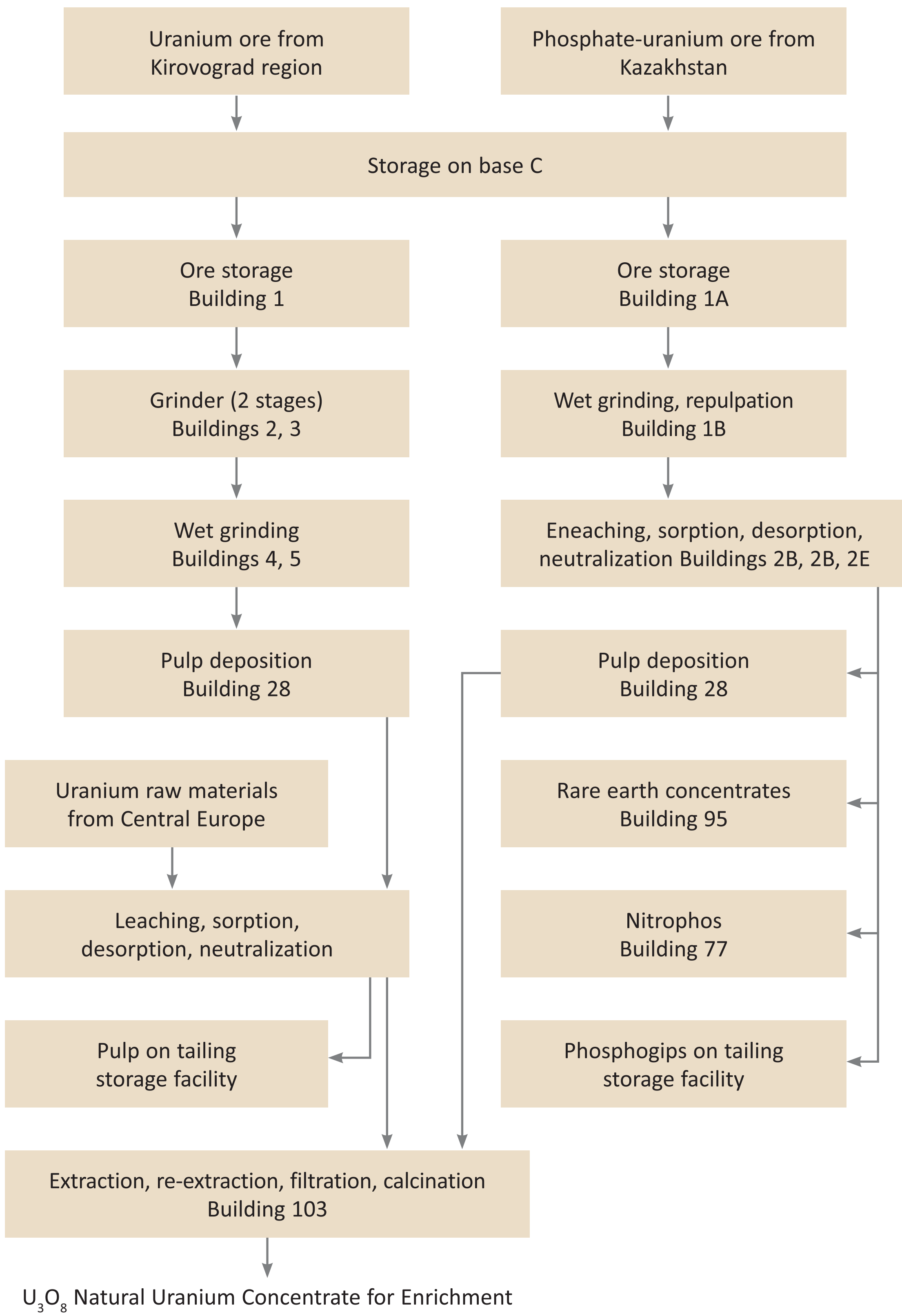

Fig. 2. Scheme of hydrometallurgical processing of uranium ores on PCP.

Mining of the ore was carried out to sand and sludge fractions with a particle size of 5 to 0.074 mm, which were subsequently transported for leaching and extraction of uranium. Sulfuric and nitric acids were used for leaching. Deposition and leaching were carried out in the premises of buildings No. 6 and No. 2B. The final production of the uranium concentrate took place in buildings No. 103 and No. 104. Concentration of the yellow cake was usually carried out in the chemical forms of ammonium ($(NH_4)_2 U_2O_7$) or other compounds of the chemical forms of uranium nitrate.

The final stage of extraction of uranium from ore used on PCP ended with calcination of yellow cake in the form of uranium oxide (U_3O_8) in Building No. 103. The process of extraction on PCP was based on ion-exchange sorption with pulp and, mainly, acid extraction processes at a hydrometallurgical plant. The waste after the extraction process was neutralized with chalk, alkali and transported by pipeline to the tailing storage facilities.

The products of radiochemical processing of blast furnace slag, such as sodium nitrate, were transported to the neighbouring 'Dniproazot' plant for further production of ammonium nitrate and nitrate. After leaching of uranium from phosphate ores and purification from iron, thorium and rare earth elements and discharge of phosphoric acid, materials in the form of phosphogypsum with high concentration of radium, thorium and other radioactive substances were transported to the tailing storage facilities of Sukhachivka and Dniprovskyi.

Low-concentration phosphoric acid compounds were used to produce nitro phosphate (fertilizers) and other various chemicals. The solid residues of crushed materials after the extraction of uranium from acidic solutions were neutralized with sodium bicarbonate in Building No. 6 and delivered to the tailing storage facility. The precipitates after decontamination of the solutions were delivered to the furnace (Building No. 112) and then transported to Building No. 6 for leaching of the secondary metal. Solid waste was also removed in the tailing storage facility. These wastes contain high concentrations of radium and thorium, as well as their decay products and toxic metals. The precipitations from the last cycle of sorption of rare earth elements contained a high concentration of actinides in the lanthanum fraction and were removed into a special storage on the territory of Sukhachivka tailing storage facility (Building 602 "Lanthanum fraction ").

1.2.1. Production volumes

By the early 90's, PCP was a large, multidisciplinary, modern enterprise in the former USSR. The maximum annual output was:

- concentrate of natural uranium from all sources of uranium raw materials 4000 tons;
- nitrophos and ammophos, sodium nitrate 650 thousand tons;
- rare earth elements 1.5 thousand tons;
- ion-exchange resins 4.5 thousand tons;
- 120 nuclear-pure zirconium 120 tons.

2. GENERAL CHARACTERISTICS OF THE PC INDUSTRIAL SITE

2.1. Location and infrastructure

The former production association "Prydniprovsky Chemical Plant" is located in the industrial area of Kamianske city (until August 2016 – the Dniprodzerzhynsk). This is a city of regional importance in Dnipropetrovsk oblast, it is the administrative centre of the Kamianske city council, which includes, in particular, the town of Karnaukhivka and the village of Svitle. City's coordinates: 48°31′44 ″ north latitude and 34°35′49 ″ east longitude.

The city is located in the central part of Ukraine 430 km southeast of Kyiv and 35 km from Dnipro regional centre.

The town of Kamianske is located on both banks of the Kamianske (formerly Dniprodzerzhynsk) reservoir in the middle course of the Dnipro river, below the dam of the Middle Dnipro Hydroelectric Power Plant. The main part of the city is located downstream of the HPP. The city’s area is about 138 km^2. The length of the city: from east to west is 22 km; North to South – 11 miles The population as of February 1, 2018, according to the Central Statistics Office in Dnipropetrovsk oblast – 241 288 people.

Residential areas account for 41% of the city area, while industrial and communal facilities account for about 18%. Industrial enterprises are located in the right-bank part of the city and are grouped into industrial zones.

Adjacent settlements:

- on the left bank of the Dnipro
- Kulishi village, Yelyzavetivka, Kurylivka town of Petrykivka rayon;
- on the right bank of the Dnipro – Aula town, Ukrainka village of Krynichansky rayon, Karnaukhivka town and Svitle village, subordinate to Kamianske city council.

Until recently, the industrial complex of the city covered 48 largest enterprises belonging to 10 different industries, mainly metallurgical and chemical industries, as well as mechanical engineering, construction materials, electricity, woodworking, foodstuff , textile production, printing and other industries. The largest industrial enterprises are: "Dnipro Metallurgical Plant", "Dniproazot", "Dniprovagonmash", "Bagleycox" and "Dnipro Coke Plant".

The former PCP consists of 2 industrial sites. The main industrial site is Kamianske (Dniprodzerzhynsk) site. Uranium processing facilities and related chemical redistribution facilities were located directly on this site. The second is Sukhachivka site, located to the southeast of the city, which consists of two uranium objects: the Sukhachivka tailing storage facilities (sections 1 and 2) and the former uranium ore deposit, the so-called Base C.

Kamianske site. It is located on the eastern outskirts of the city in an industrial area and covers an area of about 250 hectares. The site is divided into northern and southern parts both functionally and by radiation-contamination level. In the southern part, there are former shops, buildings and structures associated with processing of uranium ores. Contamination of the territory is extremely uneven; the highest levels of gamma radiation intensity are detected near the major technological buildings (103, 104, 2B) and tailing storage facilities (Zakhidne, Tsentalnyi Yar and Pivdenno-Skhidne, located in this part of the industrial site. Existing production facilities for the production of mineral fertilizers, ion exchange resins, auxiliary and other facilities are located mainly in the northern part of the industrial site. Gamma-intensity in this area, except for a small area in the eastern part, is observed at the level of the natural background (0.15–0.20 μSv/h). In the framework of the implementation of the European Commission project U4.01/10G "Development of a method (strategy, technology) for the reclamation of the territory of the former uranium object "Prydniprovsky Chemical Plant", the information about which is provided in section 6, a preliminary inventory of the availability of buildings and structures in northern and southern parts of the site was performed. Information about their current owners and the use of the facilities was received. Thus, in the polluted southern part of the site there were about 100 buildings and structures, in the north – about 60 buildings and structures. The majority of structures in the northern part of the site are used in production activities (production of mineral fertilizers, ion exchange resins, energy and water supply), and only few buildings (about 20) in the southern site are involved in production processes.

The infrastructure objects of Kamianske industrial site includes also Dniprovskyi tailing storage facility, located in a floodplain on the settling basin of the Dnipro river, at the distance of 0.8–1.2 km north of the PChP industrial site. The distance from the tailing storage facility to the river Dnipro is about 1 km. Konoplyanka river flows 0.6–1.0 km north of the PCP site and 50–100 m northwest of the Dniprovske tailing storage facility. Hemp flows into the River Dnipro downstream of the PCP site.

To the north of the Dniprovske tailings storage facility, there are slime tanks of the PJSC Dnipro Coke and Chemicals Plant (DCCP). Slime tanks and slug waste piles of the Dnipro Metallurgical Plant (DMC) are located to the east of the tailing storage facility. The general view of the PCP industrial site is shown in Fig. 3.

Sukhachivka site. The infrastructure of the former PCP includes the Sukhachivka tailing storage facility – sections 1 and 2, located 14.5 km southeast of Kamianske and 2 km northwest from Taromske. The so-called building 602 "Lantana fraction" with thorium enriched waste is located on the territory of section. According to the data which require clarification, containers with soil contaminated with caesium-137 (^{137}Cs) are placed in the Lantana fraction. This waste was generated as a result of the elimination of a radiation accident (depressurization of the capsule with an ionizing radiation source used for well logging). Near the Sukhachivka Tailing is Base C, the former uranium ore deposit containing residuals of uranium ores as well as contaminated soils. Radioactive contaminated structures of the dismantled blast furnace # 6 of the Dnipro Metallurgical Plant are also stored in this area. In 50's -80's, iron ore with high content of uranium was smelted in the blast furnace # 6 (BFR-6 Storage).

The general view of the Sukhachivka site is shown in Fig. 4.

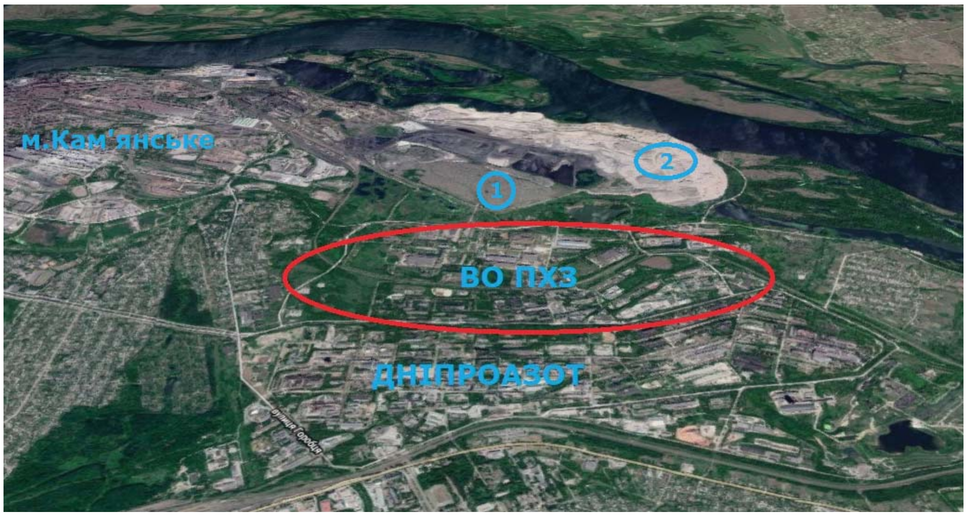

Fig. 3. PChP Industrial Site Placement Map
(1 – Dniprovske tailing storage facility; 2 – slug waste piles of DMC)

Fig. 4. Map-diagram of the objects' location on Sukhachivka site

2.2. Terrain

The city of Kamianske lies at the junction of the Ukrainian crystalline core-area and the Dnipro-Donetsk basin, which determines the complex terrain of the city. The left-bank part of the city is located on the Dnipro lowland. The height above the level of the Baltic Sea does not exceed 65 meters (hereinafter – m BS). The right-bank part (except the coastal strip 700-1000 m wide) is located mainly on the spurs of the Cis-Dneprian Uplands (Prydniprovska vysochyna). Here the surface is wavy, separated by ravines and beams, the height ranges from 80 to 180 m BS. The site where the PCP facilities are located includes a hilly terrace (plateau) as well as the river Dnipro terrace and Dnipro floodplain. The height of the plateau is from 100 to 180 m BS. The river Dnipro floodplain has elevation marks from +54 to +56 m BS, and the terrace area has elevation marks from +56 to +67 m BS. The slope from the plateau to the Dnipro terraces is riddled with numerous ravines and beams (up to 20-40 m deep). In three of these ravines, tailings (tailing storage facilities) have been formed on the territory of PCP: the West, the Central ravine and the Southeast tailings.

Altitudes at the plant site range from +110 m to +55 m BS. During the construction works, the plateau, slope and terraces of the Dnipro were levelled at the site of the plant. The floodplain surface between the Dnipro and Konoplyanka rivers is filled with soil and construction debris and levelled. In the floodplain is the Dniprovske tailing storage facility with a height of +63 to +73 m BS, dumps of DMC cast iron smelter with a height of +65 to +83 m, and DCCP sludge tanks with a height of +69 to +70 m BS. The terrain of the PChP site and of Dniprovske tailing storage facility is shown in Fig. 5.

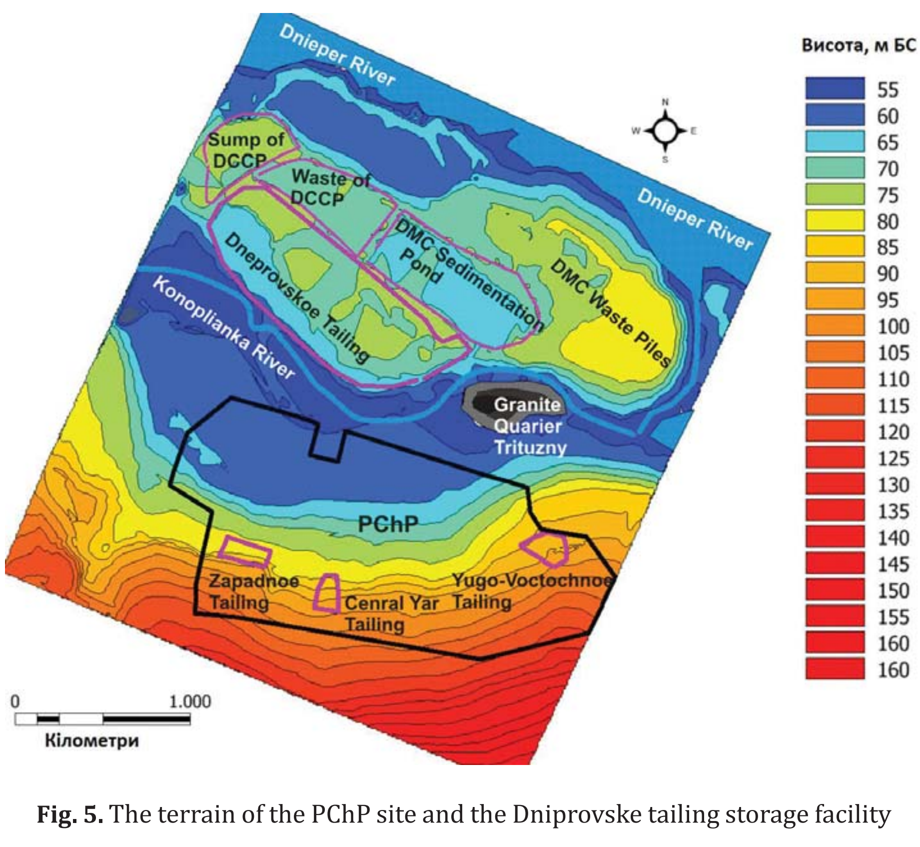

Fig. 5. The terrain of the PChP site and the Dniprovske tailing storage facility

The territory of the Sukhachivka tailing is located at the mouth of the Rasolovata ravine, which belongs to the network of ravines of the Sukha Sura river. The study area is a hilly area with a developed network of erosion ravines and beams. The Suha Sura river is a right tributary stream of the Dnipro river. The highest absolute height of the surface of the earth in the area of the Sukhachivka tailing is +165 m BS, while the lowest absolute height is +82 m BS, which corresponds to the place where the Rasolovata ravine joins it.

Landscapes are represented by forest lowlands, indented with steeply sloping, mostly coastal ravines, with outcrops of crystalline rocks, with washed away ordinary low humus and leached chernozems, with ravine oak forests. The stony area belongs to the landscapes of calcium-magnesium geochemical class.

Mixed-type vessels are navigated along the river Dnipro and the Seredniodniprovske water-storage basin. Other rivers are small, their banks are gentle, sometimes steep. The float is dry, sometimes with meadows. There are few forests in the territory, species of trees – deciduous (oak, acacia, ash), there are young pine plantings, bushy underbrush.

2.3. Geology and Soils

The geological structure of the right bank part of the town of Kamianske, where the PA PChP industrial site is located, is formed by crystalline rocks of the Precambrian period, as well as sediments of the Paleogene, Neogene and Quaternary periods. On the slopes of the plateau, deposits of red-brown clays of the Paleogene, Neogene, and late Quaternary periods were washed away during the formation of the valley of the river Dnipro. The geological section of the PA PChP territory and the Dniprovske tailing towards the river Dnipro is shown in Fig. 6.

The Precambrian rocks are mostly represented by gneisses and granite gneisses, which are fragmentarily covered with crust formed by the weathering of gravel and clay, and with mantle from sedimentary deposits of Paleogene, Neogene, and Quaternary Paleozoic-Cenozoic period.

The crystalline rocks have an uneven surface and occur at a depth of several meters in the floodplain of the river Dnipro and in the bottoms of large ravines to a depth of 180 m or more in areas of the inland plateau (with sinking in the eastern direction). The rock base on the plateau itself is covered with a gravel or kaolin crust 0–50 m thick. Crystalline rocks are present throughout the site.

Paleogene deposits are represented by sands alternating with clays, marls, sandstones and silts with a total thickness of up to 100 m. They are widespread in lowerigns in the crystalline base of the plateau. Neogene deposits are present almost everywhere. They are represented by clay with layers of marls, limestone and sand of the Sarmatian period with layers of clay and sandstone of Poltava composition. Quaternary period sediments form the upper part of the geological section with a total thickness of several meters in floodplains and in areas at the bottom of large ravines up to 180 m in areas of the inland plateau. The lower part of the Psychologic layer is formed by red-brown clays and limestone deposits of the early Quaternary period, 0.3 to 30 m thick, which are typical of plateaus, slopes and are washed away to the bottom of ravines and valleys. The upper part of the Psychologic layer consists of limestone sediments and mid- to late- Quaternary period, which extend up to 40

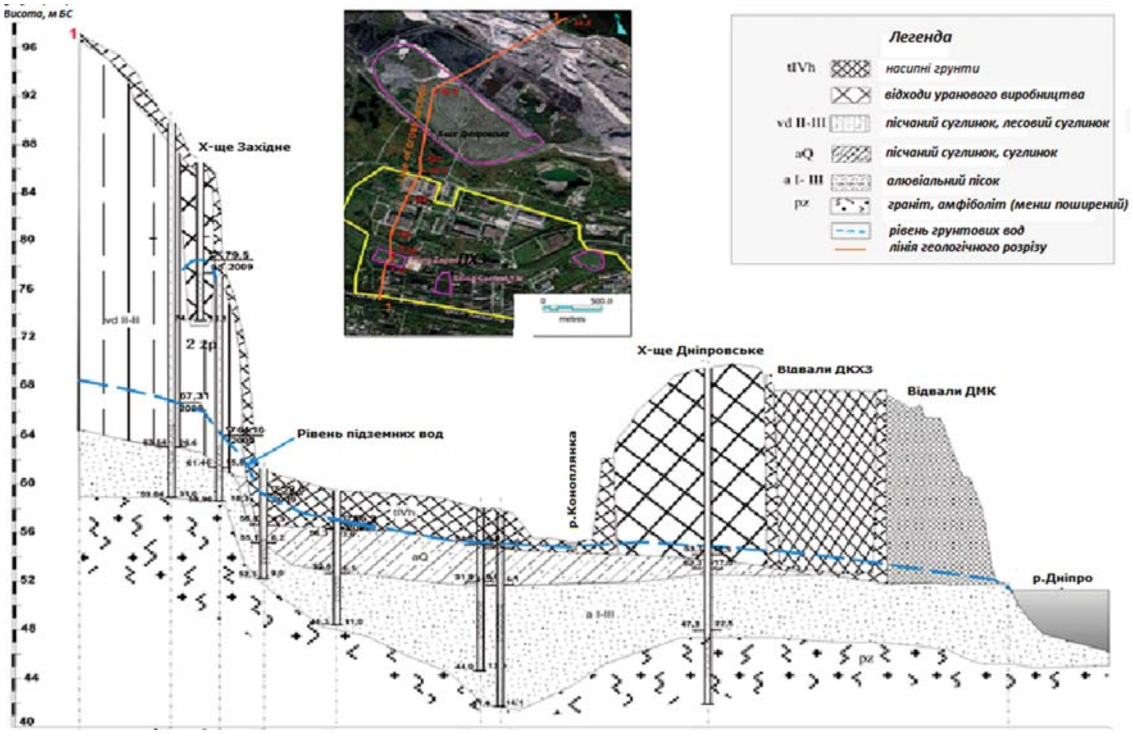

Fig. 6. Geological and hydrogeological section of PA PChP territory and Dniprovske tailing

m in plateaus and slopes, as well as modern sediments of alluvial and scree loams, sandy loams and sand that form the lower layers of large ravines (up to 5 m thick) and alluvial sands and sandy loams in the river Dnipro floodplain up to 20 m thick.

According to the State Service of Geology and Mineral Resources of Ukraine, spreading and activation of exogenous geological processes are observed in the investigated area. The total number of landslides and landslide areas within the city is 22. The area of the right slope of the valley of the river Dnipro within the basins of the Omelnyk, Domotkan and Samotkan rivers (the territory of Verkhinodniprovsky, partly Piatyhatsky and Krynychansky rayons) is characterized by numerous landslides on the slopes of small rivers, beams and ravines, as well as on the coast of the Dniprodzerzhynsk water-storage basin. They are interconnected with the active ravine-beam erosion of permanent and temporary streams (mudslides, landslides-flows), as well as with the intensive abrasion activity of the waves of the Dniprodzerzhynsk water-storage basin (landslides-landfalls). In Kamianske, an active landslide site is located on the right slope of the Shamyshyn beam (Cheryomushki residential area, Onishchenko Street, Skalyka, Tsiolkovsky) in the central part of the city. The landslide areas located in the beams of Kamianske town remain dangerous for engineering structures and human life [4].

2.4. Seismicity

According to the provisions of the State Building Standards of Ukraine B.1.1-12: 2014 "Construction in seismic regions of Ukraine", Annex A, seismicity in Kamianske town (for average soil conditions) is 6 points on the MSK-64 scale. Seismicity of the region depends on the Crimean-Black Sea and Azov-South seismically active zones and the Vrancea zone in Romania.

2.5. Climate

According to the climate atlas of Ukraine, the town area belongs to the temperate climate zone, to the area of Atlantic-continental influence, which means that the climate is affected by the Atlantic Ocean and the European continent from one side and the northern (Arctic) and southern latitudes from the other. One of the peculiarities of climatic conditions is the considerable fluctuations of the weather conditions from year to year. Moderately wet years alternate with extremely dry. In general, the climate is characterized with a relatively cool winter with unstable snow cover and frequent thaws and hot, dry summers. The main climate forming factors of the city region are the general circulation of air masses and solar radiation. Under the influence of radiation factors, the continental air is actively formed. At the same time, the transfer and transformation of air masses are reflected in the peculiarities of the annual and daily course of meteorological elements: they cause non-periodic changes of weather, overlapping the effect of radiation and local climatic conditions. This effect on the weather has a clear seasonal variation. The invasion of the Atlantic masses in winter raises the temperature of the air, in summer they are associated with gloomy and cold weather. In winter, invasion of the mainland (Arctic) masses causes sharp and significant cold snaps.

The climate around the PChP industrial site is moderately continental, characterized by hot (sometimes dry) summers and relatively cold winters. Winter is relatively mild, with cloudy weather and thick fog. According to the Ukrainian Hydrometeorological Center, the average air temperature in winter is –3… –5 ° C. The average temperature of the coldest month (January) is –5,4 ° C, and the minimum daily temperature was also observed in January and reached –38 ° C. The summers are warm, and in some years hot, dry. The average monthly air temperature in the summer is + 19–21 ° C, and the hottest month (July) is +22,3 ° C, with a maximum temperature of +40 ° C. The course of average monthly air temperature as well as average monthly maximum and minimum temperatures is shown in Fig. 7.

The winter and autumn months are characterized by relatively windy weather. The highest wind speed is observed in November and reaches 34 m/s, while the highest average monthly wind speed is observed in February and is 4.1 m/s. Data on wind characteristics (maximum and average monthly speed, frequency (%) of wind direction and calm) are presented in Table. 1, and also in Fig. 8 and Fig. 9. Winds from the north are the most frequent in the city , the northwest and southwest winds are the least frequent.

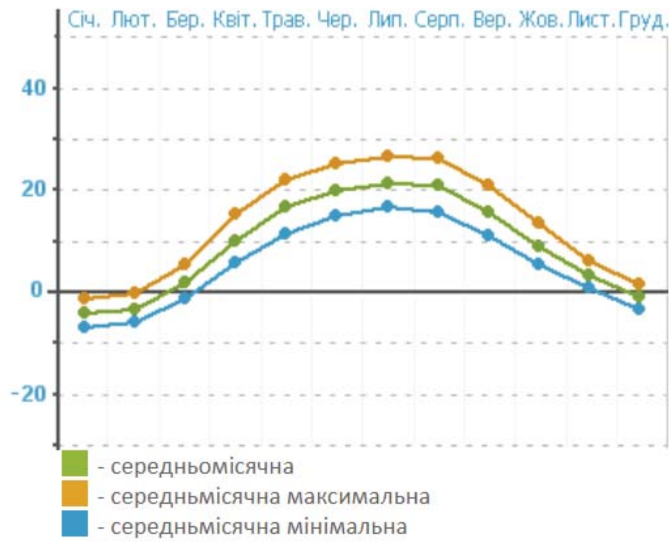

Fig. 7. Course of average monthly air temperature, average monthly maximum and average monthly minimum temperature

Table 1. *Monthly average and maximum wind speed, m/s*

Month	01	02	03	04	05	06	07	08	09	10	11	12
The average monthly wind speed	4,0	4,1	3,7	3,5	3,0	2,6	2,7	2,6	2,8	3,2	3,6	3,8
Maximum wind speed	28	24	28	23	24	21	20	29	20	24	34	28

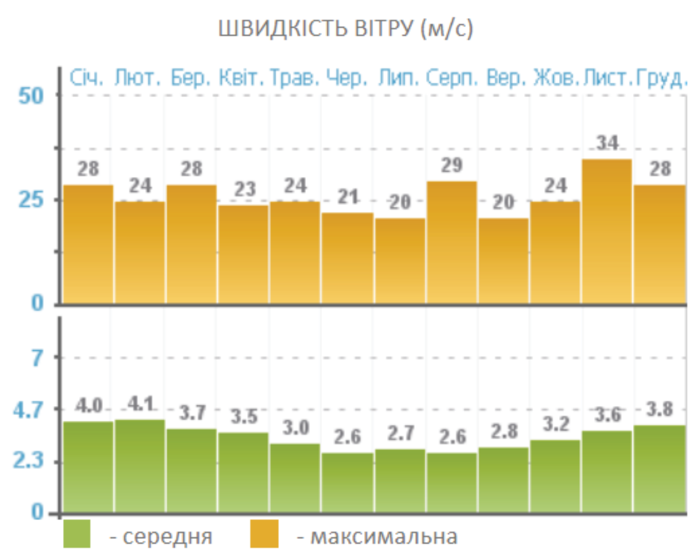

Fig. 8. Average monthly and maximum wind speed, m/s

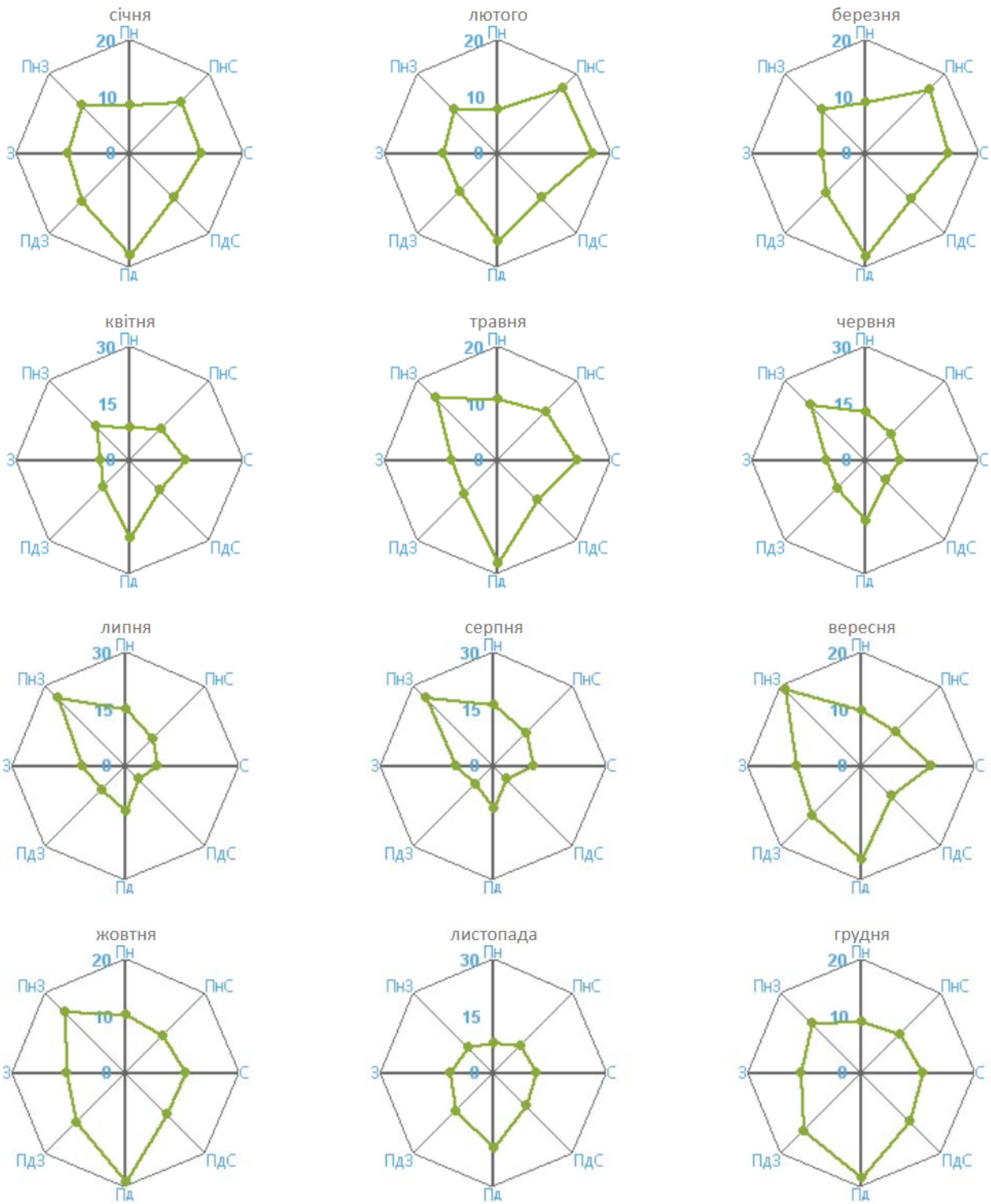

Fig. 9. Repeatability (%) of wind and still direction by months of the year

The average annual rainfall in the city area is 513 mm. The maximum monthly rainfall for the observation period (since 1899) is 160 mm and is observed in June, and the minimum amount is 30 mm and was observed in March. The maximum daily rainfall is 82 mm. The average monthly and maximum rainfalls (mm) with wetting corrections during the observation period are shown in Fig. 10.

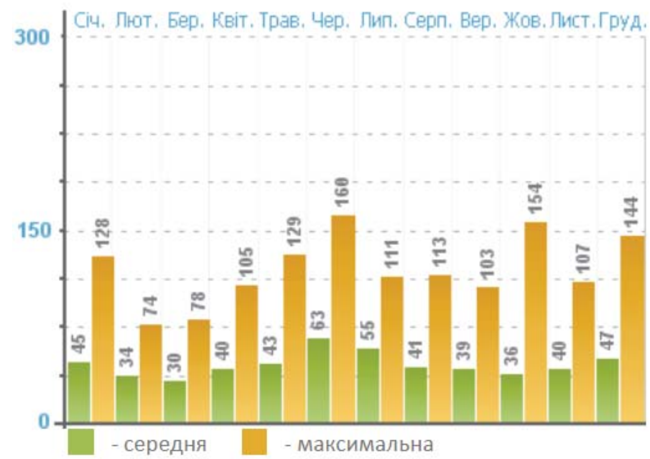

Fig. 10. Distribution of average and maximum rainfall during the year, Kamianske

The number of days during which precipitation is observed is extremely uneven by month. Thus, in winter months, the number of days with precipitation during the month ranges from 11 to 13 days, while in the summer and autumn months the minimum figures are observed – 7 days (August – October). In total, on average there are 122 days a year with precipitations of varying amounts in the form of snow or rain. The monthly distribution of days with different rainfall during the year is shown in Fig. 11.

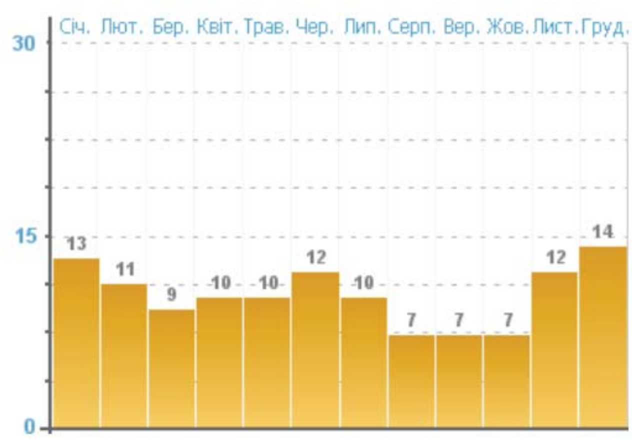

Fig. 11. Monthly distribution of days with varying rainfall during the year

Climate formation in the area is influenced by the approach of the city to the Kamianske (Dniprodzerzhynsk) water-storage basin , namely the evaporation of water from its surface. According to the results of researches of scientists of the Ukrainian Research Institute of Hydrometeorology, the calculated evaporation from the water mirror of the water-storage basin observed in dry, low-water years is about 930 mm. Evaporation in wet, high-water years is 678 mm. The average evaporation value is calculated at 818 mm/year, which is significantly higher than the annual rainfall of 513 mm.

The average monthly relative humidity during the year ranges from 80-83% in the winter, decreasing to 40-42% in the summer months. The data on the average monthly air humidity during the year, observed in Kamianske, are given in Table. 2.

Table 2. *The average monthly humidity during the year in Kamianske*

Humidity,%	1	2	3	4	5	6	7	8	9	10	11	12	Year
Absolute (g/m^3)	4,2	4,2	5,2	7,4	10,4	14,0	15,5	14,6	11,3	8,4	6,6	5,0	8,9
Relative	83	80	73	52	44	43	43	42	45	62	78	83	61

2.6. Surface water

The river Dnipro flows near Kamianske from the northwest to the southeast. In the area of the site, the PChP has an average width of 450 to 600 m and a depth of 5 to 8 m. The river bed is divided into several branches with sandy islands. The river Dnipro is used for drinking water supply, navigation, irrigation, and fishing and for recreational purposes.

The flow velocity in the river Dnipro in April and May is 0.7-0.8 m/s, while in the summer and autumn it varies from 0.25 to 0.3 m/s, with an average speed of 0.5 m/c. The maximum water level in the river Dnipro near the PChP site during the flood of 1% repetition is 56.58 m BS, the maximum water consumption of 1% repetition – 15.7 thousand m^3/s. The maximum flow velocities and water levels in the Dnipro during periods of floods of different frequency are given in Table. 3.

Table. 3. *Maximum flow velocities and water level in the Dnipro during periods of floods of varying frequency*

Repeatability, %	0,5	1,0	2,0	3,0	5,0
Maximum water consumption, m^3/s	17 300	15 700	13 700	12 600	11 000
The maximum level, m BS	+56,82	+56,58	+56,29	+56,10	+55,79

Konoplyanka river flows from 0.6 to 1.0 km north of the PChP site and 50 to 100 m northwest from Dniprovske tailing. Characteristics of Konoplyanka river basin: the area of the basin is 32.2 km^2, the length is 13.6 km. The basin covers both industrial and residential areas of the city. Untreated industrial wastewater, as well as storm drains from drainage collectors, including from the PChP industrial site, enter Konoplyanka river.

The river bed near the mouth runs along the Dniprovske tailing in an artificial channel. The width of the river is in average from 8 to 10 m; its depth – from 0.2 to 0.8 m, flow velocity is from 0.1 to 0.2 m/s. The water level in Konoplyanka river depends on the water level in the Dnipro river. The maximum level during the spring flood is 55.0 m BS, the minimum level is 51.1 m BS. The maximum water velocities during spring and rain floods at the mouth for different recurrence are given in Table. 4.

Table 4. *The maximum water consumption, observed in the Konoplyanka river*

Repeatability, %	**1**	**2**	**3**	**5**
The maximum flow velocity of water in the spring flood, m^3/s	31,4	26,5	23,4	19,3
The maximum flow velocity of rain floods, m^3/s	50,0	25,0	10,0	–

2.7. Groundwater

Hydrogeological conditions of the investigated area are characterized by the presence of aquifers in "technogenic" deposits (materials of tailings), in Quaternary alluvial and forest sediments, Neogene, Paleogene and Precambrian rocks.

The aquifer in the technogenic deposits is formed in the tailings (in the thickness of the tail materials). Aquifers are uranium ore wastes, carbon and sludge. They are characterized by the predominance of dusty-clay fractions with hydrophilic properties, which contributes to the water saturation of such deposits. In particular, the aquifer of technogenic sediments is present in the Zakhidne, Dniprovske and Sukhachivka tailings (sections 1 and 2). Aquifers are fed by precipitation infiltration.

The aquifer in alluvial deposits is present within the floodplain and terrace of the Dnipro river. Aquifers consist of sands with variable particle size distribution (silt to gravel), silt loam and sandy loam. Within the 2nd sub-floodplain terrace, the lower part consists of loamy loam and sandy-clay soils above the sandy bed. The thickness of the aquifers varies from 2 to more than 20 m. The distribution of groundwater levels and flow direction in alluvial aquifers based on flow simulation results are shown in Fig. 12.

The hydraulic conductivity of aquifers varies widely and is: for loam – 0.01 m/day; for sandy loam – 0.1-0.7 m/day; for sand – 1-2 m/day; for fine-grained and fine gravel – 1.0-27.0 m/day.

Nutrition in the aquifer is due to the infiltration of precipitation and the influx of groundwater from the technogenic aquifer above. The range of infiltration rate into the aquifer is estimated from 15-25 mm/year (for sites on the slope of the plateau) to 50-100 mm/year on the terraces and sections of the Dnipro floodplain. Groundwater discharge occurs into the Konoplyanka and Dnipro rivers, as well as into the aquifer in the fractured crystalline rocks below.

The aquifer in the forest sediments is the first from the surface within the plateaus and slopes of the River Dnipro basin. This aquifer is composed of sediments of loamy loam and loess of lower and upper Quaternary ages, which lie above the Neogene waterproof upper Neogene and lower Quaternary clays.

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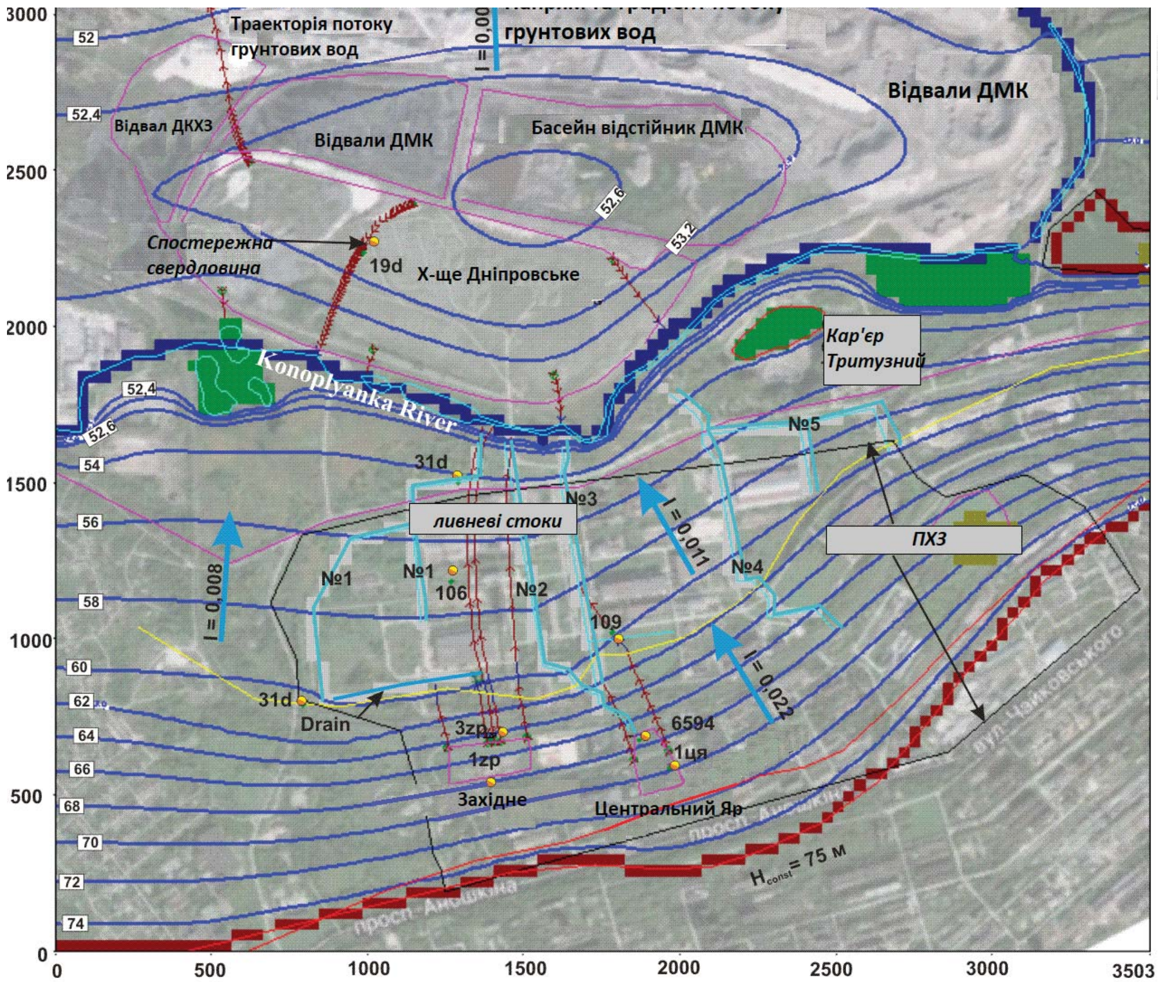


— groundwater flow path.

Fig. 12. Distribution of groundwater levels in a stream section
at a PChP industrial site under existing conditions based on modelling using a regional groundwater flow model (Bugay, Skalsky and Kubko, 2014)

The aquifer is unpressurized. The average moisture conductivity of aquifers is 0.05-0.1 m/day. Nutrition of the aquifer is due to the infiltration of precipitation. Groundwater from the aquifer is discharged into Quaternary alluvial and/or Neogene sediments, which lie below.

The aquifer of the Neogene deposits in the deposits of the Poltava Neogene Formation has a regional distribution. Aquifers are fine-grained sands with a thickness of 7-10 m with interbedded sandstones and limestone with a thickness of 0.5 to 3 m. Depth of the level ranges from several meters at the bottom of ravines to 110 m in sections of the watershed plateau.

The average moisture content of a water bearing deposits is 6.5 m/day. Access to the aquifer is due to the drainage of groundwater from the forest aquifer, infiltration of precipitation and surface water at the bottom of the ravines, as well as from the tailings (in the case of the Sukhachivka tailing). Groundwater discharge occurs into the river system and the lower aquifers. The distribution of hydraulic pressures in the Neogene aquifer in the Sukhachivka tailing area is shown in Fig. 13

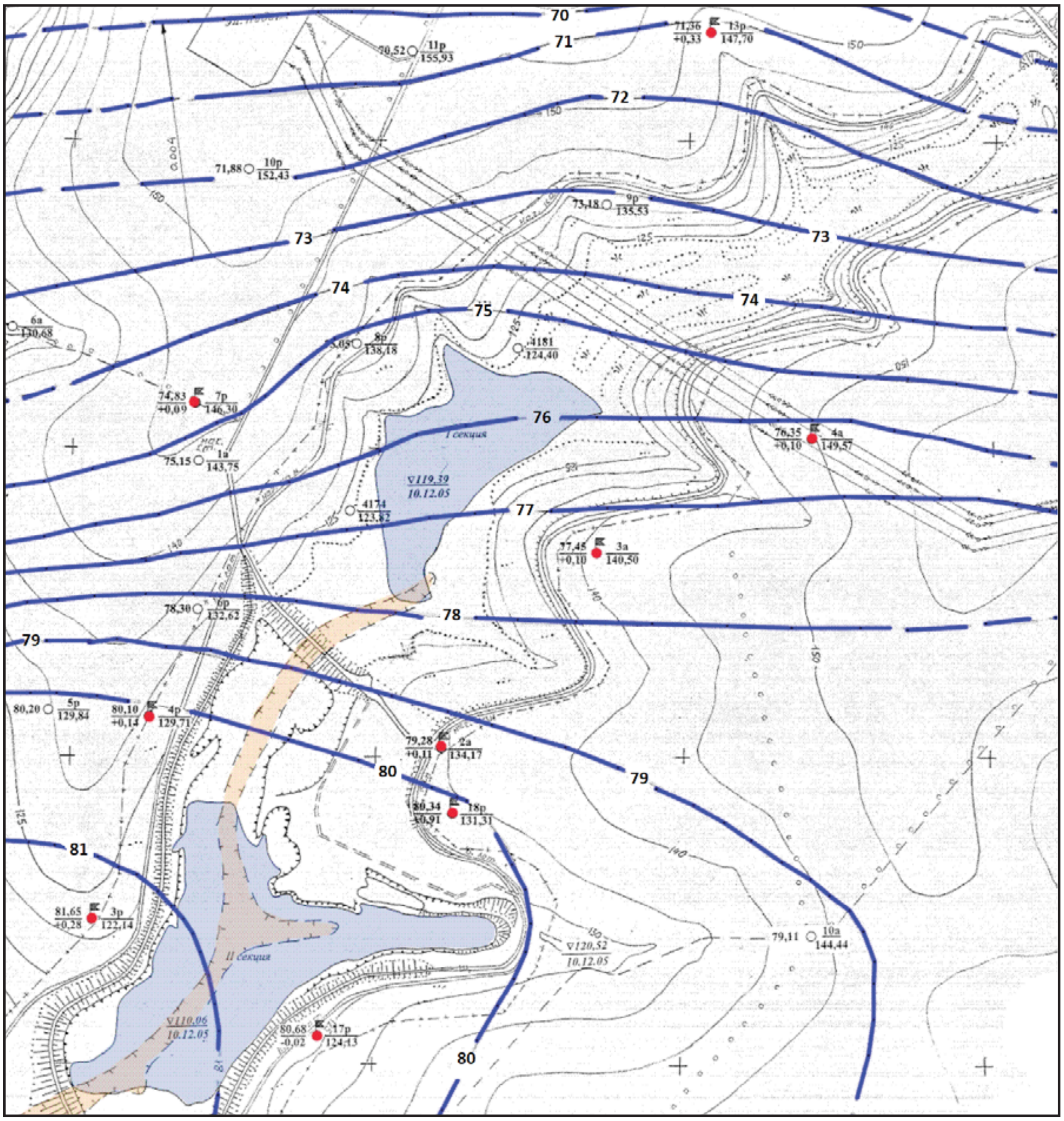


Fig. 13. The distribution of water levels in the sediments of the Neogene aquifer at the site of Sukhachivka tailing.

The aquifer in crystalline rocks of the Precambrian age consists of weathered sand-gravel crust and fractured zones of crystalline foundation. The aquifer is widespread. The depth of the aquifer ranges from several meters in floodplain areas to 180 m in basins. Aquifers are fractured granites, gneisses, diorites, and magmatites. The thickness of the saturated fractured zone is 35-40 m. The aquifer is partly retaining, partly unsupported. Feeding is due to the infiltration of precipitation and surface water, as well as the flow from the upper aquifers. Kaolin weathering bark, which is a local water resistance, appears sporadically only at the bottom of the crystalline base and does not prevent the close hydraulic connection between the aquifers of Quaternary alluvial and Neogene deposits and aquifers in crystalline rocks.

Hydraulic coupling between aquifers ensures continuity of pressure levels up to the first from the surface aquifer. Groundwater outflow occurs in the floodplains of the Dnipro and Mokra Sura rivers. The general mode of levels, conditions of feeding and leaving of aquifers in alluvial deposits and crystalline rocks allows combining them into a single aquifer system.

The chemical composition of groundwater in the PCP impact zone is characterized by extreme spatial variability and exceeding of the maximum permissible concentrations of a number of macro- and micro-components (in particular uranium thorium radionuclides and toxic metals) throughout the industrial zone, including downstream zones from the tailings. Relevant monitoring data are presented in the following sections for individual sites.

2.8. Biodiversity

2.8.1. Stone site

The main industrial site of the Prydniprovskyi Chemical Plant is located on the territory of the industrial area and is adjacent to the residential districts of Kamianske.

The vegetation in the residential area of the city is made up of trees growing along streets, avenues, boulevards and parks. The trees are mainly poplars, maples, chestnuts and other species. The city's Central Park of Culture and Recreation is an object of the Nature Reserve Fund of Ukraine.

Fruit trees and berry bushes are grown in the "private sector" (i.e., in the area occupied by private residential and summer houses). Fruit trees are mainly apple, pear, cherry, plum and apricot. Currants, raspberries, grapes, cornel and other berries are grown in gardens. Bog willow, cattails, and reeds grow on the banks of the Konoplyanka river.

Due to the nature of the area (industrial and residential areas), wild animals are represented only by small rodents such as rats and mice, as well as stray dogs and cats. Birds are mainly represented by pigeons and sparrows. Predatory species, such as owls, crows, hawks, can occur in park areas. Some private farms may keep domestic animals, such as pigs, goats, chicken, etc.

2.8.2. Sukhachivka site

Vegetation. Much of the investigated area, in particular parts of the sanitary protection zone directly adjacent to the Sukhachivka tailing, is used for agricultural activities, including growing of cereals (wheat, barley, maize, oats) and, to a lesser extent, of industrial crops.

Forest vegetation in this area is represented by "woodland belts" on a plateau along agricultural fields. Acacia predominate with forest vegetation. From the undergrowth, vegetation is represented by thistle, elder, buckthorn, hawthorn, hazel, wild rose, etc. Different types of apples, pears, apricots, cherries, plums grow in gardens and backyard areas in local settlements. Raw slopes and gullies are often used for haying and grazing.

The animal world is represented by small rodents such as mice and rats. Small animals such as hares and foxes also occur. Private households keep domestic animals such as cows, pigs, goats, chickens, geese and ducks.

National protected natural resources (zones) are not directly adjacent to the Sukhachivka site.

2.9. Land use

The PChP site is located in the eastern outskirts of Kamianske in the industrial area of the city. The area of the PChP industrial site is about 250 hectares. The PChP industrial complex also includes the Dniprovske tailing (0.77 km^2), located between the PChP industrial site and the Dnipro river.

in the immediate vicinity of the Dniprovske tailing (in the north and northwest direction) are sludge dumps and DMC wastes, as well as sludge tanks and DCCP wastes. The territory along the river Dnipro to the west from the Dniprovske tailing is an industrial area occupied by DMC and other small enterprises.

According to archive data, project No. 231-0158-1 "Sanitary protection zones of Prydniprovsky chemical plant", a sanitary protection zone (hereinafter – SPZ) was established for the PA PChP industrial site. The project was developed in the 1980s by the State Specialized Design Institute (Moscow, Russian Federation). SPZ was established by chemical parameters and did not take into account radiation factors. According to the mentioned project, the PChP SPZ covered an area of about 4 km within a radius of the centre of the PChP industrial site. The following objects are within the SPZ:

- Dniproazot plant located to the southeast of PChP;
- Residential area of Dniprodzerzhynsk (area of 4.3 km^2), located to the west of the PChP;
- another residential area (0.25 km^2), located to the south of the PChP (near the Dniproazot plant);
- summer house settlement with a total area of 0.6 km^2, located to the east of the PChP industrial site. In this area local residents and summer residents grow vegetables and fruit.

In the residential area to the west of the PChP in an area of about 1.1 km², urban residents live in private houses where they grow vegetables, fruit and possibly livestock.

In the Konoplyanka river, which flows along the Dniprovske tailing, the locals citizens go fishing (fish used for consumption). In the floodplain area on the right bank of the river the citizens have gardens and grow vegetables.

Sukhachivka site. The first and second sections of the Sukhachivka tailing cover approximately 3.4 km². The area of the former uranium ore deposit "Base C", which is part of this group of sites, is 0.34 km².

Most of the controlled area of the tailing storage facility (in particular, part of the SPZ) is used for agricultural activities. About 90% of the total agricultural area of the agricultural fields is used for growing mainly cereals (wheat, barley, corn, and oats) and, to a lesser extent, for industrial and feed crops (see Fig. 14).

Fig. 14. View of the Sukhachivka tailing and adjacent territory.
Photo by I. Bigdan from Open Source *https://ibigdan.livejournal.com/12916742.html*

Raw slopes and gullies bottoms are used for haying and cattle grazing. In the settlements in the observation area (Sukhachivka, Gorkogo, Ordzhonikidze, Mykolaivka) there are livestock farms and complexes for the production of meat and dairy products. A poultry farm (egg and poultry production) is located 2.2 km northwest of the tailings. Ponds in the Tomske village and the area near the poultry farm are used for fish rearing.

3 km to the north-west of the Sukhachivka tailing, in the upper part of the Rasolovata ravine (Yasinova beam) there are sludge tanks of the Dniproazot plant, where ash and slag mass are stored, as well as waste water from the TPP, waste from the production of polystyrene, chlorine, caustic soda, etc.

The four-lane highway ”Dnipro – Kremenchuk” passes through the territory of Sukhachivka site, from which asphalt roads depart to the villages of Taromske, Sukhachivka and Gorkogo. A network of unsurfaced roads is developed along tree plantings and, to a lesser extent, in fields. The Prydniprovska railway crosses the investigated area along the village of Taromske.

2.10. The socio-economic situation

This section was prepared using the following information sources:

The State Statistics Service of Ukraine *(http://ukrstat.gov.ua/)*;

- The Main Statistics Directorate in Dnipropetrovsk Oblast *(http://www.dneprstat.gov.ua/statinfo% 202015/ds/)*;
- Information site of the Ministry of Finance of Ukraine *(http://minfin.com.ua/)*,
- and also using the document "Strategy for the development of the city of Dniprodzerzhynsk until 2020" *(decision of the City Council of the Dniprodzerzhynsk city No. 1162-58/VI of 26.12.2014)*.

In general, the demographic, economic, environmental and social situations in the Dnipropetrovsk oblast have been difficult and mainly characterized by negative trends over the last decade. In 2014, the socio-economic situation in Ukraine deteriorated further due to political instability, annexation of the Crimea and the military conflict in Donbas.

2.11. Demographic situation

The estimated population of Ukraine as of September 1, 2019 was 41976,2 thousand people. Between January and August 2019, the population decreased by 177.0 thousand people. The number of deaths over the number of live births remains significant: 100 deaths – 53 live births *(State Statistics Service of Ukraine, Express Edition of October 18, 2019)*.

Kamianske is the third largest city in Dnipropetrovsk oblast after the cities of Dnipro and Kryvyi Rih. The population density is about 1.8 thousand per 1 km^2. The current demographic situation in Kamianske is characterized by unfavourable trends and negative shifts in population structures. Over the last few years, the natural population growth has been negative. Mortality outweighs the birth rate by 2 times in average. The population decreased from 250.1 to 239.7 thousand people from 2010 to 2018 (Table 5, Fig. 15).

Table 5. *Changes in Kamianske population, 2010-2018.*

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Number of people	250 115	249 550	248 800	248 400	246 900	247 600	243 643	241 432	239 712

Between January and August 2018, more than 2.4 thousand people died in the city for various reasons, and 1.1 thousand babies were born.

The population of the city as of 01.01.2019 was 239 712 people. The population dynamics of the city of Kamianske during 2010-2018 is shown in Fig. 15.

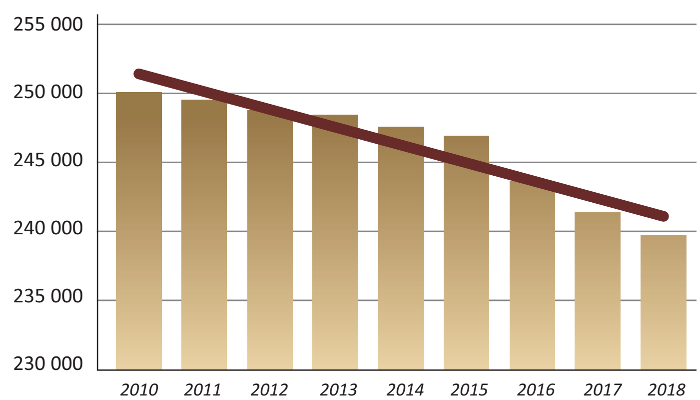


Fig. 15. Population dynamics in Kamianske during 2010–2018

2.12. Employment of the population and the labour market

As of 01.11.2018, there were 3.1 thousand registered unemployed persons (at the level of the previous year) registered at the Kamianske employment centre, of which 66.4% were women, 35.6% were youth under 35 years.

The average number of full-time employees employed at enterprises, institutions and organizations of the city was 45.9 thousand people (in the corresponding period of 2017 – 49.3 thousand people).

During January – October 2018, 5.1 thousand people were employed and 574 persons were trained by employers' order *(REPORT on the implementation of the Program of socio-economic and cultural development of the city for 2018)*.

2.13. GDP, income of the population

In 2018, gross domestic product (GDP) in Ukraine averaged 84 192 UAH (or 3095 USD) per capita. GDP growth was 19.9% in 2018, but in 2014 and 2015 GDP declined significantly in dollar terms (minus 25.2% and 29.8% respectively) due to political instability, annexation of Crimea and the military operations in Donbass. In September 2019, according to the National Bank's comment on the inflation rate, consumer inflation decelerated to 7.5% (8.8% in August). Prices increased by 0.7% monthly. This is evidenced by data published by the State Statistics Service of Ukraine. The actual inflation rate was lower than the official forecast (7.7%), published in the "Inflation Report" (July 2019). In September, the pace of growth of core inflation as well as administratively regulated and fuel prices were lower than expected, primarily due to further strengthening of hryvnia. According to the National Bank of Ukraine, as of the end of September 2019, important indicators were:

Consumer inflation (% pa).. 7, 5

Refinancing rate (% pa)..16, 5

Official exchange rate for Euro (UAH → EUR)..................................27, 90
(27,904742)

Official exchange rate for US dollars (UAH → USD)........................24, 98

(24,975156)

International reserves (billion USD)..21, 4

In 2013, inflation was 0.5%. In 2014, due to the aforementioned negative factors, the inflation rate reached 24.9%.

The average nominal salary of a full-time employee of enterprises, institutions and organizations in the Dnepropetrovsk region in December 2018 amounted to UAH 10 188, which is 2.7 times higher than the minimum salary rate (UAH 3 723). Compared to November 2018, the average nominal salary increased by 10.3% and compared to December 2017 – by 23.5%. The index of real salaries in December 2018 compared to November 2018 was 109.4%, and compared to December 2017 – 113.1% (State Statistics Service of Ukraine Main Directorate of Statistics in Dnepropetrovsk region. Express release from 30.01. 2019).

As of April 1, 2019, there were 11.4 million pensioners registered with the Pension Fund of Ukraine, their average pension amounting to UAH 2 899.04. Compared to January 1, 2019, the size of the pension increased by UAH 253.38 (amounted to UAH 2 645.66). The subsistence minimum for able-bodied persons as of 01.07.2019 was UAH 2 118. As of April 1, 2019 Dnipropetrovsk oblast, with 955 617 people, was the leader in the number of pensioners in Ukraine. As of January 1, 2015, the Kamianske Pension fund had 74,000 pensioners (about 29% of the population). About 24.8% of the total number of pensioners continue to work.

The official unemployment rate in Ukraine in 2018 was 8.8%. The detailed information on unemployment rates by population categories is given in Table. 6. Unemployment benefit amounted to UAH 1,154/month. About 10-12% of Ukraine's population lives below the poverty line, and another 12-15% close to the poverty line.

Table 6. *Unemployment rate of Ukraine (by ILO methodology) by gender, type, and age groups in 2018*

Name of the population category	Number, thousand people	% of economically active population of the appropriate age
All population aged 15-70 years, including:of working age	1578.6	8.8
	1577.6	9.1
Total women, including:	635.4	7.4
	634.8	7.7
of working age	943.2	10.0
	942.8	10.4
Total men, including: of working age	1063.1	8.6
	1062.1	8.9
Total rural population, including: of working age	515.5	9.2
	515.5	9.6

According to the results of a sampling survey of the population (households) of Dnipropetrovsk oblast for 9 months of 2018 on economic activity, the number of employed population aged 15-70 years for 9 months of 2018 was 1 409,4 thousand people, and the number of unemployed persons of the relevant age – 117 , 4 thousand people. The employment rate of the population aged 15-70 compared to the same data of the previous year increased by 0.7 percentage points (further – pp) and amounted to 58.9%, and among the population of working age – by 1.6%. This was 69.4%. The unemployment rate among the economically active population aged 15-70 years in 9 months of 2018 decreased by 0.7 in comparison with 9 months of 2017 and amounted to 7.7% *(State Statistics Service of Ukraine Main Directorate of Statistics in Dnipropetrovsk region. Express issue of 28.12.2018)*.

2.14. Industry

The leading branch in the city's economy is industry, so the dominant factor in the stability of the urban economy is the sustainable functioning of leading industrial enterprises. Industrial production is mainly shaped by industries such as metallurgical, chemical and coke-chemical, mechanical engineering. The city's industrial complex comprises 36 leading large and medium-sized enterprises employing over 23,000 people. The most important industrial products are cast iron, steel, rolled metal, coke, cement, and mineral fertilizers, industrial and main carriages. Consumer goods produced are paint and varnish and adhesives, roofing material, household goods, construction materials, etc. The annual sales volume is UAH 40.3 billion. The share of city enterprises in the regional volume of sales – 9.6%, in the national – 1.8%.

Kamianske is among the leaders of Ukraine in the metallurgical products' production. The city with a population of 0.6% of the population of Ukraine produces 8.5% of all-cast iron, 19% of steel.

The volume of ferrous metallurgy production makes up 62.9% of the city's total production volume. One of the most powerful metallurgical enterprises of Ukraine – PJSC "Dniprovskyi metallurgical plant named after. F.E. Dzerzhinsky" is the only manufacturer of rolled axial workpiece for railway transport, sheet piles of "Larsen" type, subway rails and a wide range of other products in Ukraine.

Kamianske is also one of the most powerful centres of chemical industry in Ukraine. The chemical industry ranks second in the city's manufacturing structure (17.2% of total production). The share of the coke industry is 10.1% of the total city production. The city's enterprises produce almost 18% of Ukrainian fertilizers. The product range of the PJSC "DNIPROAZOT" contains about 50 product types, the main of which are ammonia, carbamide, caustic soda, liquid chlorine. In 2018, there were negative trends in the production activity of one of the city-forming enterprises of the city and a significant producer of chemical products – JSC "DNIPROAZOT". Its main production capacities have been in a durable downtime since June this year. The shutdown of the enterprise is due to the economic inexpediency of carrying out the production process due to the increase in the price of natural gas (the share of which in the cost of production ranges from 40 to 90%) and the lack of working assets to purchase the required amount of raw materials.

The share of the machine-building industry is 5.5% of the total production in the city. PJSC Dniprovagonmash is one of the leading enterprises of Ukraine in designing and manufacturing freight wagons for main railways and various industries.

The volume of construction works performed by construction enterprises of all types of ownership is UAH 296.5 million or 3% of the total volume of works in the region. Developers of all forms of ownership put into operation 1.1 thousand m^2 of the total area of housing or 0.6% of the total volume of housing commissioned in the oblast.

The number of business entities (legal entities) – 3978, including small enterprises – 1083, business entities (natural persons) – 11 440. The number of small enterprises per 10 thousand of population – 44. Share of production, sold by small enterprises, in the total production volume – 8.9%. The average number of employees employed in small enterprises is 5.6 thousand.

2.15. General environment condition

The analysis of the environmental status of the city combines an assessment of the state of the major environmental components: air, water and waste management. The text of the section is given in accordance with the annex to the decision of Kamianske city council of 27.06.2019 № 1467-33/VII "Information 'On the ecological state of the city of Kamianske and the course of implementation of the environmental program of the city of Kamianske for 2016-2020'".

Atmospheric air

In the city, the total number of registered business entities which emit pollutants is 55. The major air pollutants in the city are PJSC "Dniprovskyi Metallurgical Plant", JSC "YUZHKOKS", PJSC "Dniprovskyi Coke Plant" and PJSC "Dniproazot".

According to the general data of the Main Directorate of Statistics in Dnipropetrovsk Oblast in 2018, about 103.3 thousand tons of pollutants were emitted into the atmospheric air from stationary sources, in 2017 – 57.8 thousand tons. This indicator increased by 45.5 thousand tons or by 78.7% (Table 7).

Table 7. *Dynamics of pollutant emissions from stationary sources of city enterprises during 2017-2018, tons*

Company Name	2017, tons	2018, tons	%, + increase/ –decrease
PJSC Dnipro Metallurgical Combine	52 509.8	99 010.3	+88.5
PJSC "Dnipro Coke Plant"	1335.9	1322.0	–1.1
PJSC "YUZHKOKS"	1547.1	1495.1	–3.3
JSC "DNIPROAZOT"	706.3	312.4	–55.8
PJSC "Heidelberg Cement Ukraine"	74.5	92.1	+23.7
PJSC "Dniprovagonmash"	66.1	229.8	+247.7
LLC "ZIP"	306.3	388.228	+26.7

in 2018 emissions have been reduced in: JSC "DNIPROAZOT" by 55.8%, 2018 – 312.4 tons, 2017 – 697.7 tons, PJSC "YUZHKOKS" – 3.3%, 2018 – 1495.1 tons, 2017 – 1547.1 tons, JSC "Dniprovskyi Coke Plant"; – by 1.1%, 2018 – 1322.0 tons, 2017 – 1335.9 tons.

The highest percentage of atmospheric air pollution in the city is accounted to PJSC "Dnipro Metallurgical Works", in 2018 the amount of emissions was 99.01 thousand tons, which is 46.5 thousand tons or 88.5% more than in 2017. (52.51 thousand tons).

The diagram of the ratio of emissions to atmospheric air, in particular per unit of production, and the payment of environmental tax by the main pollutant, PJSC "Dnipro Metallurgical Plant" is shown in Fig. 16.

Also in 2018, the emissions of PJSC "Dniprovagonmash" increased by 247.7%, in 2018 – 229.8 tons, in 2017 – 66.1 tons, in the LLC "ZIP" – by 26.7%, in 2018 – 388.2 tons , 2017 – 306.3 tons, PJSC Heidelberg Cement Ukraine plant by 23.7%, 2018 – 92.0 tons, 2017 – 74.4 tons, due to the increase in production.

The Air pollution observation laboratory of Kamianske city has analysed 22 730 samples for 9 ingredients in 2018. The laboratory recorded 1311 exceedances of the maximum permissible concentrations, which is 5.8% of the total number of samples.

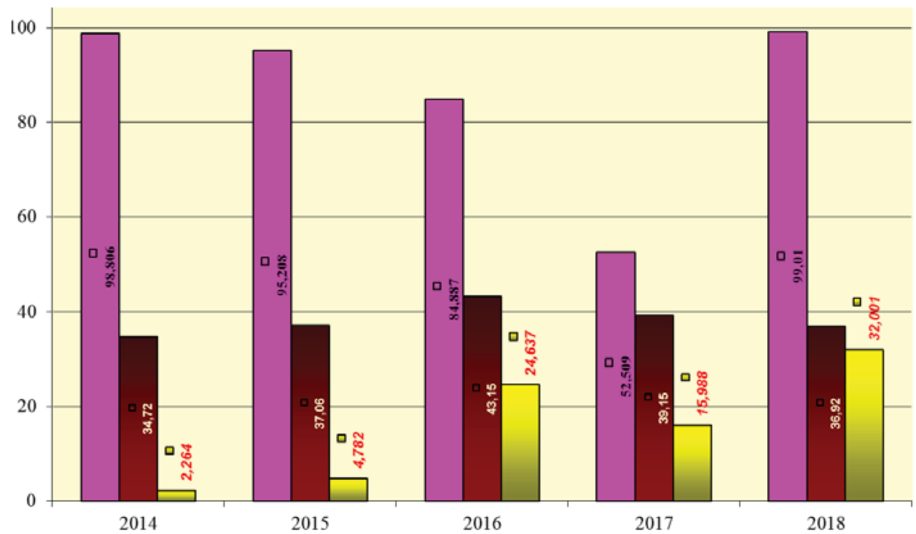


Fig. 16. Diagram of the ratio of emissions to atmospheric air, including per unit of production, and payment of environmental tax PJSC "Dnipro Metallurgical Plant"

The highest number of exceedances during the year of maximum one-time concentrations was recorded for the following ingredients: 17.9% for dust; 12.7% for hydrogen sulphide; 12.1% for phenol. In 2018 average concentrations exceeded the maximum permissible concentration (MPC) for dust by 2.7 times, for nitrogen dioxide by 1.8 times; for phenol – 2.3 times, for ammonia – 1.3 times, for formaldehyde – 3.0 times.

According to the observation network data of the National Hydrometeorological Center of Ukraine, the city's complex pollution index in 2018 was 12.9, which is characterized as a high. Emissions per 1 km^2 amounted to 748.6 tonnes, emissions per person – 428.5 kg versus 237.6 kg in 2017.

Water objects

Water objects of the city are: Dnipro river, Konoplyanka river, Kamianske) water-storage basin, drainage channels. The main waterway of the city is the Dnipro River.

The hydro chemical state of the Dnipro river is mainly affected by such enterprises of the city as PJSC Dniprovskyi Metallurgical Plant, JSC Dniprovske TPP, JSC Dniproazot, MUNICIPAL PRODUCTION ENTERPRISE OF KAMIANSKE CITY COUNCIL ”Miskvodokanal”, SE Smoly, Branch of Seredniodniprovske Hydroelectric Power Plant, PJSC “Ukrhydroenergo”.

According to the Dnipropetrovsk Regional Water Resources Administration (statistical reporting), the water consumption in 2018 amounted to 109.4 million m^3, which is 13.3 million m^3 (13.8%) more than in 2017 – 96.07 million m^3 (see Table 8).

In 2018, 99.5 million m^3 of wastewater was discharged into surface water, with which 9.5 thousand tons of pollutants were dumped. Compared to the previous year, the total volume of wastewater discharges increased by 14.9 million m^3.

Table 8. *The key figures of water consumption in 2017-2018.*

Indicator	2017	2018	Increase, %
Water consumption, million m^3	96.07	109.4	13.3
Wastewater discharged into surface water objects, million m^3,	84.6	99.5	17.6
including polluted wastewater, million m^3	63.6	71.2	19.0

Waste management

The city belongs to the cities of Ukraine with a high concentration of industrial enterprises, which contributes to the generation of large amounts of industrial and household wastes.

One of the priority areas to minimize the accumulation of industrial waste in our enterprises is to return them to production in order to extract valuable components and use them as secondary resources (waste disposal).

According to the data of the Main Directorate of Statistics in Dnipropetrovsk Oblast, 171.13 thousand tonnes of hazardous wastes of class I – IV were generated in the city in 2018, which is 28.05 thousand tonnes more than in 2017. Of these, class I – II hazard – 17,03 tons, III class of hazard – 2,51 thousand tons, IV class of hazard – 168.60 thousand tons.

City Council measures for environmental protection

The Kamianske City Environmental Program for 2016-2020 provides for measures aimed at preventing the negative impact and elimination of the consequences of the enterprises' operation, improvement of the condition of atmospheric air, surface water, groundwater, and elimination of flooding, other environmental pollution and environmental protection.

The financial sources for the Programme's activities were the environmental protection funds of all levels and the enterprises' own funds.

In 2018, UAH 7063.95 K were spent on implementation of the programme's activities – funds from the special fund of the local budget and UAH 16 703,679 K from the state budget.

Summing up, it can be noted that, as in previous years, major environmental problems of the city need to be addressed: pollution of the city atmospheric air with emissions of industrial enterprises and vehicles, pollution of water objects, problems with waste management, conservation and increase of the area of green space.

2.16. SWOT-analysis for Kamianske city

Interesting is the SWOT-analysis (SWOT – Strengths, Weaknesses, Opportunities, Threats) presented in the document "Strategy for the Development of the City of Dniprodzerzhynsk until 2020" (Decree of the City Council of Dniprodzerzhynsk No. 1162-58/VI of 26.12.2014).

City's strengths:

1. Favourable (relative to transport routes) geographical location.
2. Diversified and developed industrial infrastructure of the city.
3. Significant power generation capacity.
4. Availability of skilled workers.
5. Concentration of intellectual resources (availability of higher education and scientific institutions).
6. The compactness of the city.

Weaknesses:

1. Obsolete housing, slow housing construction development.
2. Disruption of urban traffic, depreciation of electric transport.
3. Difficult environmental situation.
4. Obsolete housing and communal infrastructure, depreciation of fixed assets.
5. Unsatisfactory state equipment and material procurement of municipal educational institutions.
6. Low level of maintenance of medical institutions and shortage of medical personnel.
7. Insufficient development of private enterprises, small and medium businesses.

External opportunities of the city:

1. Restoration of former industrial sites for further development.
2. Introduction of alternative energy sources.
3. Implementation of new environmental measures in the industrial sector of the city.
4. Development of infrastructure of urban recreational zones using the territory close to the Dnipro river.
5. Intensification of fruitful cooperation between local authorities, public and business representatives aimed at city development.

External threats to the city:

1. Deterioration of the demographic situation, decrease (outflow) of the population.
2. Increased competition from surrounding industrial cities and rayon centres.
3. landslides and floods in residential areas.
4. Rapid increase in the share of the old housing stock.
5. Constant increase in the number of vehicles, with deterioration of the quality of roads.
6. Increased risks of man-made hazards, environmental degradation.

3. ECONOMIC ACTIVITY AT THE PCHP SITE AFTER THE COLLAPSE OF THE USSR

The main activity at the production association "Prydniprovsky Chemical Plant" in the period from 1949 to 1991 was processing of uranium raw materials in order to obtain a concentrate of natural uranium for the needs of the military-industrial complex of the former USSR. Due to the collapse of the Soviet Union and the subsequent decentralization processes, PA PChP ceased operation, without complying with the requirements for its elimination, conservation or redevelopment as an uranium object.

In conditions of insolvency of PA PChP, a restructuring procedure for the plant was introduced, which took place against the background of its bankruptcy, with the subsequent privatization of individual objects and their commercialization. In some radiation-contaminated territories and in the former workshops of the plant, various economic activities were introduced that are not peculiar to the uranium object, and production or commercial activities were carried out without observing the basic requirements for radiation safety. The decommissioning of the main facilities of the former uranium cycle by dismantling the most valuable equipment and decontamination of some buildings and territories was largely motivated by economic interests without due regard to compliance with the radiation safety requirements of workers and the environment. At the same time, separate state-owned enterprises, such as Zirconium, Smoly, Dniprodzerzhynsk Mineral Fertilizer Plant, were set up, with the responsibility for the safety of employees and the environment entrusted to their governing body.

From the memories of former PChP CEO Yuriy Korovin, who chaired the PChP for 24 years:

"The collapse of the USSR not only stopped work on the further development of all industries, but also "sentenced" PA "Prydniprovsky Chemical Plant", because all the production, in one way or another, was connected with Russia: supply of raw materials, energy resources, chemical reagents, markets for products, financing scientific programs.

In the first two years the company was transferred to the Office of Prospective Shipbuilding! ?? What kind of support could we talk about? Coming to resolve any issues, I was looked at as a "ram on a new gate". This was followed by a transfer to Goskomatom (Committee on Nuclear Energy Use of Ukraine) *.

Despite all efforts to preserve the PChP Production Association as a whole, it was not possible to do this – the company collapsed into separate factories *(" I am in pain for the collapse of PChP ", "Sobytie" newspaper, http://sobitie.com.ua/istoriya/yuriy-korovin-me-sick-for-spoil-phz).*

(*) In December 1991, the Ukrainian nuclear power plants were merged into the Ukratomenergoprom concern, which in January 1993 was reorganized into the State Committee on Nuclear Energy Use of Ukraine – Derzhcomatom of Ukraine.

In the late 1990s, the plant was restructured into several units. A number of individual companies were created on the basis of PChP, among which the most powerful were:

Company name	Year of registration	Direction of activity	Status as of today
SE "Prydniprovskyi chemical plant"	2000	The successor to the former PA PChP, no activity was carried out	Since 2000 in bankruptcy, since 2010 in termination
State Research and Production Enterprise "Zirconium"	1997	Production of nuclear-pure metal zirconium and hafnium, zirconium alloys with niobium. Zirconium and Hafnium Alloys and Alloys with Copper, Nickel, Aluminum, Iron, and wide range of Zirconium and Hafnium chemical compounds	Since 2000 in bankruptcy, since 2010 in termination
SE "Smoly"	1998	Production of ion-exchange materials: anionites, cation exchanger, sorbents for hydrometallurgy (extraction of uranium, gold, etc.), for chemical water treatment at thermal and nuclear power stations, for purification in drinking water preparation	Operational
SE "Agrofos"	1997	Production of components of mineral fertilizers	Till 2002
SE "Amofos"	1997	Production of components of mineral fertilizers	Till 2002
Prydniprovsky State Hydrometallurgical Plant	1998	In the 2000s, there was activity in the processing of ore from the Muzhievsky field in the Transcarpathian region.	In the phase of termination of activity, founder – the Ministry of Energy and Coal
Prydniprovsky plant of non-ferrous metals	1997	Recycling of scrap and waste containing precious metals. Refinement of platinum and platinum group metals. Technologies of induction smelting, refining, welding of precious metals. Recycling of scrap and platinum waste	The works were initiated in accordance with the Decree of the Cabinet of Ministers of Ukraine of March 15, 1999 No. 383. Bankruptcy since 2008, liquidated on 10.2016.
SE "DNIPRO VDM"	1997	Production of precious metals. Refinement of gold and silver with the manufacture of standardized ingots. Founder – the Ministry of Economic Development and Trade of Ukraine	Operational. The works were initiated in accordance with the Decree of the Cabinet of Ministers of Ukraine of March 15, 1999 No. 383
PJSC "Dniprovskyi Mineral Fertilizer Plant"	2002	It is a corporation of JSC Ukragrohimholding. Production of complex mineral fertilizers containing in one pellet nitrogen, phosphorus and potassium in different ratios	It was established through the merger of SE "Agrofos" and SE "Amofos". Operational
LLC "Polihimprom Plant"	Unknown	Recovery of sorted waste, recycling of catalysts for the production of sulfuric acid for the production of vanadium oxides	Activity on the stew a terminated in about 2014. LLC's assets were sold to the new owner

In 2000, to ensure the safety of activities in the territory and facilities of the former PA PChP; a specialized state enterprise "Barrier" was established on basis of laboratory D (Laboratory of Dosimetric Control) of PChP. Such uranium facilities as 5 tailings with uranium ore wastes and some of the most polluted industrial buildings (workshops) used in the uranium production technological chain were transferred to this SE.

Business entities which currently operate or own real estate on the industrial site:

- SE ”Barrier”, enterprise of the Ministry of Energy and Coal Industry, provides maintenance of the tailing storage facilities and the most polluted buildings of the former PA PChP, financed from the state budget;
- SE "38th Military Engineering and Technical Unit", the enterprise of the Ministry of Energy and Coal Industry, provides protection of the industrial site, is financed from the state budget;
- State Research and Production Enterprise "Zirconium" (in the stage of liquidation – sale of property);
- SE “Smoly”, enterprise of the Ministry of Energy and Coal Industry (production of ion-exchange resins);
- JSC "Dnipro Mineral Fertilizer Plant";
- LLC “Ecoplast” (production of thermal insulation materials);
- LLC “Marsa Plus” (owner of the facilities, no activity is carried out);
- PJSC “Ferrexpo” (the owner of the objects of the liquidated Prydniprovsky State Hydrometallurgical Plant, no activity is carried out);
- Dniprodzerzhynsk Chemical Plant, Separate Subdivision of SE “Eastern Mining and Processing Plant”. The unit was formed by restructuring the former State Zirconium Research and Production Company, hafnium production;
- LLC "Polihimprom", logistics services, wholesale warehouse of the LLC.

Following the cessation of uranium raw material processing at the PA PChP in 1992-1994, the Engineering Investigation Department of the State Specialized Design Institute (Moscow) conducted a radiation survey of the southern industrial site. In 1995, the"D" laboratory of PA PChP conducted a radiation survey of buildings 2B, 6, 104, 103, 95 (measurement of gamma radiation, α-, β-particle density).

In 1996, within the framework of the Gold of Ukraine Program, SE “UkrNDPRIPromtechnologies” developed a working project of an exploratory industrial facility for the processing of gold ores in the Muzhievsky deposit, Transcarpathian region.

Within the framework of the said project the following works were carried out:

- radiation survey of buildings 1, 2, 3, 4-5, 6, 28;
- Technical examination of the condition of building structures;
- Working documentation was prepared for the decontamination of the buildings of the Production Association "Prydniprovsky Chemical Plant".
- Various tasks identified as important and not completed:
- the gravel under the railway tracks in Building No. 1 (ore composition) has not been replaced;
- No decisions were taken to deactivate the bunkers;
- the foundation of the mill № 4 in Building № 4-5 was not deactivated;
- The problem of cessation of radon exhalation from “Zakhidne” tailing through an underground tunnel to Building # 6 was not solved.

On the production areas of SE "PGMZ" (Prydniprovsky hydrometallurgical plant) (buildings 1, 2, 3, 4-5, 6, 28) it was supposed to organize processing of polymetallic ores, but due to the difficult socio-political situation in the country the decision to start decontamination works was postponed indefinitely. After the restructuring of PA PChP, production facilities for the production of phosphate fertilizers (nitrophos, ammophos), located at the southern and northern industrial sites were transferred to CJSC “DZMD”, as well as the building of the former workshop № 22 (2B, 2G, 2E) and the railway workshop.

At this time PJSC “DZMD” carries out its production activity (phosphorous fertilizers) at the northern industrial site. Hazardous radioactive contaminated buildings (buildings 1A, 1B, 2B, 2B, 2E) are not used.

Following the restructuring, Polychimprom Plant LLC received Building No. 84 (production of Aluminum potassium sulphates), a sump No. 230, and Building No. 85 (raw material warehouse). To carry out waste processing activities of sulfuric acid catalysts for the production of vanadium oxides. The company ceased its active production activity after about 2010, and the plant's facilities were sold to a new owner who dismantled the equipment for scrap.

All buildings and structures of the former uranium processing facility require a full radiation examination. It is also necessary to evaluate the technical (engineering) condition of the building structures as their lifecycle (50 years) has passed.

4. LEGAL FRAMEWORK. REVIEW OF RELEVANT STATE REGULATIONS

Since its formation, Ukraine has been demonstrating its commitment and willingness to prioritize human and environmental safety through the use of nuclear energy to the world, the introduction of effective means of protection against potential hazards, in order to protect individuals, society as a whole and the environment from the hazardous effects of ionizing radiation spent fuel and radioactive waste generated in the nuclear fuel cycle. This is confirmed by the signing by Ukraine of the "Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management" of September 29, 1997 in the framework of the international movement under the aegis of the IAEA to improve radiation safety in the sector. The Joint Convention was ratified by the Law of Ukraine of April 20, 2000.

In accordance with the requirements of the Joint Convention, Ukraine recognizes the highest priorities for radiation safety for workers, the general public and the environment, in particular for the management of uranium heritage. Thus, Article 12 of the Joint Convention "Existing installations and practices in the past" states that each Contracting Party shall take appropriate measures in due time to consider:

(ii) past performance to determine the need for any intervention to achieve radiation protection, whereas the reduction of adverse effects resulting from dose reductions should be sufficient to justify the harm and costs, including social, intervention.

The basic law governing uranium activity is the Law on Uranium Ore Extraction and Processing (1997). According to this Law it is required that the operation of uranium objects can be terminated by their elimination or re-profiling for production of other products, as well as temporary suspension (conservation) in accordance with the procedure established by the legislation of Ukraine. Liquidation, conversion or conservation of uranium objects shall be carried out within the projects approved in accordance with the procedure established by the legislation of Ukraine. At the same time, there is no activity to rehabilitate the former objects of uranium heritage, and there is no definition of such activity in this law. It is envisaged that the existing legislative gaps will be minimized by the adoption of a new Law ”On the Management of Nuclear Heritage Sites”, a draft law under development. The work on the draft law is being carried out within the framework of the project with the financial support of the EC. This law defines the basic principles and requirements for the management of the sites of nuclear heritage and for the implementation of remedial measures in the existing radiation situations. The purpose of this Law is to ensure a unified state policy in the field of management of sites of nuclear heritage in the territory of Ukraine, protection of modern and future generations from the hazardous effects of radiation exposure, preservation and dissemination of information about sites of nuclear heritage, activities to bring them to an ecologically safe state and achieve results.

General requirements for the safety of conducting activities in the field of mining and processing of uranium ores, as activities in the field of nuclear energy use and in the conditions of ionizing radiation are defined in such legislative and regulatory acts:

- The Law of Ukraine “On the Use of Nuclear Energy and Radiation Safety” of February 8, 1995 No. 39;
- The Law of Ukraine “On Protection from the Effect of Ionizing Radiation” of January 14, 1998, No. 15;
- The Law of Ukraine “On Permitting Activities in the Field of Nuclear Energy Use” of January 11, 2000, No. 1370;
- The Law of Ukraine "On Physical Protection of Nuclear Installations, Nuclear Materials, Radioactive Waste, Other Ionizing Radiation Sources" of 19.10.2000 No. 2064;
- Radiation Safety Standards of Ukraine (SRSU-97). State hygiene standards (SHS 6.6.1.-6.5.001-98). Approved by the Resolution of the Chief State Sanitary Doctor of Ukraine No. 62 of December 1, 1997;
- Ukraine's radiation safety standards. Addition: radiation protection from sources of potential radiation SRSU-97/D-2000. State hygiene standards (DGN 6.6.1.-6.5.061-2000). Approved by Resolution No. 116 of the Chief State Sanitary Doctor of Ukraine dated 12.07.2000;
- "Basic Sanitary Rules for Ensuring Radiation Safety of Ukraine", approved by the order of the Ministry of Health of Ukraine dated February 2, 2005, No. 54, registered at the Ministry of Justice of Ukraine on May 20, 2005 under No. 552/10832;
- Requirements and security conditions (Licensing conditions) for carrying out uranium ore processing activities, approved by the Decree No. 101 of the SNRC of May 27, 2015, registered with the Ministry of Justice of Ukraine on June 12, 2015, 700/27145;
- Methodological instructions “Radiation and hygienic regulation of work on objects of liquidated Prydniprovsky chemical plant (PCP)”, approved by the order of the Ministry of Health of Ukraine dated January 11, 2007 # 3;
- Procedure for issuing permits for the use of lands and reservoirs located in the sanitary protection zone of a nuclear installation, an object intended for radioactive waste management, a uranium object (Order of the State Nuclear Regulatory Inspectorate of Ukraine 16.01.2012, № 8, registered in the Ministry of Justice of Ukraine on February 6, 2012 under No. 181/20494);
- Requirements for the administrative control of uranium sites within the limited exemption from regulatory control (Order of the State Nuclear Regulatory Inspectorate of Ukraine 21.02.2017, No. 60, registered at the Ministry of Justice of Ukraine on March 15, 2017 under No. 353/30221) ;

- Requirements for the report on the safety analysis of uranium ore processing activities, approved by the Ministry of Energy Resource Order No. 90, 11.03.2001, registered at the Ministry of Justice of Ukraine on 27.03.2001 under No. 278/5469;
- Procedure for exemption of radioactive materials from regulatory control in the framework of practical activity, approved by the Order of the State Committee for Nuclear Regulation of Ukraine No. 84 of July 1, 2010, registered at the Ministry of Justice of Ukraine on August 20, 2010 under No. 718/18013;
- Procedure for conducting the state examination of nuclear and radiation safety (NP 306.1.107-2005), approved by the Decree of the SNRCU on 21.02.2005 No. 21, registered at the Ministry of Justice of Ukraine on 07.04.2005 No. 372/10652;
- General requirements for the management system of activities in the field of nuclear energy use (NP 306.1.190-2012), approved by the Decree of the SNRCU No. 190 of December 19, 2011, registered at the Ministry of Justice of Ukraine on January 10, 2012 under No. 17/20330;
- Procedure for conducting training and testing of knowledge on radiation safety issues in personnel and officials of subjects of certain types of activity in the field of nuclear energy use, Order of the SNRCU No. 143 dated 02.10.2014, registered at the Ministry of Justice of Ukraine on 02.12.2014 No. 1549/26326.

Regulation of emergency response and physical protection activity is sufficiently present in the Ukrainian regulatory framework and is not covered in this review.

According to the Law of Ukraine "On Permitting Activities in the Field of Nuclear Energy Use" (2000), such activities as uranium ore processing are subject to mandatory licensing.

General radiation protection limits in force in Ukraine are similar to international safety standards and are set out in two key radiation protection documents: Radiation Safety Standards of Ukraine 1997 (SRSU-97) as amended by Radiation Safety Standards Supplement of Ukraine: Radiation Protection from Sources of potential exposure (SRSU-97/D-2000) ", which in particular contain the main principles and approaches to limit potential exposure to radioactive waste storage facilities released in 2000, and the" Basic Sanitary Rules for the Radiation Safety of Ukraine "(2005) BSRU-2005.

Chapters 16 and 17 of BSRU-2005 describe the rules of radiation safety in the case of radiation from sources of natural origin. These rules, in particular, apply to all processes of uranium mining and processing, and workers engaged in these types of production qualify as personnel, if working with these sources is an integral part of radiation and nuclear technology. According to SRSU-97, such personnel belongs to category A.

Pursuant to Clause 17.3 (OGPU-2005), in the context of practical activities that do not contain works and radiation-nuclear technologies, personnel may also be exposed to additional irradiation by man-made sources of natural origin. In this case, dose criteria are established for the need to control and account for the natural component of personnel exposure, and such personnel may belong to category B (in accordance with SRSU-97).

The Law of Ukraine “On Radioactive Waste Management” (1995) provides for general provisions and principles of state policy on radioactive waste management in all sectors, which generally comply with international principles and recommendations. At the same time, this law does not provide specific requirements for the management of waste with radioactivity, which are considered by SRSU as a special category of ”technological-reinforced sources of natural origin” (TRSNO) with appropriate specific requirements and safety criteria.

Moreover, there is still a legal framework in Ukraine regarding the impact on the human body of TRSNO, it does not contain detailed recommendations for eliminating problems related to the activities of former objects of uranium ore extraction and processing and its consequences. In particular, there are still no clear requirements to help to establish the criteria of tailings remediation and decontamination of former uranium objects. There are no clear recommendations in the regulatory framework regarding the methodology for safety and environmental impact assessment or specific requirements for the characterization of the uranium site, the extent and types of radioecological monitoring.

Over the last decade, there have been several attempts to fill in the gaps in regulatory and safety criteria and reclamation requirements. In particular, at the request of the regulatory body, experts from the Institute of Hygiene and Medical Ecology (now the Human Health Institute) have developed requirements and recommendations for control levels and safety criteria that should be applied when conducting activities within the PChP. On the basis of this document, the Ministry of Health, by its Decree No. 3 of March 11, 2007, approved the document: Guidelines “Radiation-hygienic regulation of work at the facilities of the liquidated Prydniprovsky chemical plant (PChP)” (MB 6.6.1.2.6 .-136-2007). This document is designed to ensure adequate radiation safety and radiation protection for persons working at Barrier during the rehabilitation and decontamination of hazardous facilities of a liquidated PChP production association and workers in other PCP territories. It also provides recommendations for the introduction of a special monitoring program for the territory of the former Prydniprovskyi Chemical Plant and surrounding areas. According to this document, the following dose limits have been set and are currently applicable to the PChP site:

– 20 mSv/year for Category A employees (”Barrier” enterprise personnel);

– 5 mSv/year for Category B employees (i.e. for any other personnel of enterprises operating in the territory but not involved in waste management, decontamination or monitoring);

– 1 mSv/year for the population.

Control levels for the receipt of radioactive substances through the respiratory system, water intake are also set out in document 6.6.1.2.6.-136-2007. The main drawback of this document is that it has not been registered with the Ministry of Justice of Ukraine and is therefore not required to be performed by all entities on the PChP. In addition, the document does not contain requirements and criteria governing levels of contamination of materials, scrap, etc. that are exported outside the PChP.

In order to provide methodological assistance within the framework of the international ENSURE-II technical assistance project, drafts of separate documents have been developed aimed at eliminating gaps in the area of rehabilitation activities, such as:

– Requirements to ensure the safety of decommissioning and the safe condition of former uranium facilities (Draft, 2011).

– Recommendations on observance of radiation safety for the period of implementation of rehabilitation measures on the territory of the former industrial site of PJSC "Prydniprovsky Chemical Plant" (Draft, 2012).

The documents have been prepared in the light of international best practice and are based on the recommendations of Publications 101, 103 and 104 of the International Commission on Radiation Protection and also comply with IAEA recommendations. Unfortunately, the above mentioned documents have not acquired official status in the conditions of regulatory deficit and still remain drafts.

It also draws attention to the fact that one of the main documents determining the requirements for the preparation of a report on the analysis of uranium ore processing activities was dated 2001. Given even a small progress in the regulatory support of this activity, this document is outdated.

The latest document, developed in 2017 with the financial support of the Norwegian Radiation Protection Authority, is "Requirements for the administrative control of uranium sites as part of their limited exemption from regulatory control."

Thus, a number of legislative and regulatory acts regulating the rehabilitation activities of former uranium objects are absent in Ukraine and in need of priority development.

5. STATE PROGRAMS FOR BRINGING HAZARDOUS OBJECTS OF THE PRODUCTION ASSOCIATION "PRYDNIPROVSKY CHEMICAL PLANT" TO AN ECOLOGICALLY SAFE STATE AND THE RESULTS OF THEIR IMPLEMENTATION

Ukraine got involved in the issue of bringing the Soviet Union's uranium heritage to a safe state only in 10 years after the independence. By this time, a certain legislative and regulatory framework for the use of nuclear energy and radiation safety, including requirements for the safety of carrying out uranium ore processing activities, had been developed and a state nuclear regulatory authority had been established and developed. Uranium ore processing activities were subject to the Law on Permitting Activities in the Field of Nuclear Energy Use.

5.1. The state program for bringing hazardous objects of the production association "Prydniprovsky Chemical Plant" to an ecologically safe state and ensuring protection of the population from the hazardous effects of ionizing radiation for 2005-2014

The first governmental decision to solve PChP problems was the adoption of the State Program for bringing dangerous objects of the production association "Prydniprovsky Chemical Plant" to an ecologically safe state and ensuring protection of the population from the hazardous effects of ionizing radiation for 2005-2014 (Resolution of the Cabinet of Ministers of Ukraine of 26.11 .2003, № 1846).

Given the social need to maintain the ecological equilibrium and radioecological status of the uranium objects of the Prydniprovsky Chemical Plant, the Program envisaged the implementation of such measures:

– to create a system of radiation monitoring on uranium objects and informing the population about the radioecological state of the environment;

– to carry out studies aimed at studying the content of natural radionuclides in the areas of the location of uranium tailings and storage facilities, improving methods of preventing the migration of radionuclides into natural ecosystems;

– to create data banks of tailings and storage facilities for uranium production;

– to carry out cleaning works and decontamination of the territory of the industrial site of the Prydniprovsky Chemical Plant and storage facility for uranium production of Base C;

– to dismantle Building No. 103, decontaminate and dismantle technological pipelines;

– to carry out filling of exposed radioactively contaminated sites in the territory of uranium production waste of base C and the surface of the Southwestern tailing storage facility, of the dried bottom areas in the territory of the first section of the Sukhachivka tailing to prevent radioactive spread;

– to prepare methodological developments and scientific recommendations on the management of uranium production waste;

– to amend the legislation.

The estimated need for funds for the implementation of the Program was determined at UAH 25.26 million (US $ 4.7 million at the time). At the same time, UAH 15.02 million (2005-2010) were allocated for the measures to minimize the impact of uranium objects on the environment and the state of health of the population, and about UAH 7 million –b for the organization and conduction of radioecological monitoring since 2010 .

Results of the Program implementation

Considering the conclusions of the audits conducted by the Auditing Chamber and the SNRCU, the results of the Program implementation should be considered unsatisfactory.

Thus, ***in the Report of the Auditing Chamber of Ukraine for 2008 on the results of the audit of the use of the state budget funds aimed at the implementation of the State program of bringing hazardous objects of the Production Association "Prydniprovsky Chemical Plant" into environmentally friendly safe condition and protection of the population from the hazardous effects of ionizing radiation in 2005-2007 and the first half of 2008,*** it is mentioned that:

Due to the failure of the Ministry of Fuel and Energy to adopt the unified strategic plan of actions, carried out during 2005-2007 and the first half of 2008, measures at the uranium production facilities of the former production association "Prydniprovsky Chemical Plant", contracted by SE ”Barrier”, were local in nature. None of the six program measures has been completed to minimize the impact of uranium objects.

Continuous radiation monitoring has not been organized, complete inventory of all potential sources of radioactive contamination in the territory of the former production association "Prydniprovsky Chemical Plant" and their certification has not been performed.

SE ”Barrier”, together with the contractors selected by it on a tender basis, did not create a single database of radiation hazardous objects and a proper regime of non-distribution of contaminated waste beyond these territories and exclude the possibility of free access of the population to hazardous objects, which led to abduction of 6 units of radiation contaminated containers.

In the period under review, UAH 11.2 million or 86.3% of the revenues approved by the budgetary allocation plans were used for the implementation of the Program.

The 2011 Auditing Chamber Report on the implementation of the Program concludes:

- The Ministry of Fuel and Energy of Ukraine as the state customer, organizer and responsible executor of the state programs for bringing into operation the objects of the production association "Prydniprovsky Chemical Plant" (hereinafter – PA PChP) and the main manager of the state budget funds allocated for this purpose, in 2008-2010, did put in place any effective system for bringing hazardous objects of radiation pollution into an environmentally safe state.

- As a result, the envisaged program measures were not fulfilled and UAH 26.7 million, or over 70% of the funds received during 2008-2010 from the state budget for the implementation of the relevant state programs, were used inefficiently and in violation of the law.
- Thus, radiation contaminated PA PChP facilities remain an area of high danger, adversely affect the environment and present a potential threat to the health of nearly 300,000 residents of Dniprodzerzhynsk and surrounding settlements, and as a result of possible landslides and radioactive substances in Dnipro water – a large part of the population of Ukraine.
- Addressing this problem requires the urgent determination of the final status of technologically dangerous objects of PA PChP facilities and the introduction of an efficient system at the state level to bring them into an environmentally sound condition.

In the statement of the Decree of the Board of the SNRCU of May 27, 2008, No. 16, the results of the Program implementation indicated:

At present, the extent of research done does not allow us to make sound decisions about further ways of eliminating the uranium objects of the former PA PChP. The current technical and radiation status of the tailing storage facilities and the level of their physical protection do not meet the requirements for radiation safety. Dosimetric control of the territory and objects, with the exception of cargo control at the exit from the territory of the former PA PChP, is practically not carried out; free access of workers is possible on radiation-hazardous objects, and on objects located outside the site – the population. In the summer of 2007, there was a theft of radiation contaminated equipment (12 tonnes total weight) used in the uranium ore processing and the incident was informed to the IAEA.

It should be noted that the lack of state-regulated provisions on the status of the territory of the former PA PChP uranium production significantly affects the efficiency of the management of the systems of protection and dosimetric control, aimed at preventing the illegal distribution of radioactively contaminated materials outside the site of the former PA PChP, limiting the impact of the former PA PChP site the city's population, the environment, and the staff of businesses.

The Board decided to consider the state of fulfilment of the tasks of the State Program for bringing dangerous objects of PA PChP into ecologically safe state and ensuring protection of the population from the hazardous effects of ionizing radiation for 2005-2014 by the Ministry of Fuel and Energy **as unsatisfactory**.

Almost the only effective and efficient measure undertaken within the framework of this Program is the dismantling of the contaminated pipelines from the overpasses, located near the buildings 103 and 102 (the building of the existing main production shop of SE “Smoly”). In total, about 5,000 ppm of contaminated process pipelines with an exposure intensity of 2 to 10 μSv/h was dismantled. In addition, within the framework of the business activity of SE “SchidtGZK”, about 200 tons of unused uranium was exported from the former uranium ore (Base C facility), which also contributed to the improvement of the ecological situation of the settlements of Taromske and Gorky located near the storage facility. At the same time, the reclamation of the territory of Base C after the completion of the works was not carried out properly.

The Decree of the Cabinet of Ministers of Ukraine No. 1029, 2009 abolished the Program; the same Resolution approved the new State target environmental program for bringing uranium objects of the Production Association "Prydniprovsky Chemical Plant" into safe condition, with a 5-year term of validity (2010-2014)

Due to the imperfection of the first Program for 2005-2014 and the shortcomings in its implementation by the Government in 2008 and 2009, some decisions were made aimed at improving the environmental and social status of Dniprodzerzhynsk. Such decisions were:

”Plan of the priority measures for the period of improvement of ecological status of Dniprodzerzhynsk for 2009”. Approved by the decree of the Cabinet of Ministers of Ukraine of November 12, 2008 No. 1425-p;

"Plan of the Measures to Ensure Environmental Safety of Dniprodzerzhynsk and Improve Social Protection of the City Population", approved by the Decree of the Cabinet of Ministers of Ukraine dated August 11, 2010 № 1628-р.

"Plan of the Priority Measures for the Improvement of the Ecological Status of Dniprodzerzhynsk for 2009", in addition to duplication of the main activities of the Program, envisaged measures aimed at ensuring the protection and physical protection of hazardous objects of the plant and regime territory”.

The major part of the Dniprodzerzhynsk Environmental Security Measures Plan and Improvement of Social Protection of the Population of the City concerned the social sphere.

Regarding these Government Action Plans, the Report of the Auditing Chamber of Ukraine 2011 states: “... did not contain scientifically sound ways of solving problems, a specific list of objects on which the relevant works should be carried out, or the criteria for their selection. Separate measures of the regular programs are not compatible with the measures of the previous programs, and the priority environmental measures in the city of Dniprodzerzhynsk are duplicated with the measures on the objects of the former production association."

5.2. State Target Environmental Program for Safeguarding Uranium Objects of the Production Association “Prydniprovsky Chemical Plant”

The State Target Environmental Program for Safeguarding of Uranium Objects of the Production Association ”Prydniprovsky Chemical Plant” was adopted by the government in 2009, with a term of implementation from 2010 to 2014 (Decree No. 1029 of the Cabinet of Ministers of Ukraine, 2009). .

The implementation of the Program was supposed to enable:

– elimination of uranium objects or bringing them into ecologically safe condition, protection of the population from the hazardous effects of ionizing radiation, protection of the environment and create the foundations for the sustainable development of the territories;

- prevention of the occurrence of radiation accidents related to the further storage of uranium production waste in tailings not adapted for this purpose;
- minimizing of the costs of organizing the physical protection of uranium objects and maintaining them in good technical condition;
- return of the contaminated plant area (35 hectares) to commercial use;
- reduction of the costs of enterprises engaged in industrial site activities related to providing radiation protection to personnel (350 persons);
- reduction of the level of social tension among the residents of Dniprodzerzhynsk;
- creation of additional jobs at specialized facilities elimination enterprises;
- substantial reduction of the risk of radiation accidents associated with the long-term storage of uranium waste, unauthorized access to it and possible attempts to use radioactively contaminated materials for criminal purposes.

The estimated funding for the Program was UAH 84.3 million (about USD 10.5 million at the NBU rate).

Results of the Program implementation

The only positive result of the implementation of the Program was the restoration work of the Southwestern tailing storage facility.

The results of the efficiency of the use of the state budget funds for the implementation of measures for the implementation of the State Target Environmental Program for the Safeguarding of Uranium Objects of the Production Association "Prydniprovsky Chemical Plant" in 2011-2013 are stated in the Auditing Chamber of Ukraine Report for 2014:

- The main objective of the State Program – elimination of the negative environmental consequences of the activity of PJSC “Prydniprovsky Chemical Plant” for bringing hazardous uranium objects into ecologically safe state and protecting the population and the environment from the hazardous effects of ionizing radiation – **has not been achieved**.
- Despite the fact that at the final stage of its implementation, ”Barrier” State Enterprise utilized UAH 22.8 million and implemented 34 of the 43 identified measures, no decontamination of the contaminated area was carried out.
- There are no new rules for the elimination, conservation and conversion of radioactive ore mining and processing enterprises at the time of the audit, and the previous ones were approved in 1991 and have not been adapted to IAEA requirements.
- The audit also found that, in the context of limited funding for the Programme's activities in 2011-2013 (69.4% of the volumes determined by it) and in the absence of control by the Ministry of Energy and Coal Industry as a state customer, organizer and responsible executor of the Program, the Barrier SE allowed the dispersion of budget funds for non-priority measures, the results of which were not implemented during the implementation of rehabilitation measures at uranium facilities.

- At the same time, UAH 15.6 million was used for organizing the activities of ”Barrier” State Enterprise in 2011-2013, which is 1.7 times higher than the amount determined by the Program. At the same time, in 2013, the Company practically did not implement the Programme's activities.

The Report on the results of the audit of the effectiveness of the management of the Ministry of Energy and Coal Industry of Ukraine of state-owned objects in the nuclear-industrial complex, approved by the decision of the Auditing Chamber of 17.09.2016 No. 17-5

The State Target Environmental Program for the Safeguarding of Uranium Objects of the Production Association "Prydniprovsky Chemical Plant, which was calculated for 2010-2014, with financing amount of UAH 84.3 million, financed by budget funds in the amount of UAH 24.2 million, or by 28, 7%. In 2013-2014, the company used UAH 8.6 million of budget funds to organize the provision of the activity of the State Barrier and payment of land tax. Capital expenditures were not made. In 2015, due to the completion of the aforementioned program and the absence of a new one, no funds from the state budget were allocated.

The operation of the ”Barrier” SE in 2013-2015 was ineffective and the Ministry of Energy and Coal did not take all measures to ensure the stable operation of the enterprise.

The SNRCU's position on the results of the work on bringing the former PA PChP objects into an environmentally safe state is set out in the Minutes of the Board meeting dated 14.10.2015 No. 14, namely the Board notes:

During 2013-2014, the SE ”Barrier” carried out its licensed activities within the framework of the State Target Environmental Program for the Safeguarding of Uranium Objects of PA PChP (hereinafter – the State Program) approved by the Cabinet of Ministers of Ukraine on September 30, 2009. No. 1029. Currently, the State Program has expired. The issue of prolongation of the State Program's validity has not been resolved so far.

The termination of the State Program resulted in the actual termination of the financing of SE “Barrier” from the state budget in 2015. This, in turn, led to numerous violations of SE “Barrier” of requirements of norms, rules and standards on radiation safety and license conditions of series OJ No. 000927, which was fixed in the act of inspection dated 24.09.2015 № 21-28/64.

SE “Barrier” is not provided with financial and material resources, personnel to maintain the level of safety stipulated by radiation safety norms, rules and standards, as well as the conditions of the license series OJ No. 000927 of 19.06.2013 for the right to conduct uranium processing activities ores, which is in violation of the requirements of Art. 32 of the Law of Ukraine “On Nuclear Energy Use and Radiation Safety”.

The SNRCU License Commission at its meeting on 26.10.2015 decided to recommend suspending the license series OJ No. 000927 of 19.06.2013 for the right to conduct uranium ore processing activities.

The Board DECIDED:

1. To declare the state of affairs in bringing the former PA PCP objects into an environmentally sound condition **is unsatisfactory**.

2. To recognize the inability of Barrier SE to carry out activities within the scope of the license series OJ No. 000927 of 19.06.2013 for the right to conduct uranium ore processing activities in the part of the termination of uranium facilities of the former PA PChP.

5.3. State Targeted Environmental Program for Bringing Uranium Objects of the State Enterprise ”Barrier” for the Period 2015-2017 (Decree of the Cabinet of Ministers of Ukraine of December 23, 2015 No. 1091)

The State Target Environmental Program for the Safeguarding of the Uranium Objects of the State Enterprise ”Barrier” for the period 2015-2017 was approved by the Cabinet of Ministers of Ukraine Decree No. 1091 of 23.12.2015. According to the Program, its implementation will enable:

– to prevent radiation accidents while performing work on uranium objects;

– to restore the stable operation of the uranium facilities maintenance company with the maintenance of material, personnel, information and technical resources;

– to develop and implement a long-term strategy;

– to ensure the participation of domestic enterprises and organizations in the development of a long-term strategy, an objective analysis of the state of sources of potential radiation exposure, ways of generating doses of radiation personnel who will be involved in the implementation of projects to safeguard the uranium objects and the population;

– to develop a plan of priority actions to safeguard uranium objects, to target and economically use budget and international technical assistance funds to solve the problem;

– to reduce the social tensions among the population about the hazardous effects on human health and the state of the environment of radioactive and chemical pollution, the sources of which are uranium objects.

Funding for the Program was estimated at $ 67.74 million ($ 2.8 million at the NBU rate). Considering the time of approval, the practical implementation and funding of the program began in 2016.

Results of the Program implementation

No practical results of the implementation of the Programme's activities during 2016-2017 have been received. Funds from the partial financing of the Program were mainly spent on the maintenance of the SE ”Barrier” staff, carrying out some radiation monitoring work, paying off past debts and taxes. During these 2 years the company failed to recover the lost license. As for the lawfulness of the use of part of the funds aimed at the implementation of the Program, criminal cases were instituted in 2018.

The Report on the results of the audit of the effectiveness of the management of the Ministry of Energy and Coal Industry of Ukraine of state-owned objects in the nuclear-industrial complex, approved by the decision of the Auditing Chamber of 17.09.2016 No. 17-5, states:

One week before the end of the 2015 fiscal year, the Government approved the State Target Environmental Program for the Safeguarding of Uranium Objects of ”Barrier” State Enterprise for 2015-2017. The planned amount of financing is UAH 67.7 million (including from the state budget – UAH 49.9 million, from other sources – UAH 17.8 million). Given the timing of the approval of this program, its funding could be implemented only in 2016. The State Budget Law for 2016 approved assigning of UAH 18.8 million. However, as of September 1, 2016, no funds were received.

In October 2018, the results of the implementation of the Program were considered at a meeting of the Verkhovna Rada Committee on Environmental Policy, Environmental Management and Consequences of the Chornobyl Catastrophe (Minutes of the Committee meeting No. 80 dated 16.10.2018). The information of the Information Administration of the Verkhovna Rada of Ukraine's Office dated 19.10.2018 states:

According to the Ministry of Energy and Coal Industry of Ukraine and the Ministry of Finance of Ukraine, the total volume of financing for the period 2015-2017 under the budget program of the CPCWC 1101480 "Safeguarding of uranium facilities" amounted to 24 236 thousand UAH, or 48,6% from the approved amount of budget funds.

The program envisaged the implementation of 24 activities within 4 tasks, of which only 4 activities were fully completed, 6 activities were not fully implemented and 14 activities were not carried out.

According to the results of the state supervision on the conditions and requirements of the license, the State Nuclear Regulatory Inspectorate of Ukraine concluded that the SE ”Barrier” carried out its activities with numerous violations of the requirements of the legislation of Ukraine in the field of nuclear energy use, which led to numerous prescriptions, penalties and terminations of the license.

This situation jeopardized the implementation of both the Program and the international technical assistance project “Implementation of Emergency Measures at the Prydniprovsky Chemical Plant” (currently under implementation and in which the SE ”Barrier” is defined as the Beneficiary).

The analysis of the information on the state of implementation of the State Target Environmental Program for bringing the uranium objects of the state enterprise ”Barrier” gives reason to state, that the **ultimate goal of the Program has not been achieved. The development and implementation of the state program did not become an effective mechanism in addressing the issue of safeguarding uranium objects**.

Following the results of consideration of this issue the Committee recommended to the Cabinet of Ministers of Ukraine, the Ministry of Finance of Ukraine, the Ministry of Energy and Coal Industry of Ukraine and the Ministry of Ecology and Natural Resources of Ukraine:

- to strengthen the departmental control over the activity of the SE ”Barrier” as the main contractor for the ecological safeguarding of the objects of the former PChP;
- to urgently take the necessary measures to restore the ability of the Barrier SE to carry out licensed activities with unconditional adherence to the requirements of radiation safety norms, rules and standards and license conditions;

– consider the feasibility of re-subordination to the SE ”Barrier”;

– to develop a new State Targeted Environmental Program to safeguard the uranium facilities of the Barrier State Enterprise, eliminating any shortcomings of the previous programs and complying with applicable legislation in the field of development and implementation of the state target programs.

5.4. State Targeted Environmental Program of Priority Measures for Safeguarding the Objects and Site of Former Uranium Production of the Production Association ”Prydniprovsky Chemical Plant” for 2019-2023

Despite the understanding of the problem by the authorities concerned and the specific assignments, during 2018 and almost 3 quarters of 2019, the new State Program on PCP was not approved.

The State Target Environmental Program of the Priority Measures for the Safeguarding of the Objects and Site of the Former Uranium Production of the Prydniprovsky Chemical Plant Production Association for 2019-2023 was approved by the Governmental decision of August 21, 2019 No. 756. The main purpose of the Program is to prevent any emergency on the territory of Ukraine as a result of the deterioration of the ecological state on the territory of the former production association "Prydniprovsky Chemical Plant", conducting constant monitoring of radiation, safeguard of uranium and thorium ore processing facilities of this production association, which are currently on the balance sheet of the state-owned eenterprise ”Barrier”, technical supervision and priority measures to safeguard the uranium facilities, and to ensure the creation of safe living conditions in Dnipropetrovsk region. The estimated amount of financing of the Program at the expense of the state budget is about UAH 250 million (about USD 9.5 million at the NBU rate).

According to experts, the Program has a significant drawback, since its measures do not provide for the direct maintenance of the SE ”Barrier” staff and its infrastructure, taxes, etc., which will not stabilize the operations of the site operator. In addition, the Program for the next 5 years does not envisage priority rehabilitation work at the Base C repository, which is located directly near densely populated areas.

5.5. Conclusions

The solution to the problem of ecological safeguarding of the PA PChP uranium objects through the implementation of state targeted programs in Ukraine at the state level was implemented in 2003, or 12 years after independence. During this time, the Government adopted 4 governmental programs that were in place for the years 2003-2014, 2016-2017. In 2015, 2018 and almost all 2019, the Programme's activities were not envisaged, implemented or financed. It is envisaged that the full implementation of the latest state program measures will start in 2020.

It was foreseen to allocate a total of about $ 18 million for the governmental program decisions. At the same time, the actual level of funding for individual programs was 30-70% of what was planned at different times. The main purpose of all the approved programs was:

– to eliminate uranium objects or ecologically safeguard them;

– to prevent radiation accidents while working on uranium objects;

– to support for the proper technical condition of the uranium facilities;

– to organize and conduct radioecological monitoring.

All these measures were of primary/stabilization nature and emergency response, and the rehabilitation direction as such was practically not envisaged by the programs. The results of numerous audits carried out by the Auditing Chamber of Ukraine indicate that none of the aims of three Programs has been achieved or that the implementation of state programs has not become an effective mechanism in addressing the problem of ecological safeguarding uranium objects. It is difficult to disagree with the Accounting Chamber's findings regarding the lack of a long-term strategy for ecological safeguarding of PChP site. It is the lack of an approved strategy for ecological safeguarding of PChP that has resulted and results in an inefficient use of the limited amount of budgetary resources, and the lack of continuous activities from program to program.

This long-term strategy, based on the best European experience, was first developed during 2015-2016 by a Consortium of: Facilia AB, WISUTEC GmbH, WISMUT GmbH, C&E GmbH, within the framework of the European Commission project U4.01/10G strategies, technologies) for the reclamation of the territory of the former uranium object "Prydniprovsky Chemical Plant". According to the developed strategy, the total cost of rehabilitation works, including the costs of infrastructure waste management rehabilitation activities, is around € 250 million over 10 years. At present, the strategy has been approved by the project beneficiary, the Ministry of Energy and Coal Industry, but has not yet been implemented as a governmental decision.

Program breaks and unstable funding, along with other management weaknesses, also made it impossible to carry out continuous radio-ecological monitoring as a basis for further management decisions on possible rehabilitation work.

Based on the above, it is considered appropriate:

– to change the ideology of developing government programs for ecological safeguarding of the PChP site and introducing a new approach based on the government-approved PChP rehabilitation strategy as an object of uranium heritage;

– Significant improvement in the status of operation with involvement of the international donor assistance.

6. INTERNATIONAL PROJECTS

6.1. Overview of Major Prior Projects for the Risk Assessment of Objects at the PCP Site

Over the last decade, national rehabilitation programs at PA PChP have been assisted by a number of international projects, including Swedish Government-funded technical assistance projects (ENSURE-I and ENSURE-II projects), IAEA technical cooperation projects, and projects under the "International Program of the European Union as an Instrument for Nuclear Safety Cooperation ”. Brief information on major projects is given below.

Project name	Time of implementation	Sources of funding	The volume of financing,	Implemented by
ENSURE-I	2008 – 2009	Swedish agency SIDA	Not known	Facilia AB, Sweden
ENSURE-II	2010 – 2013	Swedish agency SIDA	Not known	Facilia AB, National Academy of Sciences of Ukraine
ISIAB U4.01/10G Project, Development of a method (strategy, technology) for the reclamation of the territory of the former Uranium object of the Prydniprovsky Chemical Plant. Project code: EuropeAid/134871/C/SER/UA Project No: NSI/2014/291-798	04.2014 – 12.2016	European Commission, through JSO and STCU	Not known	Facilia AB, Sweden in Consortium with: WISUTEC Umwelttechnik GmbH, Germany WISMUT GmbH, Germany C&E Consulting and Engineering GmbH, Germany
EC Project: U4.02/16B1, “Implementation of Emergency Measures at the Dnipro Chemical Plant”. ”Capacity Building/Radiation Protection/ Engineering Design and Oversight of Immediate Security Management Measures”	11.2017 – ongoing	European Commission, through JSO and STCU	1 001 056	Consortium Facilia AB, WISUTEC GmbH, GEOS GmbH, Ukratomprylad Corporation (Ukrainian Atomic Instruments and Systems Corporation), under the direction of Facilia AB
Risk Reduction, Control of Radioactive Contamination and Improvement of Environmental Monitoring System at the Site of the Dnipro Chemical Plant in Ukraine	10.2019 – ongoing	Norwegian Radiation and Nuclear Safety Authority (DSA)	Not known	ÅF Norway, ÅF Ukraine

6.1.1. ENSURE-I

The ENSURE-I project (Assessment of Risk to Human Health and the Environment from Uranium Tailings In Ukraine) was implemented in 2008 with the support of the Swedish International Development Cooperation Agency – Sida and the Swedish Radiation Safety Authority (SSM). The beneficiary of the project was the Ministry of Energy and Coal Industry of Ukraine. The Swedish consultant was Facilia AB. The focus of the project was on the promotion of safety assessment studies and the identification of radiation risks for personnel in the PA PChP (Sukhachivka Tailings were not covered by the project). The evaluation used a set of models and data published by the Federal Ministry of Environment, Nature Conservation and Safety of Nuclear Reactors in Germany (BMU, 1999) [1]. These models have previously been used to assess the radiological hazard of sites contaminated as a result of uranium mining or processing activities in East Germany under the Bismuth Project. The models were implemented in a special computer tool based on Ecolego software developed by Facilia. ENSURE-I's work has allowed the identification of contaminated sites presenting high potential risks (e.g., contaminated buildings, points of increased radioactivity), as well as identifying major routes of exposure.

6.1.2. ENSURE-II

ENSURE-II was a continuation of the ENSURE-I project. A key theme of the ENSURE-II technical assistance project, funded by the Swedish agency SIDA in 2011-2013, was "...developing and applying a PA PChP site safety assessment methodology to provide a basis for the site rehabilitation...” The project was implemented by Facila AB in cooperation with Ukrainian consultants (Ecomonitor LLC) and institutes of the National Academy of Sciences of Ukraine. The ENSURE-II project resulted in the development of sophisticated computer tools and software libraries based on Ecolego software for simulating radionuclide transfer and analysis of dose estimation. Computer tools have been specifically designed to monitor the transfer of radionuclides from uranium objects, and take into account the factors and parameters of specific sites. Another result of the project is a security assessment methodology adapted for former uranium facilities, developed by the international panel of experts based on the IAEA ISAM methodology for surface-based waste facilities. The tools and methodology developed were used for a detailed safety analysis of two contaminated PA PChP sites: Western Tail and Building No. 103. These sites were selected because they were representative of two major groups of contaminated sites (tailings and buildings) that represent priority objects and have been relatively well studied. In addition to the above works, the ENSURE-II project assisted in the development of Ukrainian radiation safety rules for tailings’ rehabilitation. An international expert review of some recently drafted regulatory acts was carried out and drafts guidelines were prepared. The SE ”Barrier” supplied radiometric and monitoring equipment (in particular, an automatic weather station).

6.1.3. IAEA Projects

Technical Cooperation Project RER/9/010. Further technical assistance for the rehabilitation of PA PChP territory has been provided to Ukraine through a number of IAEA projects. In particular, an IAEA expert mission visited PA PChP in April 2012 to assess the radiation situation, review the monitoring program, plan rehabilitation activities, etc. The mission assessed the situation and advised the national government on improving the national regulatory framework for former uranium facilities and improving the management of PA PChP restoration planning.

Training of Ukrainian specialists in regulation, safety assessment methodology, monitoring, etc. for former uranium facilities was also carried out in 2010-2014 through regional IAEA projects, such as ***RER/9/010 project – Support for preparation for rehabilitation of the former uranium production*** (participating countries – Central Asian countries CIS, Russia, Ukraine). IAEA Bilateral Three-Year Technical Cooperation Program – ***Ukraine UKR/9/032 "Development of Decontamination, Reclamation and Reconstruction Infrastructure for Existing Uranium Mines and Former Uranium Production Facilities"*** was launched in 2014. One of the main objectives of this program is to facilitate planning rehabilitation activities for PA PChP territory. This program provides for further assistance in the development of a national regulatory framework, training of reclamation technology personnel, joint seminars on the exchange of international experience, expert assistance and missions.

6.1.4. Projects funded by the European Commission

Following the completion of the ENSURE-II project, work on the former Prydniprovsky Chemical Plant was launched as part of the European Commission Instrument for Nuclear Safety Cooperation (INSC), activities were introduced at the former Prydniprovsky chemical plant aimed at its ecological safeguarding. The organization and control over the execution of works is entrusted to the Joint Support Office at Kyiv (JSO), the selection of the contractor to perform the works and the contracting with the Contractor is carried out by the Science and Technology Center of Ukraine (STCU).

The activities are planned to be implemented in the following phases:

- Phase 1: Long-term PChP decommissioning and rehabilitation strategy.
- Phase 2: Immediate action to eliminate inevitable risks for PChP staff.
- Phase 3: Support for initial PChP deactivation and decommissioning work.

As of now, Phase 1 activities have been completed (2014-2016), namely a PChP industrial site rehabilitation strategy has been developed, and work is underway under Phase 2. According to information posted on the JSO website, the ideology of urgent action is as follows:

Before any decommissioning and rehabilitation measures are taken, immediate steps must be taken to improve the safety and security of the site:

- Mitigate the risk of radiation exposure for workers and the general public.
- Take measures to prevent further spread of contamination and the unauthorized removal of radioactive material from the site.
- Exercise proper monitoring of the site with regard to both radiation safety and physical protection.

Given that the site contains several significant radiological hazards, before decontamination and decommissioning can be considered, it requires modern detailed mapping, complete characterization and robust security analysis.

In the medium to long term, the PChP site will require extensive decontamination and all contaminated materials will require permanent and safe handling and eventually disposal. However, the most urgent task in the near future is to improve the security and security of the PCP site, including, but not limited to:

1. Improvement of legislation and regulatory framework covering uranium heritage sites in Ukraine.

2. Control and stabilization of radiological hazards.

3. Provision of institutional support to the operator of the Barrier SE site.

4. Provision of the operator with urgently needed equipment.

Without the implementation of these urgent measures in the territory of the PChP, it is not possible to ensure a safe environment for workers and the population living around. Immediate measures to reduce the risk of the further spread of radioactively contaminated materials, as well as unauthorized access to contaminated buildings and territories can be achieved in the near future. However, without the establishment of an appropriate regulatory framework, the sustainability of the improved safety and security of the PChP site will be unsustainable.

Detailed information on the implementation of European Commission projects at the PChP site is given below.

6.1.4.1. Development of a method (strategy, technology) for the reclamation of the territory of the former uranium object "Prydniprovsky Chemical Plant"

The overall purpose of the UIWS U4.01/10G Project is to develop modern, effective techniques and tools for planning rehabilitation activities and developing methods (strategies and technologies (j)) rehabilitation measures at the former uranium facility "Prydniprovsky Chemical Plant", based on international best practices. The project aims to characterize the risks associated with this facility, to develop a common site rehabilitation strategy and conceptual rehabilitation projects for the selected priority sites.

The objectives of the project were:

- creating an up-to-date list of tailings, buildings and site data describing radiological and chemical composition, physical condition (e.g. volume, area), etc. .;
- developing recommendations on the application of international best practices for the planning and implementation of rehabilitation work on former uranium sites at the PChP site, taking into account the regulatory framework of Ukraine and existing technologies;
- radiation risk assessment for non-radiological personnel at the site and the population around the site;
- developing a method (strategy, technology (s)) for conducting rehabilitation work at the PChP site;
- Development of a plan and feasibility study for the remediation of selected objects at the PChP site.

The project envisaged the following tasks:

- Task 1: Project Preparation and Initial Phase.
- Task 2: Analyse information and results of historical national and international research at the PChP site.
- Task 3: Analyse international experience in conducting rehabilitation, procedures, recommendations and their application at the PChP site.
- Task 4: Analyse current and future security levels and categorize PChP assets.
- Task 5: Report on the ex-PChP site rehabilitation strategy, site-specific rehabilitation plan and feasibility study to support the selection and implementation of site rehabilitation activities.
- Task 6: Final report and announcement of results.
- Task 7: Identify strategies to reduce the inevitable risks at the site.
- Task 8: Awareness of the dangers and risks of the former site.

The project began in April 2014 and was initially scheduled for completion in April 2016. However, in November 2015, the Supplementary Agreement was signed and the project implementation deadline was extended to December 2016. Under the Supplementary Agreement the initial scope of Task 2 was expanded and two new tasks were added to the project (Tasks 7 and 8 above).

All project objectives were achieved and all tasks were completed.

The main project results include the development and presentation of an overall rehabilitation strategy for the PChP site, additional characterization work for a better understanding of the radiological situation on the site, identification and categorization of risks, conceptual rehabilitation projects for a selected list of priority objects, calculations conducting proposed rehabilitation measures, identifying measures to mitigate inevitable risks, and developing and (d) on-site programs to enhance the capacity of the nuclear operator and provide information to the public about the dangers present at the site, and measures to mitigate this risk.

6.1.4.2. "Implementation of urgent measures for Prydniprovsky Chemical Plant, Kamianske city (formerly Dniprodzerzhynsk), Ukraine"

The purpose of EC project U4.02/16B1 "Implementation of emergency measures for the Dnipro Chemical Plant" is to assist Ukraine in taking urgent measures to bring the PChP facilities to safety. The project activities consist of design work to implement urgent measures at the site of the former PChP (Task 2), create a quality management system and supervise the implementation of stabilization measures, which include:

– temporary isolation of radioactive materials and contaminated objects, which are sources of actual or potential spread under the influence of wind, with atmospheric and groundwater, as well as measures to restrict unauthorized access;

– creation of controlled areas, including safe or radioactive materials and waste management sites (temporary storage);i

– Identification, collection and transfer to a specially prepared site of radioactive materials, which are located on the site and can be easily moved.

The project, in addition to the above, provides for a separate block of activities aimed at:

– providing support to the End User through staff training, capacity building and the establishment of an appropriate management system or systems;

– Supply of equipment that is urgently required by the End User to perform day-to-day PChP site management work.

The activities of the end user support activity under the project are implemented within the framework of individual tasks, namely:

Component 3. Tasks 3.1-3.4. Capacity Building (Management Systems)

Component 4. Tasks 4.1-4.2. Measures to prepare for the supply of urgently needed equipment

Project implementation status

As of the beginning of Q4 2019, the following projects have been developed within the scope of Task 2:

Working design “Construction of controlled areas at industrial site of former PChP Plant.

Working design “Construction of a site for storage of radiation contaminated materials”.

Project “Moving of “free-standing” and “easily moved” radiological risk facilities from the PChP site to the temporary storage site”.

These projects have passed the state examination on nuclear and radiation safety and have received a positive conclusion.

According to a working design ”Construction of Controlled areas at the Industrial Site of the Former PChP Plant", it is planned to construct 4 controlled areas, which will limit the uncontrolled access of non-radiological personnel to the most polluted territories of the southern part of the site with an irradiation intensity of more than 10 m/s. (Fig. 17 is marked with red ovals).

Fig. 17. Places of arrangement of controlled areas

The working project envisages the construction of controlled areas by mounting a fence of two types: of metal profile sheets on a metal frame and supporting columns and of a rod grating (from a welded lattice) on supporting columns. A barbed spiral barrier of the "Egoza" type is mounted at the top of the fence. It also envisages the construction of checkpoint facilities, such as a swing gate, staff sanitary treatment facilities (asphalt), asphalt concrete site for the operations of decontamination of motor vehicles and a site for carrying out hoisting works and temporary warehousing. The projected fence of the controlled areas is not an element of physical protection, but is installed solely to restrict access of workers at the industrial site. More detailed schemes of location of controlled areas are shown in Fig. 18-21.

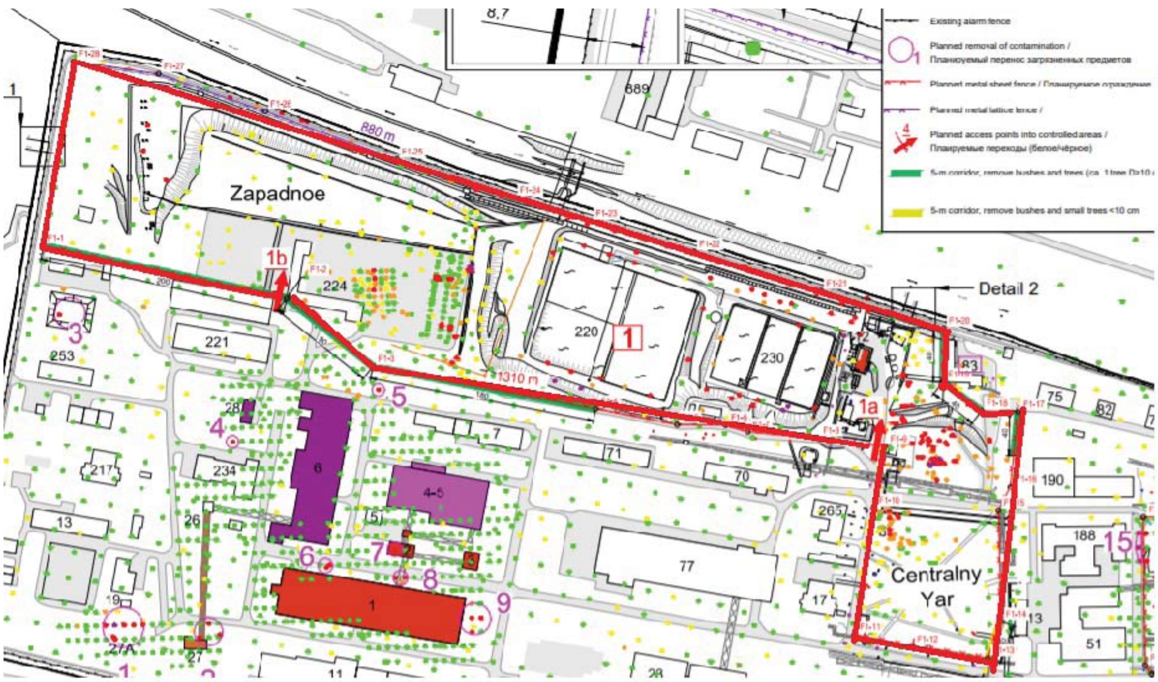


Fig. 18. Controlled area 1 encloses the following facilities: West and Central Yar **tailings**

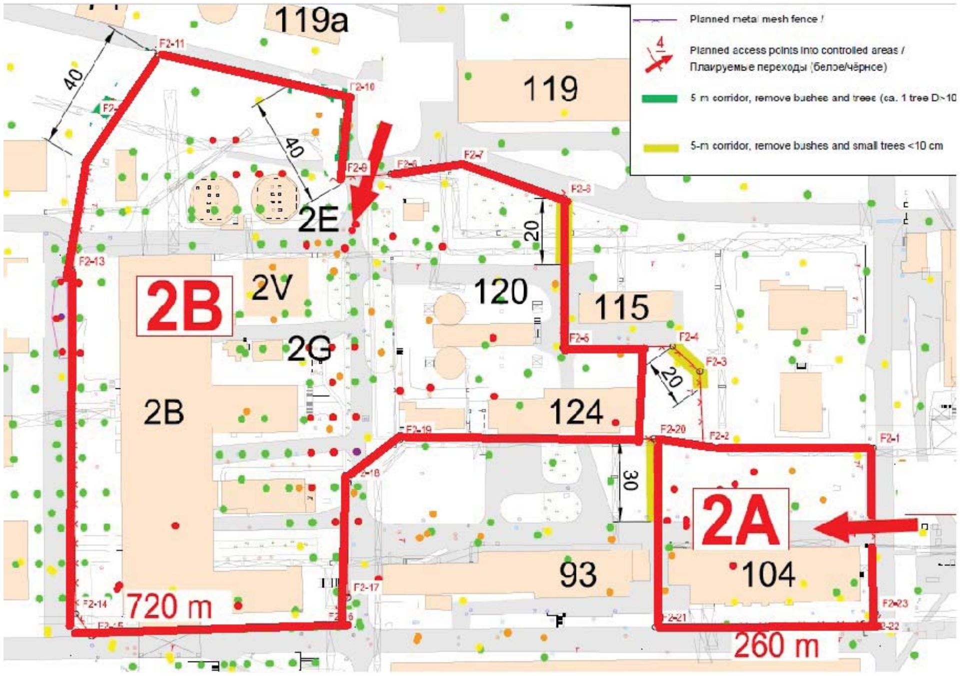


Fig. 19. Controlled area 2 (2A and 2B)

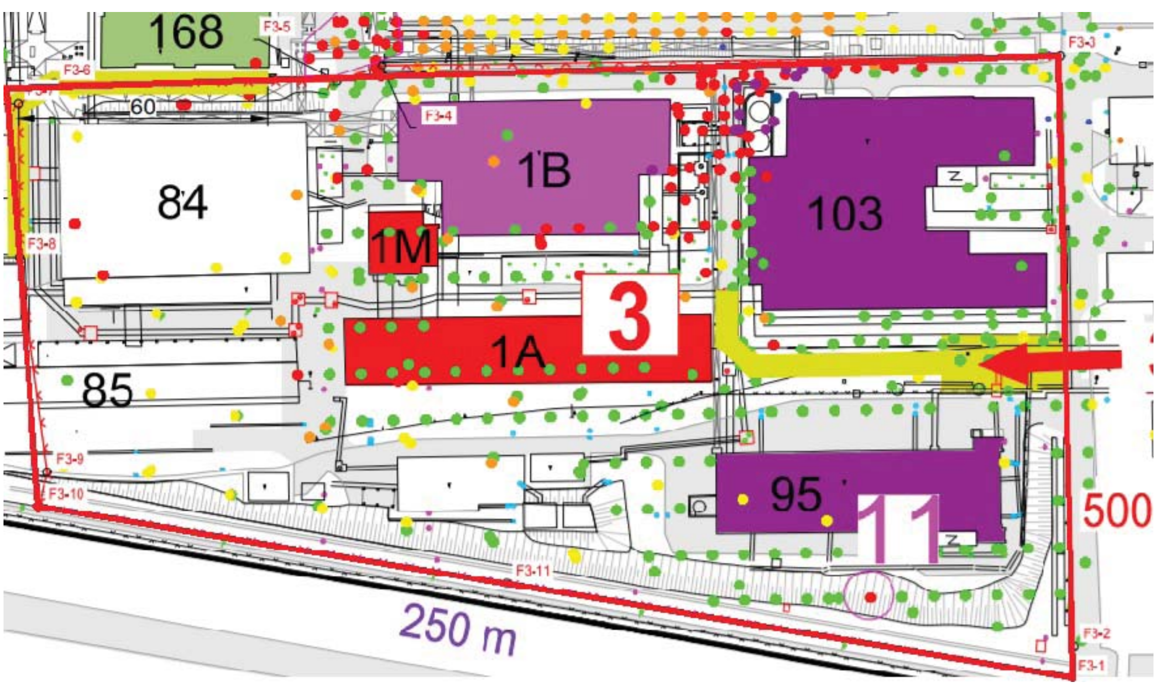


Fig. 20. Controlled area 3

Fig. 21. Controlled area 4

To provide radiation safety requirements for each controlled area, the project provides for the construction of access points that have a sanitary pass and a site for deactivation of the vehicles. The configuration of the access point is shown in Fig. 22.

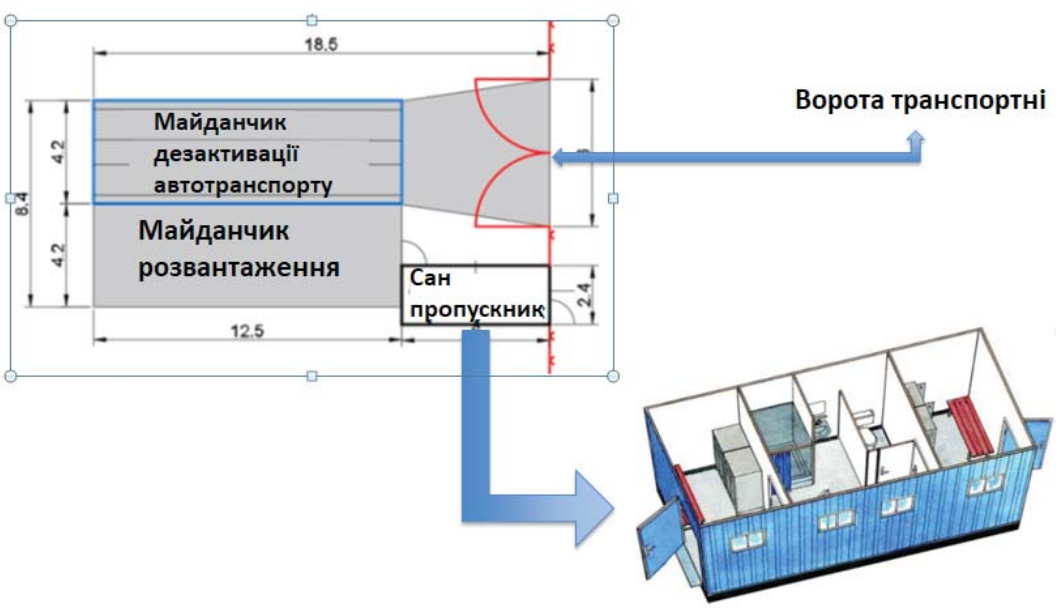
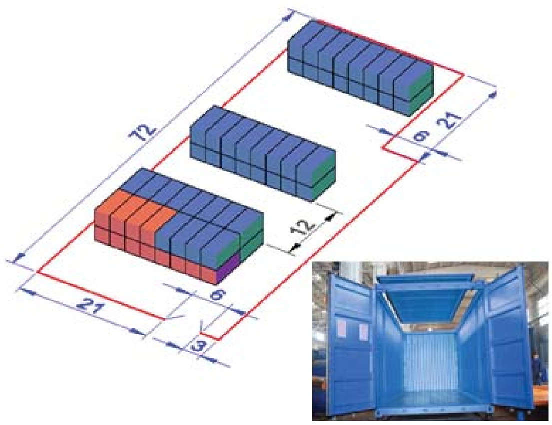


Fig. 22. Access point configuration

Working design "Construction of a site for storage of radiation contaminated materials".

According to the project, the construction of a site for temporary container storage of radioactively contaminated objects removed from the site's territory is envisaged. The outdoor area is located within the landfill of the South-eastern Tailing. The storage of radioactively contaminated objects removed from the site will take place in 20-foot Atom-type containers (IP-2 packaging). The main characteristics of the site for temporary storage of radiation contaminated materials are shown in Fig. 23.



- open concrete pad
- mechanized process of container placement
- bunk placement of containers
- wastewater collection facilities
- additional fence

Fig. 23. Basic characteristics of the site for temporary storage of radiation contaminated materials

The project of moving “free-standing” and “easily-moving” radiological risk objects from the PChP site to the temporary storage site envisages the removal of radioactively contaminated sites with a total of about 200 units. Such objects were identified during the project implementation and mainly consist of:

– transport and process containers used in the production cycle (Fig. 24);

– fragments of dismantled technological pipelines used in the production cycle (Fig. 25);

– individual accumulations of bulk and other radiation contaminated materials, of unknown composition (Fig. 26).

Fig. 24. Transport and process containers used in the production cycle

Fig. 25. Fragments of technological pipelines used in the production cycle

Fig. 19. Random accumulations of bulk materials of unknown composition

The gamma-ray exposure intensity at a distance of 1.0 m from the surface of these objects is observed at the level of 1.0 to 10 μSv/h, reaching for some objects from 48 to 100 μSv/h, with free access to such objects, which creates the prerequisites for unjustified radiation exposure of employees.

7. CURRENT SITUATION AT THE PCHP PROPERTY

7.1. Analysis of radioactive and chemical contamination of PChP territory

7.1.1. Introduction

Separate work on determining the level of radioactive and chemical contamination of the PChP site and its individual objects was carried out within the framework of the implementation of state program activities; Systematic work in this direction was carried out during 2012-2013 within the framework of the ENSURE-II project. An analysis of the available information archives and data obtained during PChP radioecological monitoring showed that the data obtained under the State Program during 2010-2012 were not sufficient to obtain a detailed description of the entire site and to complete a statistically reliable interpretation of the results. Therefore, during 2013 additional control studies were conducted on the territory of the site and its separate areas. As a result of this work, maps of gamma radiation doses were created, in particular for some most polluted areas of the plant site, as well as schemes for the spatial distribution of some radionuclides and heavy metals in the soil within the territory of the former PChP.

7.1.2. Current radiation status of the industrial site

The results of spatial analysis of gamma radiation intensity (GRI) for the site of the former PChP are presented in Fig. 27. The data show a significant difference in radiation status between the northern and southern sections of the site. In the northern part there are practically no areas with significant pollution. For the most part, the GRI does not exceed 0.20 μSv/h and is only observed at 0.5-2.0 μSv/h at a single point.

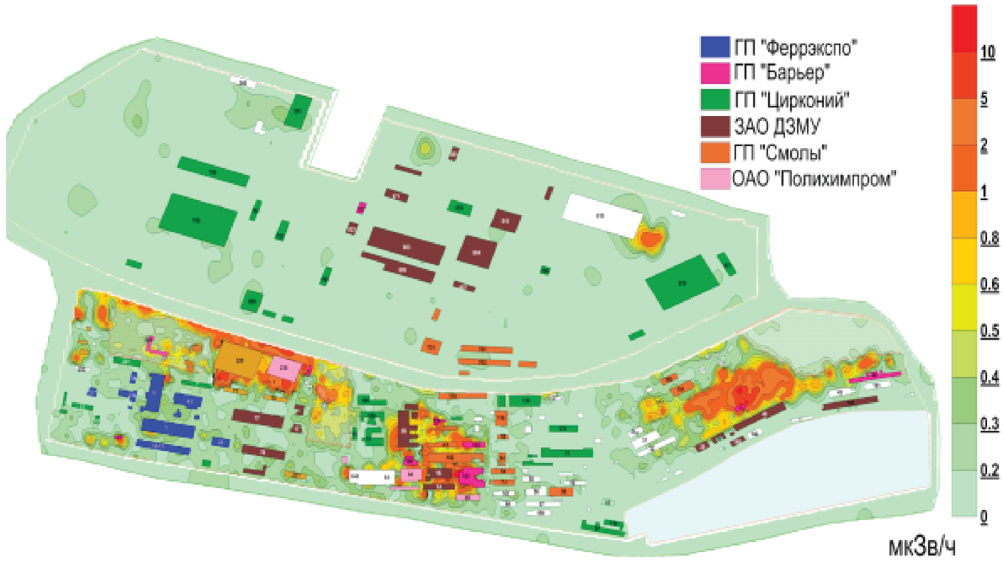
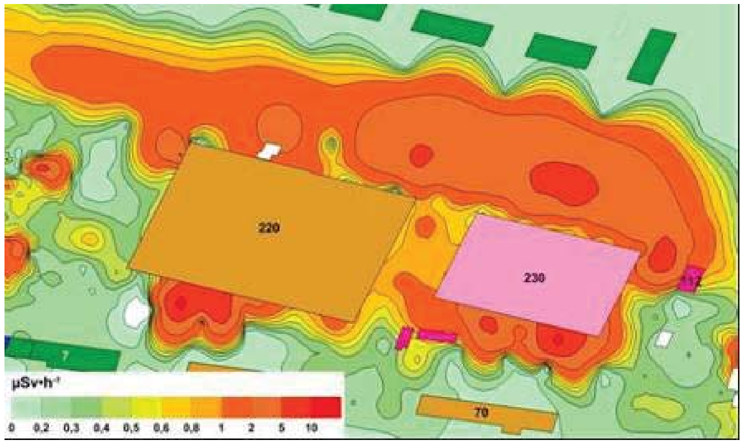


Fig. 19. Spatial distribution of gamma radiation intensityat the site of the former PChP.

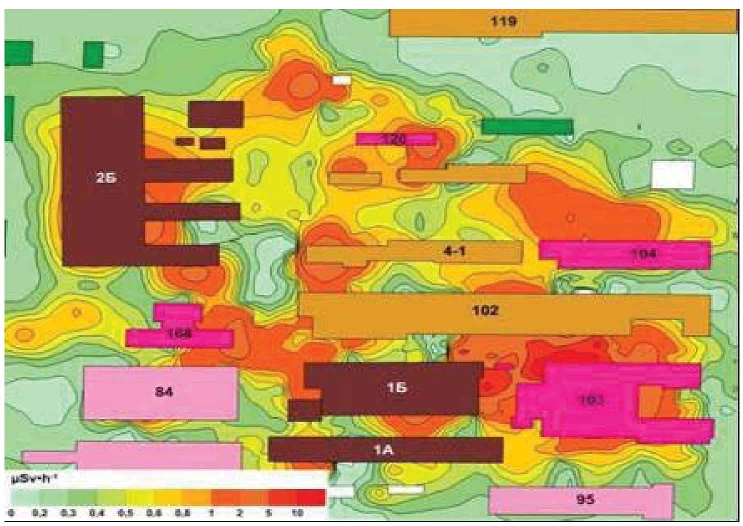
Contamination of the southern area of the site is significantly higher and extremely uneven. This is because this area of the PChP was used for unloading and storage of uranium raw materials, placement of ore preparation (crushing, grinding) and extraction of uranium, tailings and pipelines and other auxiliary lines of the uranium production cycle. These objects are the largest in the southern part of the GRI (10 or more μSv/h), with about 30% of the DER area observed at levels above 1 μSv/h. The contamination of the industrial site was due to the imperfection of technology and equipment involved in the production process and, first of all, to the neglect of radiation safety requirements, especially at the initial stage of production. The sources of existing contamination of the territories are ore deposits at storage/preparation sites and uranium processing materials at its various stages, including transportation of waste to tailings. Waste management was also not regulated in terms of safety. Production tails, contaminated waste equipment, etc. were placed in tailing storage facilities formed directly near production buildings. The tailings themselves were placed in beams and ravines in the absence of their construction projects and insulation/shielding measures for the bottom and sides. For example, the so-called Komsomolsky Park with pedestrian walkways, trees and benches for workers resting on the site of the filled and conditionally closed tailings of the Central Yar, located in the central part of the southern PChP site. It should be noted that at this time there are a number of sites on the surface of the central and northern parts of the tailings, in which the intensity of gamma radiation reaches 10 μSv/h or more in separate "hot" points.

The first regulatory requirements for the design of similar industries were put into effect in the USSR only in 1977, i.e. 30 years after the establishment of the industry. Such a document was “Sanitary norms for designing the enterprises and installations of the SNP-77 nuclear industry. Part V. Requirements for the design of ore processing enterprises”. The document "Sanitary rules for the construction and operation of tailing storage facilities of hydrometallurgical plants and ore concentrates, processing ores and concentrates containing radioactive and highly toxic substances No. 21-83" was issued later by the Ministry of Health of the USSR in 1983.

Sumps (objects No. 220 and No. 230



Former uranium extraction facilities



Uranium unloading area (Zavodskaya station)

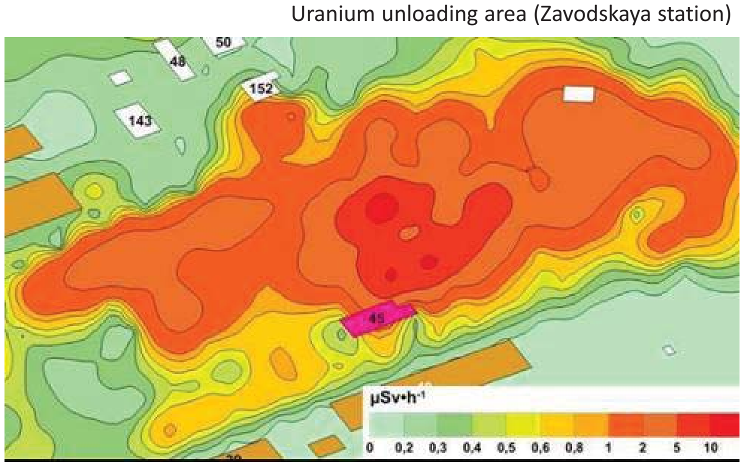


Fig. 28. Maps of gamma radiation intensity in specific areas of PChP

Fig. 29 and Fig. 30 compare the maximum GRI levels in some of the most polluted areas and structures of the southern part of the PChP and GRI site at the locations of individual sites at the ChNPP industrial site.

Fig. 29. Maximum DER levels in some of the most polluted areas and structures of the southern part of the PCpP site (μSv/h)

Fig. 30. Radiation status at the ChNPP site as of May 10, 2019.
https://chnpp.gov.ua/ua/

7.1.3. Spatial analysis of the distribution of radionuclide content in the soil

In the framework of the ENSURE-II project, the soil contamination levels of ^{238}U and ^{226}Ra radionuclides were also assessed. Soil samples were selected from several sites with high GRI levels and analysed to evaluate the spatial distribution of uranium thorium radionuclides in the topsoil (0–5 cm). The area around the settling basins 220 and 230 was selected as one of these sites. An analysis of the spatial distribution of ^{238}U and ^{226}Ra in the 0-5 cm of the upper soil layer in the adjacent area is shown in Fig. 31.

Fig. 31. Specific activities ^{238}U and ^{226}Ra in surface soil around settling pools at the site of the former PChP

The content of uranium and radium in the soil in the area around the sedimentation tanks is similar to that of the radionuclides in the tailing materials. This fact suggests that this is secondary pollution of the surrounding areas, which was caused by the deflation (wind-blown) of material of tails and residues of uranium production from nearby objects, as well as the spread of dust from dried deposits from the secondary production cycle "Polychimprom" which was previously part of the processing of uranium waste and source material with a high content of naturally occurring radioactive material.

For comparison, it can be noted that the background concentration of uranium in the surrounding areas is usually 1-2 orders of magnitude lower – about 0.05 Bq/h. According to international standards, if the activity of α-emitting radionuclides in soils exceeds 1 Bq/h, the area is subject to regulatory control or must be deactivated.

Generally, decontamination criteria for former uranium production for Ra-226 content in soils in EU and US countries are assumed to be 0.2 Bq/g in the upper soil layers. According to this criterion, all adjacent to the settling areas require deactivation as having a specific activity of Ra-226 higher than the criterion by several orders of magnitude.

Please note that such a mapping is designed on the basis of a very limited amount of data and only for a limited area of the site. Therefore, it is necessary to continue the detailed study of the territory in order to make a decision on the strategy of its decontamination and in order to identify the most "problem" areas. Based on the experience of rehabilitation work carried out previously on EU industrial sites, it has been experimentally established that areas with gamma radiation intensity above 0.5 μSv/h are subject to decontamination.

7.1.4. Spatial analysis of heavy metals distribution in soils

The high concentration of metals in the soil is typical of uranium ore processing products. The specific content of metals depends on the type of ore and the location of the ore production site. A wide range of metal content, varying from site to site, was found in soil samples collected in the western part of the southern sector of the site (including areas around the tailing storage facilities) and in the eastern part of the southern sector of the site. In particular, relatively high levels of arsenic, manganese and copper were found, whose content correlates well with radium activity in soils, indicating the origin of these toxic trace elements in the soil of the site. However, due to the insufficient number of measurements at the site, no obvious correlation was found between soil and metal contamination in the site soils. Some results of the content of metals in soils within the southern area are presented in Fig. 32 and Fig. 33. The content of Pb, Co, Cd, Mn, Ni, Cu, Fe and Zn was determined in the selected soil samples.

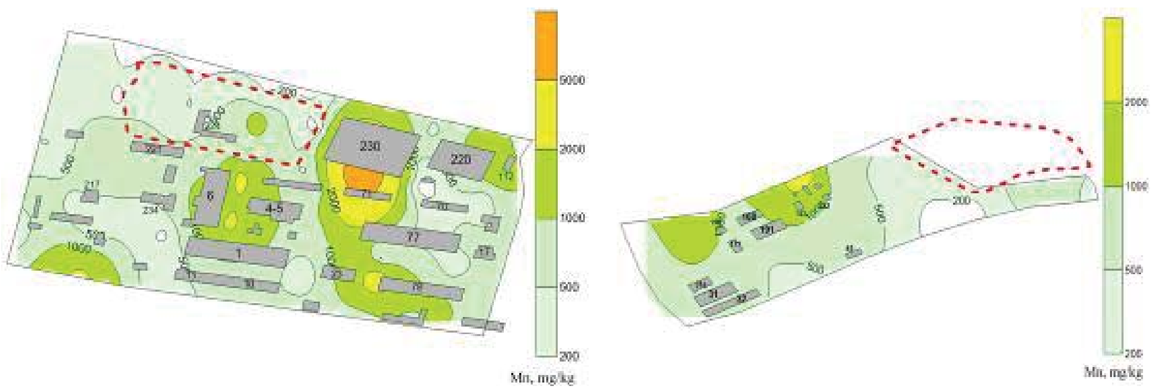


Fig. 32. Mn content in the soil surface layer of the eastern and western portions of the southern part of the former PCP site.

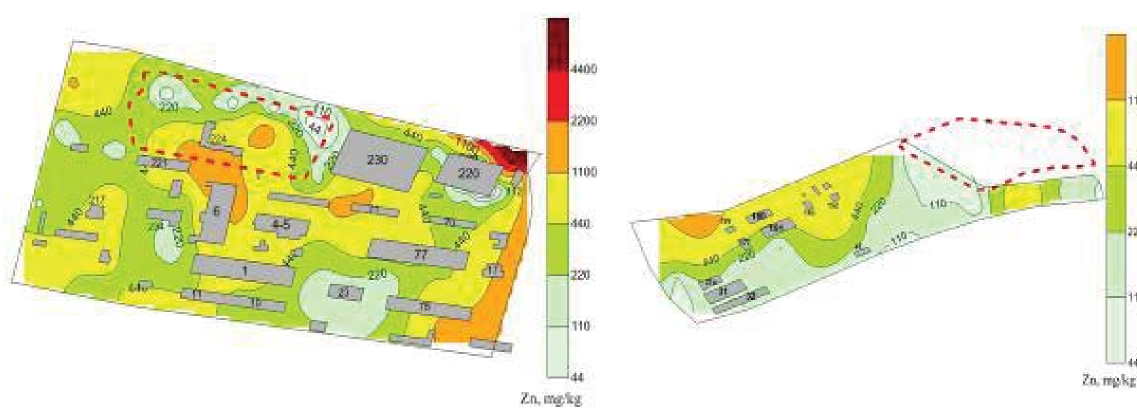


Fig. 33. Zn content in the soil surface layer of the eastern and western portions of the southern part of the former PChP site

In the future, a more systematic analysis of soils contaminated with toxic metals will be needed, with a focus on arsenic, copper, zinc and manganese.

7.2. Radiation status in former industrial buildings

In the course of the work under the state programs as well as the screening studies in 2015-2016, a preliminary list of contaminated buildings used during the operational period in separate technological cycles of ore processing at PChP was identified by the project U4.01/10G, posing a potential risk for industrial and environmental workers. Most of these buildings are geographically concentrated in three sections of the southern industrial site:

- Complex of buildings of the former workshop № 5 – buildings 1-6, 28 – the western part;
- complex of buildings of the former workshop № 22 – buildings 2B 2B, 2E, 2G – the central part; buildings 1A, 1B, 1M, 95, 103, 104 – the south-east part.

The layout of the contaminated buildings in the central and eastern parts of the southern site is shown in Fig. 34.

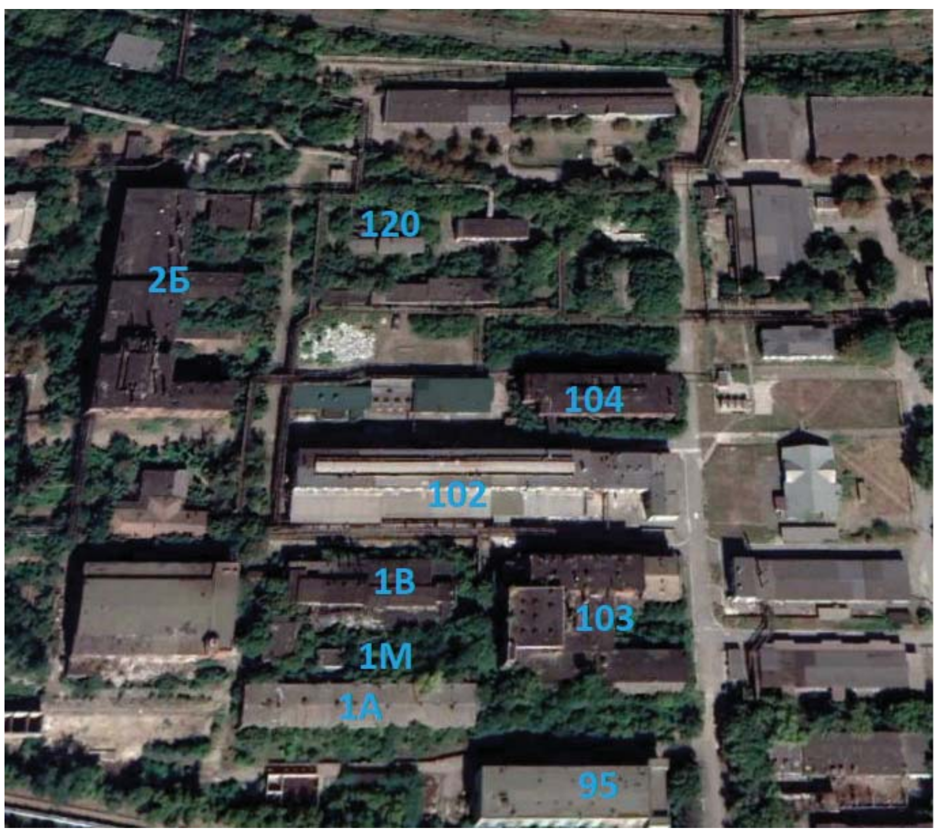


Fig. 34. Layout of contaminated buildings in the central and eastern parts of the southern industrial site

Further work on the U4.01/10G project carried out a detailed radiation survey of the condition of individual buildings. The results of the survey are given in Table. 9.

Table 9. *Results of a radiation survey of buildings on the southern industrial site*

Building No.	GRI, µSv/h		Radon concentration (Rn-222), Bq/m³		
	Min.	Max.	Min.	Max. (without hot spots)	average
26	0,08	0,17	–	–	–
3	0,1	9,2	97	384	199
1	0,11	7,69	137	451	269
2	0,15	3,2	110	527	212
3	0,20	9,2	–	–	–
4-5	0,09	29,7	249	875	389
6	0,09	51	82	1722	380
28	0,1	68	175	4950	6570
1A	0,4	12	183	387	255
1M	0,17	11	127	727	375
2B	0,13	2000	210	430	365
2C, 2D	0,50	15,0	–	–	–
2E	0,15	0,95	–	–	–
95	0,08	7,0	80	235	135
112	0,60	3,00	451	622	530
168	0,20	0,80	80	270	120
120	0,25	2,00	56	3017	1106
82	0,15	0,50	1890	6913	3890
46	0,15	1,50	36	165	90
103 Level 1 Level 2 Level 3	 0,23 0,40 0,46	 3360 620 4411	 73 56 115	 1100 740 3150	 419 300 1450
104 Level 1 Level 2 Level 3	0,20 14,7 0,18 0,08	137 285 210 172	310 150 375 160	700 670 620 550	520 475 500 300
127	0,10	5,00	433	711	580
31	0,11	0,25	65	95	80
27	0,17	2,2	–	–	–

”–” – no data.

As the data analysis showed, the individual buildings surveyed have very high levels of radioactive contamination, as evidenced by high GRI levels, high radon concentrations, and dust containing α-emitting radionuclides. Much of the equipment that was previously used in the uranium extraction process remains in its former sites. These premises, structures and equipment are heavily contaminated with uranium thorium radionuclides. Among the surveyed buildings, the most polluted are 103, 104 and 2B.

As of today, almost all contaminated buildings are in poor technical condition. The buildings are not preserved. More than half of the window openings are not glazed, the buildings are destroyed by brickwork and roofing, various contaminated materials and raw materials used in the former production. Almost all contaminated buildings after the time of production discontinuation, metal-free equipment was partially and/or completely dismantled and sold as scrap metal without dosimetric support. Individual buildings are completely dismantled and dismantled for building materials (brick, floor slabs). These processes are still underway at private property. The current status of individual contaminated buildings is shown in Fig. 35-40.

Fig. 35. Building No 1. Former storage of uranium raw materials

Fig. 36. Building No. 6. Uranium extraction workshop

Fig. 37. Building No. 95. Rare earth extraction workshop

Fig. 38. Building No 2B. Uranium extraction workshop

Fig. 39. Building No. 103. Uranium extraction production building

Fig. 40. Building No. 104. Thorium extraction workshop

To date, contaminated equipment and former premises of workshops, workshops in contaminated buildings have not been decommissioned in accordance with the requirements, norms and standards in force in Ukraine. The areas around the contaminated buildings 103 and 104 are also significantly contaminated as a result of the radionuclide dispersion of dust particles formed in the process of uranium ore processing and uranium extraction in the past. In addition, high dose levels of gamma radiation are observed in the area of process tanks located on the northwest side of Building No. 103 (Fig. 41).

Fig. 41. Appearance of process tanks near Building No. 103

Gamma dose levels measured near the tanks range from 20 to 40 μSv/h, reaching 250 μSv/h on their surface.

This situation, given that the main production workshop of SE ”Smoly” (Building No. 102) is located directly (less than 50 m) between buildings 103 and 104 (Fig. 34), leads to permanent and unjustified radiation exposure of about 200 workers. An additional factor of radiation risk is also the surface contamination of the territory in the specified area (Fig. 42).

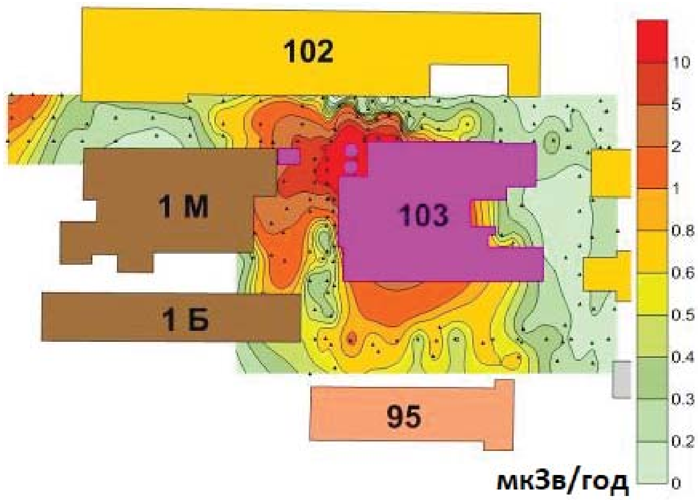


Fig. 42. Map of GRI distribution on the site adjacent to Building No. 103

Equally significant is the presence of insulation and other materials made of asbestos. They are present in many forms, including in facing building panels, slate, insulation of tanks (Fig. 41 on the left) and in the form of spray insulation on roofs and walls of buildings. Fine asbestos degrades and, in many cases, settles on footpaths, floors below and land adjacent to buildings.

Increased GRI and dispersed materials containing uranium extraction residues with a relatively high concentration of Ra-226 activity also create an area with increased Rn-222 emanation. The average concentrations of Rn-222 activity in the surrounding areas around Building No. 103 vary from 90 to 200 Bq/m^3.

Thus, the safe dismantling and removal of the above-mentioned tanks is a priority that will precede the dismantling of Building No. 103.

7.3. Tailings

In the context of this document are considered "historical" tailings that were organized, operated, and which discontinued the disposal of uranium ore processing during the 1950s and 1980s. A map-diagram of the location of such tailings is shown in Fig. 43; the technical characteristics of the tailings are listed in table 10.

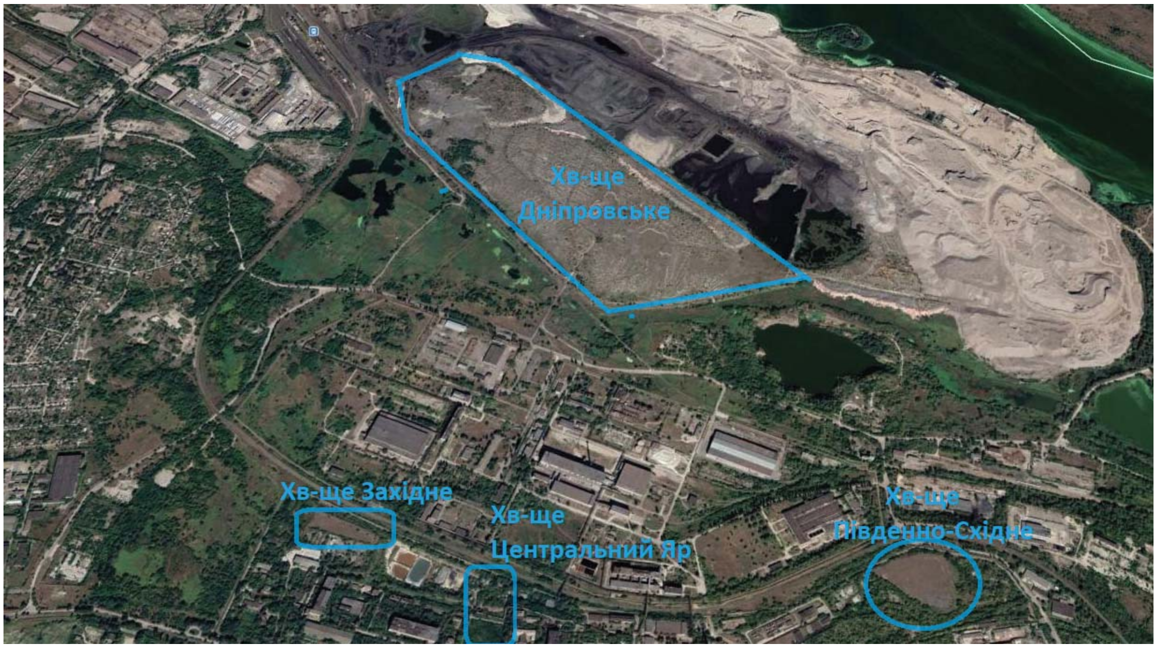


Fig. 43. Map-diagram of the location of tailings on the PChP site

***Technical characteristics** of "historical" tailings of uranium production dumps*

Tailing name	Time of operation	Amount of accumulated waste, million tons	Area thousand m²
Western (Zakhidne)	1949—1954	0,77	40,2
Dniprovske	1954—1968	12,0	730
Central Yar (Tsentalnyi Yar)	1950—1954	0,22	24
Southeast (Pivdenno-Skhidne)	1956—1990	0,33	36
Sukhachivka, I section	1968—1983	19,065	to 5,4

These tailings were arranged in the absence of projects, and accordingly measures to limit the negative impact on the environment, in particular on groundwater pollution. Their lifetime was determined solely by the time they were completely filled with uranium ore processing waste. In the case of such tailings, it is improper to use the term "tailings project volume". At the above mentioned repositories, after the end of their operation, primitive protective coatings were made, executed in the absence of projects (except for the South-East/ Pivdenno-Skhidne tailing).

Given the impossibility of further exploitation of these tailings, both in terms of safety requirements and in the absence of physical volumes for the disposal of waste, ***such a direction of discontinuation of activities as "re-profiling" should be excluded for these facilities***, and the tailings must be preserved by arranging insulation cover.

All of these tailings can also be subjected to a type of cessation of activity, such as "liquidation", i.e. complete removal of waste and contaminated soil from the bottom and sides of the tailing storage facility and transfer of this material to another tailing pond

(Sukhachivka, Section 2). In the event of such a project, the PChP site may be completely exempt from the regulatory control.

From an engineering and technical point of view, the elimination of tailings by moving the accumulated radioactive materials is quite probable, with the optimal way of termination of activity determined solely by economic feasibility and justification.

Data of comparative calculations of cost of works on elimination of tailings and arrangement of project protective cover on them indicate that economically justified is the option of termination of activity of tailings by arrangement of project protection cover on them, i.e. conversion of tailings to object intended for disposal. At the same time, the cost of the optimal option under other identical conditions (compliance with security requirements, etc.) is almost twice lower than the direction of "elimination".

It should be separately noted, that the installation of sufficient protective coatings at decommissioning tailings is a widespread worldwide practice in the field of uranium ore processing.

The results of the categorization of risks within the 10G project make it possible to determine the priority (priority) of works to be taken into account when planning tailings remediation works, namely:

Priority 1 ***Sukhachivske, section 1; Western/ Zakhidne***

Priority 2 ***Dniprovske; Central Yar/ Tsentalnyi Yar***

Priority 3 ***Southeast/Pivdenno-Skhidne***

The remediation of the Sukhachivske Dumps, Section 2, whose operation is to be resumed, should be given the highest priority as the facility where the PCP site remediation waste will be placed.

The information on the radiation characteristics of the tailings belonging to the SE ”Barrier” are given in Table. 11.

Table 11. *Characteristics of uranium production repositories*

The name of the repository		Gamma radiation power at the surface, μSv/h	Total activity,TBk
Western/Zakhidne		to 30	180
Dniprovske		to 1,0	1400
Central Yar/Tsentalnyi		to 15,0	104
Southeast/Pivdenno-Skhidne		to 0,26	67
Base C.		to 6,0	440
BFR-6		to 0,3	1,3
Lanthanum Fraction 602		to 0,3	0,86
Sukhachivske	Section I	to 5,4	710
	Section II	to 0,3	270

T – tera 10^{12}.

7.3.1. Zakhidne tailing

Zakhidne tailing is located in the southwestern part of the main industrial site of the former Prydniprovsky Chemical Plant (Fig. 43). The tailing area is 40.2 thousand m^2.

The tailings deposit operated from 1949 to 1954. In the initial period, it contained uranium waste containing slag from the processing of uranium ores in a blast furnace. During the first two years of operation, dewatered waste was sent to the tailing storage facility using a conveyor belt from Building No. 6. Starting in 1951, waste from the uranium ore processing was fed into the tailings in the form of a pulp by pipelines. After its discontinuation in 1954. The south-eastern part of the tailing was covered with a layer of asphalt. Garages and warehouses were built in the southwestern part of the tailing pond (warehouses were now dismantled, garages partially destroyed). The northern part of the tailing was covered with an organic layer of soil. The total volume of waste stored in the tailing is 0.35 million m^3, the total mass is 0.77 million tons, and the total activity is $1.8 \cdot 10^{14}$ Bq.

The general view of the Western tailing is shown in Fig. 44.

Fig. 44. General view of the Western tailing

The tailing storage facility was built in 1948 on the site of a waste clay quarry surrounded by soil dams (the quarry was located in a ravine on the Dnipro river terrace). The bottom of the quarry and dams were equipped with a protective impermeable coating. At this time, the dikes are covered with layers of soil. The tailing site has steep slopes (reaching 50 °), which raises reasonable fears about its geotechnical stability.

In 1953, the dam was destroyed. The released radioactive pulp blocked the access rail branch for freight transport, which runs through the industrial area and is located directly on the slope of the tailing. Following this accident and decontamination work, a decision was made to close the Western tailing pond and build a new large bulk tailing pond (Dniprovske) in the River Dnipro floodplain.

In the spring of 2000, tailings in the northern part of the tailings were partially destroyed (scraped) by scrap hunters looking for stainless steel equipment contained there. As a result of several intensive downpours that took place in the spring-summer 2000 after scrap excavations, contaminated wastewater from waste materials was discharged into the wastewater collector and further into the Konoplyanka river.

In order to eliminate the emergency described above, the UkrNDPRIpt Institute has developed a reclamation project. Reclamation works included:

– construction of a retaining wall 240 m long and 1.2 m high from concrete blocks on the north side of the tailing;

– backfilling of excavated territory and erosion "gullies" of the surface of the tails with loamy material;

– covering the northern part of the tailing with a multi-layered soil cover consisting of loam, blast furnace sludge and an organic layer of soil.

The total thickness of the soil cover ranged from 1.5 to 2.5 m. The slopes of the tailing were covered with layers of loam and organic soil with a total thickness of 0.5-1.0 m.

According to information requiring clarification, several dozen 200-litre containers of radioactive materials of unknown composition were disposed of in the course of construction work in the eastern part of the tailing storage facility under an equipped soil cover.

The surface of the reservoir is equipped with a drainage system for collecting surface runoff (rain water). Sesalary flows into the collector line that goes to the Konoplyanka River.

At the same time, a network of groundwater monitoring wells was set up directly next to the tailings well. The northern part of the tailing was covered by a layer of soil, the southern part by gravel and an asphalt layer 0.1 to 1.0 m thick.

In 2002–2004, the slopes of the protective dams surrounding the tailings collapsed through a series of downpours. In 2005, remediation work was undertaken to mitigate the effects of the incident. These included backfilling of the destroyed area with clay soil and reinforcing the slopes using a polymeric mesh geotechnical material. The reinforced surfaces were then covered with a layer of organic soil and sown with grass.

Production activities (such as the use of garages, etc.) in the tailing site were discontinued in 2005. The tailings surface is equipped with warning signs, the passage of workers to the territory is forbidden, but the tailing is not fenced.

Gamma radiation intensityat the tailings surface

The data of the results of the gamma survey of the surface of the Zakhidne tailing are presented in Fig. 45. Most of the tailings area is characterized by gamma radiation dose values of 0.1-0.3 μSv/h, which corresponds to the levels of radiation background at the PCP site (which are close to the regional natural background). Some hot spots with a dose of gamma radiation close to 1.0 μSv/h are located at the southeast edge of the tailing storage facility, where the area is covered by a relatively thin layer of asphalt.

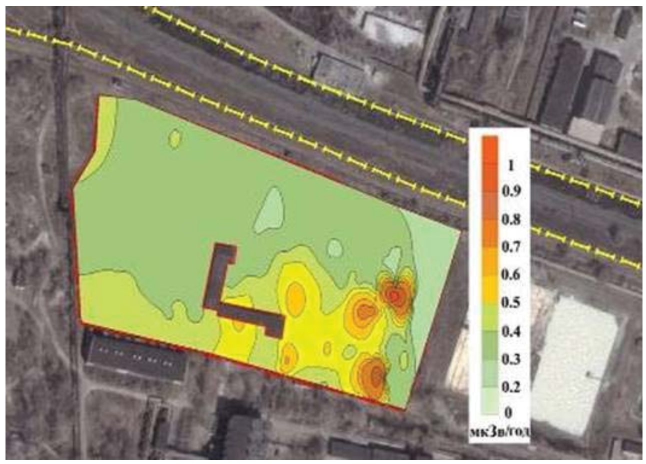


Fig. 45. Map diagram of gamma radiation intensity distribution (μSv/h) on the surface of Zakhidne tailing

The concentration of radon-222 in the air above the tailings

The concentration of radon in the air above the tailings ranges from 25 to 240 Bq/m^3, while the average concentration is about 80 ± 20 Bq/m^3.

Very high concentrations of radon (up to 25-30 kBq/m^3) were found in the basement of Building No. 6 (an abandoned garage), located at the top of the tailing storage facility.

Groundwater contamination

Groundwater monitoring data from the Western tailings deposit show, first and foremost, the intensive transfer of uranium to groundwater. Uranium concentrations (relative to the sum of U-234 and U-238 isotopes) reach 455 Bq/l in the man-made aquifer, and up to 710 Bq/l in the alluvial aquifer downstream of the tailing boundary. Increased concentrations of uranium in the alluvial aquifer were observed in a well located at a distance of 150 m downstream of the tailings (about 50 Bq/l in 2009). ***For comparison, the permissible concentration of uranium in drinking water according to SRSU-97 is limited to 10 Bq/l.***

In addition to radioactive contamination in the Zakhidne tailing, the contamination of groundwater by chemicals (such as macro-ions and toxic metals) is observed. Groundwater in man-made and alluvial aquifers is contaminated with nitrates, chlorine, sulphates, sodium and potassium, exceeding the allowable concentration in drinking water by a factor of 10 to 100. Almost the entire flow line from the tailing to the Konoplyanka river is subjected to chemical leakage.

Groundwater monitoring data for toxic metals show that the content of manganese, nickel and lead exceeds the MPC for drinking water in the tailing area. In groundwater, the MPC of cadmium and iron is often also exceeded.

7.3.2. Centralnyi Yar

The Centralnyi Yar tailing is located in the centre of the southern part of the PChP industrial site, where most of the former uranium ore processing facilities and waste storage facilities are located (Fig. 43). The area of the tailing is 24 thousand m^2. The tailing storage facility was operated from 1950 to 1954. According to the inventory, the total volume of waste stored is 0.13 x 106 m^3, the total mass is 0.22 x 106 tons, and the total activity is $1.04 \cdot 10^{14}$ Bq.

The tails are located in the ravine of the River Dnipro terrace, blocked by a dam. After the waste was filled, the surface of the tailing was covered with forest and loam soils and construction waste (total thickness – from 0.5 to 3.5 m). Later, the area was transformed into the park area of the PChP industrial site (the cafeteria and clinic were directly adjacent). A service road with an asphalt pavement and a technological overpass (former pipeline) intersects the tailings area and divides it into two parts.

The peculiarity of the Centralnyi Yar tailing is that by 2016 its surface was covered with deciduous trees. The oldest trees were 40-50 years old, while most trees and shrubs were 20-30 years old (Fig. 46). In 2016, all mature trees on the surface of the tailings were cut into firewood.

Fig. 46. Vegetation on the surface of the Tsentalnyi Yar tailing (photo by L. Uhlig, October 2014)

There is some evidence that the tailing storage facility also contains acidic soils contaminated with waste from radiochemical spills from technological pipelines (which connected Building No. 6, which carried out acid ore leaching, with Building No. 103, where extraction was carried out).

Geomorphologically, the tailing is located in a ravine that divides the river Dnipro terrace from south to north. The absolute heights of the tailings surface are located in the range from +81 to +94 m BS.

The disposal of processing wastes was carried out by the method of dry and hydraulic filling. The height of the surface of the upper layer of waste in the tailings ranges from +56.3 to +62.2 m (61.0 m BS average). The thickness of the waste layer ranges from 1-2 to 17.4 m (8.0 m average). The composition of the waste is quite diverse: it contains waste from the processing of uranium ores (from loam to sandy materials), as well as industrial, construction and household waste (such as brick, wood, metal, etc.). The surface of the waste is covered with a layer of bulk non-radioactive soil (loam and sandy loam with inclusions of construction waste) with a thickness of 0.5 to 3.5 m. 226 (the average is 53 Bq/h at the rate of 1 Bq/h). The tailings body is characterized by a significant variation in the specific activity of the accumulated materials in depth.

Gamma radiation intensity at the tailings surface

The gamma-ray data of the Centralnyi Yar tailing surface are shown in Fig. 47. Part of the tailings area is characterized by a GRI value of 0.1-0.3 μSv/h, which corresponds to the background radiation levels at the PChP site. However, there are a number of hot spots in the central and northern areas of the site, where the gamma radiation intensity reaches 30-50 μSv/h.

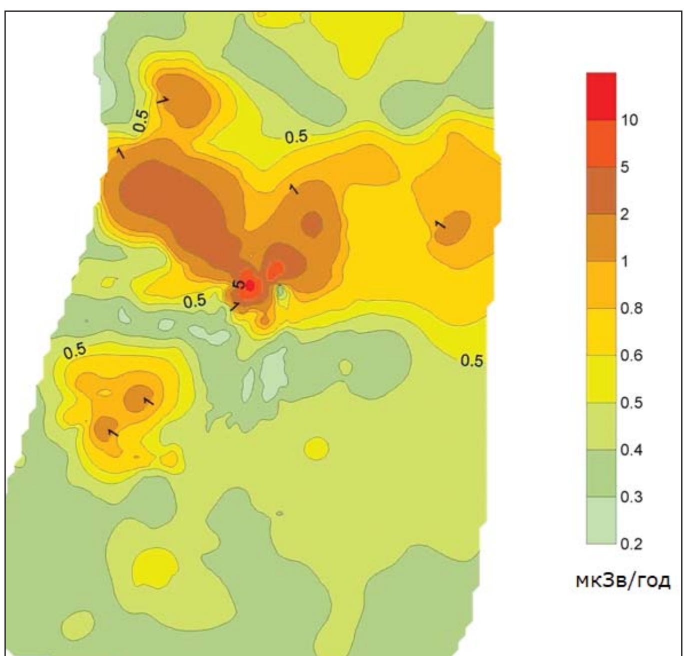


Fig. 47 Map diagram of gamma radiation intensity distribution (μSv/h) at the Centralnyi Yar tailing surface

The concentration of radon-222 in the air above the tailings

Radon concentration in the air above the tailings ranges from 70 to 620 Bq/m^3, while the average concentration is about 220-260 Bq/m^3. Seasonal measurements often change 2-3 times.

Groundwater contamination

Groundwater monitoring data for the Central Yar Tailing depict the fact of uranium migration into groundwater. However, migration is less intense than the Western tailing.

Increased concentrations of uranium are observed only in the alluvial aquifer immediately below the tailings. The maximum concentration of uranium (U-234 + U-238) recorded in one of the wells was approximately 20 Bq/l. In all other wells, the concentration of uranium in groundwater is close to the background values (0.1-1.0 Bq/l). For comparison, the allowable concentration of uranium for drinking water according to SRSU-97 is 10 Bq/l.

In addition to radioactive contamination, the contamination of groundwater with chemicals (such as macro ions and toxic metals) is observed in the Centralnyi Yar Tailing Area. Groundwater in the alluvial aquifer is contaminated with ions of nitrate, sulphate, ammonium and iron, exceeding the allowable concentrations in drinking water by 10 times or more. Comparing the composition of groundwater upstream of the tailings and downstream of it clearly shows that the source of chemical and radioactive contamination is the tailing. Similarly to Zakhidne tailing, almost the entire flow line from the tailing downstream to the Konoplyanka river is chemically contaminated with sulphate ions. Monitoring data for toxic metals in groundwater indicate that concentrations of manganese and lead exceed MPC in drinking water in the tailing area, and the MPC of nickel is also often exceeded.

7.3.3. South-eastern/Pivdenno-Skhidne tailing

Pivdenno-Skhidne tailing is located in the south-eastern part of the PChP industrial site in a large plain that penetrates the Dnipro river terrace from south to north. Other industrial buildings of the PChP are located next to the tailing storage facility (Fig. 43).

The tailing storage facility was operated from 1956 to 1990 and was discontinued after the end of operation. The landfill area is 3.6 hectares, the volume of waste is estimated at 195 thousand m^3; waste weight – 330 thousand tons; total waste activity is estimated at $6.7 \cdot 10^{13}$ Bq. The composition of the waste is rather heterogeneous and contains both radioactive and non-radioactive materials – crushed uranium ore processing waste, scrap metal, construction waste, and industrial waste, etc., mixed with loamy bulk soil. The average density of the waste is 1.69 t/m^3, the thickness of the waste layer is from 1 to 19.2 m.

The radioactivity of waste varies widely: the median specific activity of U-238 and Ra-226 is 2.1 kBq/kg and 3.6 kBq/kg, respectively; the maximum specific activities of U-238 and Ra-226 reach 16.3 kBq/kg and 236.5 kBq/kg, respectively.

Tailing conservation works by arranging a multilayer soil cover were carried out in 2009 as part of a state program. The tailings were covered with a technical coating consisting of a slag layer of cast iron, loam layers and organic soil with a combined thickness of 0.5 to 1 m. Finally, perennial grasses were planted on the surface of the soil cover. The drainage ditch for collecting surface runoff was arranged along the northeast part of the soil cover.

Within the tailings disposal site (west side) is a site for temporary storage of dismantled contaminated pipelines, containers, as well as other radioactive scrap metal and equipment from former uranium processing facilities.

Disassembled and fragmented pipelines are enclosed in rectangular piles, which are covered with metal sheets at the top and perimeter. Due to the arrangement of the specified coating in a certain way insulation of contaminated material from the effects of precipitation is ensured.

Dismantling of technological pipelines from overpasses connecting technological buildings 103, 104 and 2B was carried out in 2005 within the framework of the implementation of the State Program approved by the Resolution of the Cabinet of Ministers of Ukraine of November 26, 2003 No. 1846.

The works were carried out under the project "Dismantling and organization of temporary storage of technological pipelines of Barrier SE in Dneprodzerzhinsk" contaminated with natural radionuclides.

In total, during the works, about 6000 linear meters of contaminated pipelines were dismantled, GRI on the surface of which ranged from 1.5 to 254 μSv/h. For almost 15 years, the protective coating of the repository has corroded and degraded. One of the steps to rehabilitate a PCP site is to eliminate this object and ensure long-term safe storage of stored materials.

Gamma radiation intensityat the tailings surface

Before the tails were covered with technical soil cover, the gamma intensity on the surface of the tailings varied from 0.30 to more than 30 μSv/h with numerous radioactive hot spots (Fig. 48).

After the soil cover was installed in 2009, the intensity of the gamma radiation on the tailing surface decreased to 0.2-0.3 μSv/h.

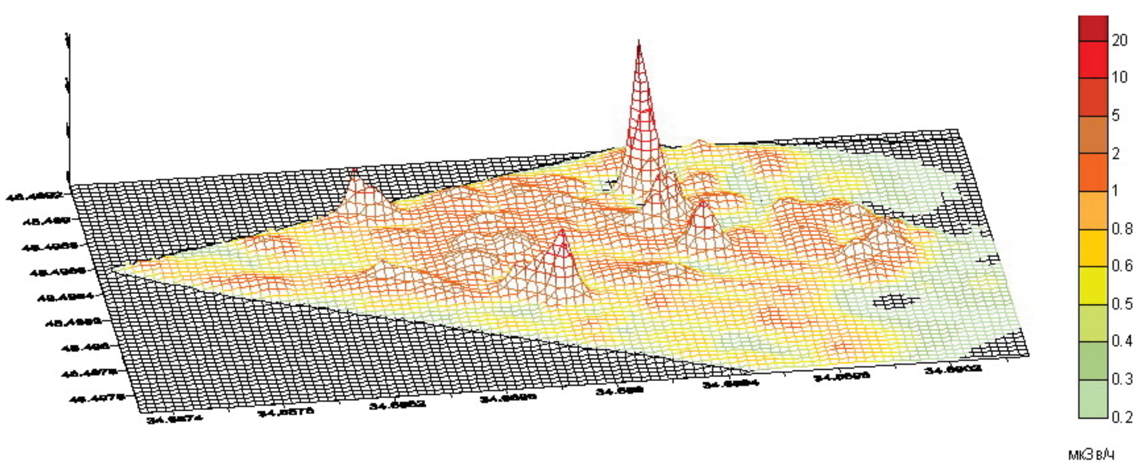


Fig. 48. Gamma radiation intensity distribution diagram (μSv/h) on the surface of the South-eastern/Pivdenno-Zakhidne tailing to the arrangement of the technical soil cover

Concentration of radionuclides in atmospheric aerosols

Data on the content of radionuclides in the air in atmospheric aerosols at the Pivdenno-Zakhidne tailing deposit show that, after the soil cover was settled in 2009, their concentrations are several orders of magnitude below the permissible limits and similar to regional background values.

Groundwater contamination

At present, the Pivdenno-Zakhidne tailing does not have an adequate groundwater monitoring system, and a monitoring network is needed.

Analysis and comparison of groundwater chemical composition in upstream and downstream wells do not show evidence that tailings are a source of chemical inputs (basic ions, toxic metals) into groundwater. The small removal of radionuclides from the tailings body into the unsaturated zone and groundwater is due to the fact that the waste was disposed of in the tailings storage in a dry state (and not by a hydraulic method – filling with a slurry). The large thickness of the unsaturated zone, consisting of clayey forest soils combined with a relatively low natural infiltration rate (~50 mm/year), provides a sorption barrier for carrying radionuclides and toxic chemicals into the groundwater.

7.3.4. Dniprovske tailing

The Dniprovske tailing site is located 0.8-1.2 km north of the PChP industrial site in the river Dnipro floodplain. The tailing area is 73 hectares. The river Dnipro flows approximately 1 km northeast of the site. Konoplyanka river flows along the southern part of the tailing storage facility and flows into the river Dnipro to the east of the tailing storage facility.

Dniprodzerzhynsk Coke and Chemical Plant sediment basins and dumps are adjacent to the tailings site from the north. DMC metallurgical sludge tanks and dumps are located east of the tailing storage facility (Fig. 49).

Fig. 49. Map-scheme of the Dniprovske tailing

The tailing storage facility was operated from 1954 to 1968. The tailing's wastes were disposed of using a hydraulic filling method. According to the inventory, the total volume of accumulated waste is 5.8 million m^3, the total mass is 12.7 million tons, and the total activity is $1.4 \cdot 10^{15}$ Bq. The general view of the tailing is shown in Fig. 50.

Рис. 50. Зовнішній вигляд хвостосховище Дніпровське з півдня на захід

Following the cessation of disposal of uranium ore processing waste, the tailings area in 1976-1980 was used for the storage of phosphogypsum (waste from the production of phosphorus fertilizers) and waste of coke production (coal slag). Most of the tailings area is covered by a layer of phosphogypsum of various thicknesses from 0.5-2.5 m (north-western part) to 8-13 m (central and eastern part). Dumps of coal slag cover the surface of the tailing storage facility in the north, northeast. These coating layers prevent the exhalation of radon-222 and the resuspension of radioactive aerosols from the tailings surface. Waste material layers are not aligned. The surface (rain) runoff is not equipped.

The tailing was set up by the construction of a closed loop of the surrounding dams. The perimeter of the dams is 4 km. The dams were constructed directly on local alluvial sands and sandy soils of the Dnipro river floodplain.

The dam body is composed of heterogeneous materials from coke-chemical waste, construction waste, as well as from local fine-grained sands, forest and sandy-clay soils. The dam and the bottom of the tailings were not equipped with an insulating (impermeable) layer. The absolute height of the dam at the beginning of operation (until 1959) was 57.45 m BS. In the later period the height of the dam was increased to 61.3-64.2 m BS. The height of the dam above the floodplain ranges from 6 to 12 m; the width of the dam along the ridge ranges from 5 to 35 m; the width of the base of the dam is 80 m. The road with concrete cover goes along the ridge of the dam. The thickness of the waste layer (uranium tails) is 6 to 10 m (8 m average). The tails are directly located on the surface of the alluvial sand and sandy-clay soils without having a protective screen.

Tails of uranium processing are represented by fine-grained sands, sandy loam and loam. The average density of the tailing material is 1.76 g/cm^3; porosity – 56%. The chemical composition of the waste is determined by the mineral composition of the ore (quartz, feldspar, hydro-mica, kaolinite) in combination with reagents and products of neutralization (sulfuric and nitric acids, lime). The tailings body is characterized by considerable variability of the radioactivity of the placed materials. This can be explained by the fact that at different times the former PChP processed uranium ores coming from different mines with different contents of uranium and daughter radionuclides.

Gamma dose power at the tailing's surface

A significant area of the phosphogypsum-covered tailing is characterized by GRI values of 0.1-0.4 μSv/h, which corresponds to background levels at the PCP site. Local hot spots are available in the north-western area of the tailing site (not covered by phosphogypsum), where GRI increases to 0.5–4.5 μSv/h.

Concentration of radionuclides in atmospheric aerosols

Data on the content of radionuclides in the air in atmospheric aerosols at the Dniprovske tailings reservoir show that their concentrations are several orders of magnitude lower than the allowable levels and are similar to regional background values. For example, the bulk concentrations of U-238 and Ra-226 were respectively 0.004 ± 0.003 and 0.005 ± 0.003 mbq/m^3 in 2010, respectively.

Groundwater contamination

Groundwater monitoring studies at the Dniprovske tailing storage facility have found significant groundwater contamination in the area of the tailing storage facility by radionuclides and toxic chemicals. It should be noted that a relatively small number of observation wells were used in the groundwater survey in 2005–2009, as a number of wells drilled in 2000–2001 were either destroyed or rendered unusable.

Uranium radionuclides exhibit the highest mobility in groundwater compared to other radionuclides. The concentration of uranium in the technogenic aquifer in 2001–2003 averaged 5–40 Bq/l, while the maximum concentration reached 325 Bq/l. For comparison, the permissible concentration of uranium isotopes in drinking water in accordance with Ukrainian standards (SRSU-97) is limited to 10 Bq/l. The concentration of uranium in the alluvial aquifers in 2001-2006 was observed at the level of 20 Bq/l.

The area of contaminated sediments of the underlying soil 2-3 m thick was formed under the tailings in the alluvial aquifer due to the geomigration process. According to the inventory, radioactivity in contaminated sediments accounted for ≈18–20% of uranium in 2000–2001 and ≈32% of the initial supply of Ra-226 in the source area (tailing bodies).

In addition to radioactive contamination in the Dniprovske tailings area, groundwater contamination with chemicals (both macro ions and toxic metals) is observed. Groundwater in the technogenic and alluvial aquifers is contaminated with nitrates, chlorine, sulphates, iron, sodium and ammonia with significant exceedances of the maximum allowable concentrations in drinking water. In general, the Dniprovske tailing is characterized by a very complex geochemistry of groundwater due to the historical changes in the chemical composition of the waste streams, as well as due to the influence of adjacent industrial waste sites.

Groundwater monitoring data for toxic metals show that concentrations of manganese, nickel, lead, cobalt, arsenic, beryllium, etc. in the tailing area often exceed the MPC for drinking water. MPC of cadmium and iron in groundwater are also exceeded.

7.3.5. Sukhachivske Tailing

Sukhachivske tailing is located in the Dnipropetrovsk region, 14 km southeast of the former PA PChP site, in the Rasolovata ravine, which flows into the valley of the Sukha Sura river – second-order tributaries of the River Dnipro (Fig. 51).

Fig. 51. Location of the site of Sukhachivske tailing storage facility and Base C

Geomorphologically, the site is located on the right bank of the River Dnipro Plateau and its slopes. The Rasolovata ravine, which divides the plateau from north to south, flows into the valley of the Sukha Sura river 5 km southwest of Section 2 of the Sukhachivske Tailing. The River Dnipro flows at a distance of 6.5 km from the northern boundary of the site. The surface heights within the sanitary zone of the objects range from +80 to +165 m BS. The site intersects the four-lane Dnipro-Kremenchuk highway. The small dirt roads of the settlements of Taromske, Sukhachivka and Gorky are adjacent to the highway.

Sukhachivske tailing site was equipped for receiving and storing PChP production waste by the hydro transport method. It consists of two sections, one after the other. The total length of the tailing pond is 4.8 km, the land area is 491.4 ha.

The tailing's bowl and dams are equipped with anti-filtration elements. The working area of the tailing is enclosed by two rows of barbed wire at a distance of 150-350 m along the perimeter. The boundary of the sanitary protection zone is located 1000 m from the side of Section 1 of the tailing and from the dam of Section 2.

On the right side of the tailings within the working area there is a closed surface storage facility – Building No. 602 "Lanthanum fraction". The repository houses the extraction of rare earth carbonates from pulp containing lanthanum and actin carbonates. The repository is a 22 × 50 m^2 concrete structure with a depth of 6 meters.

Along the left and right sides of the tailing, ditches have been installed for drainage of surface water. The estimated volume of storm drains from the catchment surface of the tailing is 156.5 thousand m^3 per year. Drainage from the ditch enters the brine gully.

Section 1, which was in operation in 1968-1983, was filled to the project levels with the waste of uranium raw materials and chemical products. The section contains 19.0 million tons of waste with a total activity of $7.1 \cdot 10^{14}$ Bq. Following the cessation of industrial operation, Section 1 periodically housed chemical production wastes from the industrial site (in the solid phase – phosphogypsum, in the liquid phase – solonchaks), to partially prevent the drying and formation of dust from the tailings beaches. As of December 31, 2006, the area of the restored beaches was 723.2 thousand m^2, the surface of the water mirror 183.6 thousand m^2 with an average depth of filled water of 0.44 m. Section 1 was not recultivated.

Section 2 of the Sukhachivske tailing was commissioned in 1983. From 1983 to 1991, Section 2 was used to accumulate both uranium waste and chemical waste. Following the cessation of uranium ore processing in 1991, Section 2 was used as storage for industrial wastes from other existing PChP production facilities: waste from apatite (phosphogypsum) processing, from ion exchange resins production, waste from zirconium and hafnium production, water from thermal power plants, solutions after regeneration of ionic filters used for the chemical purification of water, condensates from the production of mineral fertilizers, waste from the processing of gold ores.

The designed volume of the sump of Section 2 is 22.5 million m^3. At present, the available volume is about 14.8 million m^3. From 1983 to November 2005, Section 2 of the tailing was filled with a sludge mixture. The water accumulated in the tailings was used as a return for the hydro transport of the waste.

In 2005, the network of pipelines and industrial water was dismantled.

Most of the area adjacent to the tailing storage facility, including part of the sanitary protection zone outside the fence, is used for agricultural land (food crops). A small part of the territory is covered by steep slopes and hollows.

In Fig. 52 shows Section 1 with vegetation, shoreline and pond. Photo taken on the right side of Section 1. The shoreline is composed of uranium waste. In the spring, the coastline is flooded, after which the water evaporates and is filtered. The vegetation covers unheated areas.

Fig. 52. Appearance of Section 1 of the Sukhachivske tailing

The sump (cover layer of water) of Section 2 is shown in Fig. 53. The photograph was taken on the right side of Section 2. The tailing dam can be seen on the right behind the sump.

Рис. 53. Відстійник Секції 2 хвостосховища Сухачівське

Due to the decommissioning of the tailing storage facility, it can be noticed that the layer of stored waste is drying up (cracking and separating from the dams); trees and shrubs grew in the southern part. Reduced water levels on the east bank of the sump led to the exposure of contaminated solid waste.

Physico-chemical and radiation characteristics of waste

Section 1

Solid wastes in Section 1 according to their lithological features and classification are represented by sandy loam, rarely silt loam and sandy loam, sand from silt to medium.

The chemical composition of the waste consists of the basic minerals of the original uranium ore (quartz, feldspar, hydro-mica, kaolinite) in combination with the chemical compounds used to process the ore (sulfuric and nitric acids) and acid neutralization products.

In Section 1, uranium wastes were stored together with non-radioactive wastes from chemical production. These were mainly sulphate compounds.

Table 12 summarizes the data of radionuclide analysis of samples of uranium waste from Section 1 of the Sukhachivske deposit.

Table 12 *Specific activity of radionuclides in uranium waste in Section I of the Sukhachivske tailing*

Radionuclide	U	^{226}Ra	^{230}Th	^{210}Po	^{210}Pb
Specific activity, Bq/kg	2500	6200	5980	11120	11140

The liquid phase in Section 1 of the reservoir is represented by water from a slump in the central part of the section. The radionuclide composition of the wet sludge in Section 1 is characterized by the content shown in Table. thirteen.

Table 13 *The radionuclide composition of the wet sludge in Section 1*

Radionuclide	U	^{226}Ra	^{230}Th	^{210}Po	^{210}Pb
Specific activity, Bq/kg	0—37,7	0,05—1,4	0,05—4,4	0,07—1,62	0,30—6,44

The composition of the wastes stored in Section 1 is also characterized by an increased content of a number of toxic elements compared to regional indicators: lead, zinc, chromium, cobalt, molybdenum, vanadium, manganese and the like.

Section 2

The volume of solid waste in Section 2 is estimated at approximately 9.6 million tonnes with a total activity of about $2.7 \cdot 10^{14}$ Bq.

At this time, the thick surface layer of solid sediment consists of non-radioactive chemical production wastes (4-5 m). In the centre of the sump of Section 2, there are areas in which physical contact of this sludge with uranium wastes occurs.

The surface layer of waste consists mainly of gypsum (90%), Aluminum compounds (up to 2.3%), silicon dioxide (4.7-7.3%), and phosphorus compounds (1.5-2.2%). Sulphate ions (59%), nitrate ions (20%) and calcium ions (13%) are predominant in the composition of soluble salts. The content of radionuclides in the body of the tailing is given in table. 14.

Table 14. *Specific activity of radionuclides in the body of the Sukhachivske tailing, Section 2*

Radionuclide	^{238}U	^{226}Ra	^{230}Th	^{210}Pb
	Specific activity, Bq/kg			
Surface layer of waste	6,56	35—60	56,0	29—46
Phosphogypsum waste	187—427	1218—5668	2970—8404	802—4053

For comparison, the specific activities of natural radionuclides in forest loam and under red-brown clays outside the tailings area are presented in Table. 15.

Table 15. *Specific activity of natural radionuclides in surrounding soils*

Radionuclide	U	^{226}Ra	^{210}Po	^{210}Pb
	Specific activity, Bq/kg			
In the forest loam	7,2	37,7	9,5	8,9
In red-brown clays	Not identified	48,5	12,1	20,5

The chemical composition of waste on the surface of Section 2 is characterized by an increased content of a number of toxic elements compared to regional indicators in the environment: lead, zinc, arsenic, chromium, nickel, cobalt, vanadium, manganese and the like.

Gamma dose intensity at the tailing surface

Section 1

GRI at a height of 1 m above the waste surface changes in the lower part of the tailings from 0.3 to 4.1 μSv/h, in the upper part it varies from 0.6 to 4.4 μSv/h, and the average of the section is 1, 9 ± 0.6 μSv/year.

The surface layer of waste is characterized by a total α-activity of 2.7 to 7.8 ppm/cm^2 в min, β-radiation – 13-260 ppm/cm^2 в min.

Section 2

GRI on the surface of waste generated from non-radioactive materials is 0.12-0.23 μSv/h, α-radiation flux density does not exceed 1 ppm/cm^2 в min, and β-radiation – no more than 10 ppm/cm^2 · min.

Radon air pollution

The main factor in air pollution from the Sukhachivske tailing is the exhalation of radon from the surface of the waste and the deflation of dust from the surface of the drained beaches.

Section 1

The area of reclamation in the Section 1 of the Sukhachivske tailing is 906.8 thousand m^2. The radon flux density at the tailing surface varies from 0.03 to 3.2 $Bq/m^2 \cdot s^1$. The annual radon inflow from the tailing surface is estimated at $1.86 \cdot 10^{13}$ Bq.

Radon-222 volumetric activity values in most of the tailings range from 40 to 80 Bq/m^3. The relatively low levels of airborne activity in the area can be attributed to its significant humidity. Outside the reservoir at a distance of 100-200 m, the volumetric radon activity was recorded at the level of 20-60 Bq/m^3. On drained layers of the tailing (for example, in the south-eastern region) in the distance of 450-500 m from the highway, the volumetric activity of radon-222 in the air varies in the range from 150 to 365 Bq/m^3. Maximum concentrations were observed on the drained sections of the tailings beaches, where they reached 850 Bq/m^3.

Section 2

The reclamation area in Section 2 is 698.8 thousand m^2. The radon flux density on the surface of Section 2 is 0.002-0.007 $Bq/m^2 \cdot s^1$. The annual exhalation of radon from the surface of Section 2 is estimated at $2.8 \cdot 10^{11}$ Bq.

The maximum distance, where the radon concentration was reduced to background values, was found to be no more than 800 m. The expected radon concentrations at the SPZ tailing boundary were about 9-20 Bq/m^3. Almost 100% of the contribution to these concentrations is due to radon influx from the surface of Section 1.

Dust emissions from the tailings surface into the air

The area of the dry beaches of the Sukhachivske tailing, which is the source of wind sawmill, is 723.2 thousand m^2 for Section 1 and 393.2 thousand m^2 for Section 2. The estimated annual gross dust emission from the tailings surface is 61.8 t/year.

The maximum activity of aerosols in the air was measured in the area of the Sukhachivske tailing, where at a distance of 150 m from the drained beaches the content of Ra-226 in the form of aerosols exceeded the permissible concentration for the population (category B).

Groundwater contamination

Forest aquifer

Within the tailing basin, the impact on the specific volumetric activity of uranium and uranium radionuclides in the groundwater of the aquifer in 2006 did not exceed the allowable RSV_{ingest} concentrations specified in SRSU-97 for drinking water for category B (population).

Isolines of uranium content in groundwater at 1 Bq/l outline the contour of the embankment adjacent to the tailing storage facility, and only deviate westward in the direction of the discharge zone, which is located 200 m from the tailing storage facility. A chemical contamination site was formed around the tailings. Its limit is determined by isolation with a mineralization of 1 g/l.

Neogene aquifer

Chemical and radioactive contamination enters the groundwater of the Neogene aquifer from the tailing storage facility and from the contaminated groundwater of the forest aquifer through a relatively impermeable layer of red-brown clay. The pollution is then carried by the groundwater flow in the north, northwest and northeast direction of the regional stream.

In 2006, a uranium isolation of 1 Bq/l was discovered at a distance of 500 m from the dams. Within the reservoir, the specific volumetric activity of uranium and uranium radionuclides in the groundwater of the non-aquifer aquifer in 2006 did not exceed the allowable RSV_{ingest} concentrations established by the SRSU-97 for drinking water for category B (population). A chemical contamination site was formed around the tailing storage facility at a distance of 50 to 700 m. Its boundary is determined by the mineralization isolation of 1 g/l. Its maximum distance from the tailing storage facility is observed in the northeast direction and is 700 m.

It should be noted that in the period after 2005, a large number of wells have gradually become unusable for observation (or have been destroyed by locals collecting scrap metal).

7.3.6. Base C and BFR-6 storage sites

7.3.6.1. Base C repository

The Base C repository was created for the temporary stacking and storage of uranium raw materials supplied to the PChP by rail in 1960-1991.

– Michurin and Vatutin deposits in the Kirovograd region – uranium quartzites;

– deposits of Melovoye (Kazakhstan) – uranium raw materials;

– Bismuth Mining and Processing Works – uranium concentrates.

FOR REFERENCE
"Bismuth" is a joint venture of the USSR and the German Democratic Republic, the structure of which was exploration, mining and processing enterprises, which extracted and enriched uranium ore, which was supplied to the nuclear industry of the Soviet Union.

Concentrates and quartzite ore were stored in silos; raw materials from the Melovoye field were stored on an open site. The uranium feedstock from the Base C was delivered by rail to the PCP production site (Zavodskaya Station).

Base C is located in the Dnipropetrovsk rayon of Dnipropetrovsk oblast, 14 km southeast of the former PA PChP (Fig. 54).

The southern side of the storage area intersects the Dnipro-Kremenchuk (Kiev-Chisinau) highway. Agricultural land is located around the repository.

The closest settlements to the territory of the Base C are: Taromske (0,8 km to the north and east) and Gorky (0.7 km to the south).

The territory of the Base C repository with a total size of 750 × 475 m covers (Fig. 54):

- 5 open concrete bunkers with a total area of 8.1 ha in the south-eastern part of the repository, which were used for the storage of uranium ore;
- an open land plot of 6.8 ha in the southwestern part of the repository, which was used to store uranium ore from the Meloe deposit;
- BFR-6 repository in the northern part of the Base C.

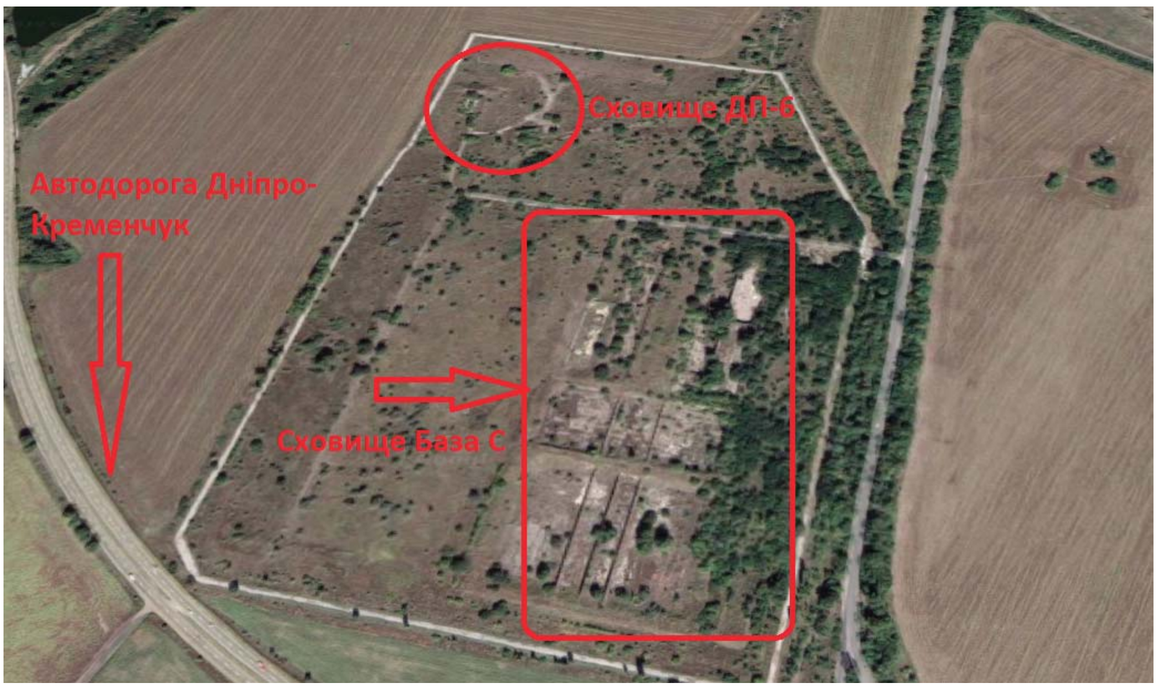


Fig. 54. Exterior of Base C and BFR-6 Repositories

The territory of the Storage Base C is enclosed by two rows of barbed wire with a checkpoint at the entrance to the territory and is protected by SE 38 WITCH.

In 2006, in accordance with the project of reclamation works in the territory of Base C, the forces of SE "SchidtGZK" and in agreement with the SNRCU, 20 thousand tons of uranium raw material were removed, from which 17 tons of concentrate were obtained.

In 2008, in accordance with the project "Decontamination of Uranium Waste Storage and Backfilling of Open Contaminated Radioactive Territories of the Repository", buildings and structures located in the northern part of Base C were dismantled and reconstructed on the area of 5.8 ha.

According to research carried out in 2010-2011, the volume of uranium raw material contained in the storage area is estimated at about 65.0-70.0 thousand m^3, or about 130 thousand tons. The total volume covers an area of about 25 hectares.

The distribution of uranium raw material in the storage area is variable in size and depth and is represented mainly by three sections:

– A site with a content of uranium 0.1-1.0% is located in the southwestern part of the deposit and is represented mainly by small material distributed in the surface half-meter layer;

– A site with a content of uranium 0.02-0.1% is located between bins No 1-2 and No 3 and is a concentrated mass mixed with soil. Distribution depth reaches 5 m;

– Uranium content of 0.1-0.6% is located southeast of bunkers No 4 and #No 5, represented by concentrated mass mixed with soil. It looks like an artificial hill up to 10 m high.

The main engineering structures in the storage area are reinforced concrete bins for the storage of uranium ore. The bunkers are surrounded by 2.5-4.5 m high dikes.

Railways, power grids, railway limestone embankments from Sukhachivske Station to Base C were dismantled.

Appearance of the bunkers and the open pit for the storage of uranium ores is shown in Fig. 55-57.

Fig. 55. View of site and railway tracks of overpass hopper 5, east direction

Fig. 56. Railway track view of hopper 4, south-eastern direction

Fig. 57. Open pit for ore storage

Radiation status of uranium ore deposit

According to the results of dosimetric gamma shooting, the GRI values ranged from 0.14 to 17.1 μSv/h. The hot spots showed maximum levels of gamma radiation up to 24.2 μSv/h (between the bins in the central part of the storage where uranium ore was stored earlier). The distribution of GRI in the air at an altitude of 1.0 m in the base C is shown in Fig. 58.

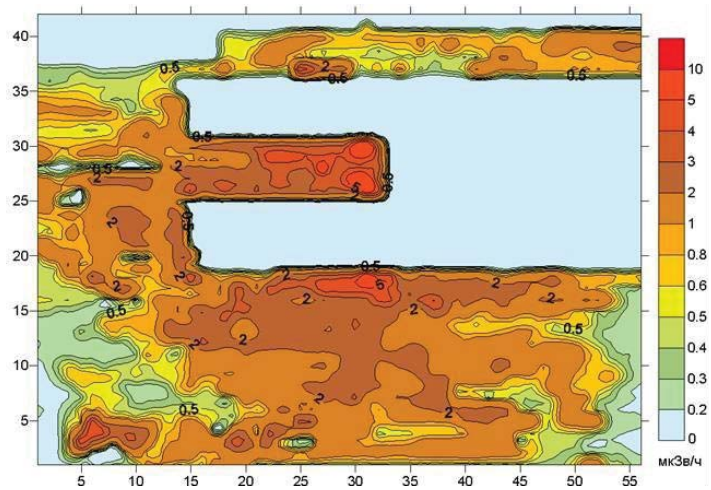


Fig. 58. GRI distribution map at 1.0 m height within the boundary of the Base C repository

Soil contamination

Availability of radioactive elements in the soil of this territory is conditioned by the nature of exploitation of the uranium raw material intermediate storage, the conditions of its transportation and storage, as well as the impact of the Sukhachivske tailing facility. According to the environmental monitoring data, the content of uranium radionuclides in the upper soil layer in the Base C storage area is:

– U-238 in the range of 1200-5500 Bq/kg;

– Ra-226 in the range of 1500-6500 Bq/kg;

– Pb-210, P-210 in the range 1800-6500 Bq/kg.

It should be kept in mind that according to the best world practice in the EU and the USA, the value of 200 Bq/kg is assumed as a remediation criterion for the former Ra-226 uranium production in the upper soil layers.

Groundwater contamination

The radiochemical composition of groundwater is formed by the infiltration of precipitation in forest loam and sandy loam. The flow of groundwater is directed west and southwest in the direction of the Rasolovata ravine, direction. Specific activity of natural radionuclides in groundwater in the storage area of Base C and Gorky village, located nearby, exceeds the SRSU-97 norms for the permissible concentration of natural radionuclides in drinking water for the population (RSV_{ingest}).

Air pollution

The radioactive contamination of the air observed in the Base C storage area is caused by the exhalation (radon flux density from the surface) of radon and the emission of radioactive substances from the object surface. The aggregate data on the average annual volumetric activity of radon-222 in the storage area of Base C and in its SPZ are respectively 120 and 100 Bq/m^3. According to the requirements of SRSU-97, the action level for the average annual equivalent equilibrium volumetric activity of radon-222 in the air of the breathing zone in the premises of buildings and structures operated with permanent residence of people is 100 Bq/m^3.

During operation and at present, the Base C repository is a source of radioactive contamination of the environment due to the presence of uranium raw material residues in the territory and as a consequence of the wind transfer of radioactive and chemical substances. The result is a negative impact on the environment and the population living in the surrounding areas.

7.3.6.2. BFR-6 repository

The BFR-6 storage facility was created after the blast furnace No 6 was dismantled at the Dniprovskyi Metallurgical Plant, which smelted iron from the Pervomayska Mine (Kryvyi Rig) ore with a content of uranium up to 0.7%. The smelting of the ore has led to the radioactive contamination of the structural components of the blast furnace and the lining. After the furnace was dismantled, the bulk of the contaminated material was transported to the Base C repository, where the material was stored in 200 × 32 m earthen tailings and 2–2.5 m deep and covered with loam and unpolluted soil. Works on complete conservation of the repository were completed in 1982. The BFR-6 repository contains 40 thousand tons (15 thousand m^3) of dismantled fragments of building structures, radioactive scrap metal and blast furnace lining with a total activity of $1.3 \cdot 10^{12}$ Bq. The deposit is covered with loam (about 1 m thick) and soil (~ 0.5 m).

Long-term observations of the radiation condition in the storage area indicate the adequacy of the protective layer. Yes, the exposure intensityat the storage surface does not exceed 0.3 μSv/h.

Given the location of the repository, it is not possible to determine its direct environmental impact, given the presence or absence of effects on groundwater contamination.

Visually, the condition of the outer cover is satisfactory, the surface of the storage well covered with perennial grasses.

7.3.7. Assessment of the impact of the PChP site on the employees and the general public

Impact assessment of workers on the PCP site

The radiation dose assessment of radiological and non-radiological workers at the PCP site was first conducted under the ENSURE-I project. The calculations used the methodology and dose models described in the publication [1]. Doses of radiation were calculated for appropriate working conditions at tailing storage facilities (namely, in the West, Central Yar and Southeast), inside contaminated buildings (buildings 103, 6, 112), as well as for other radioactively contaminated sites (hot spots, sedimentation tanks, etc.) located within the PChP industrial site.

Doses were evaluated for workers who were potentially exposed to, or near the PChP sites. During the dose assessment, scenarios were developed that consisted of conservative assumptions about the behaviour of workers on contaminated sites (worst-case model). The following main routes of exposure were considered during dose calculations:

– external exposure due to soil contamination (outside buildings) and contamination of materials/equipment (inside buildings);

– inhalation exposure due to inhalation of contaminated aerosols;

– irradiation exposure through dust entering the body (swallowing);

– irradiation exposure due to inhalation of radon-222 and its short-lived decay products.

The results of the estimation of the potential radiation doses of the employees of the enterprises located on the industrial site are given in Table. 16.

Table 16. *Estimation of potential doses of exposure of employees of enterprises located at the industrial site of PChP*

Employee category	The main ways of exposure	Total effective dose, mSv/year	
		Min.	Max.
Workers who have access to contaminated Building No. 103 during the work day spend part of their working time outside (for example, near Building No. 103), but spend most of their working time in unpolluted or poorly contaminated premises	External exposure, inhalation of Rn-222	2,3—4,0	25—35
Employees who, in accordance with their work responsibilities, have access and spend part-time in the basements of a former uranium production facility	Inhalation Rn-222	6,0—8,0	10,0—13,0
Employees whose main place of work is located near tailings and other contaminated sites (Central Yar and others)	External exposure, inhalation of Rn-222	1,0—1,6	2,5—3,5
Employees of northern PChP enterprises who spend most of their working time in unpolluted areas and part-time outside contaminated sites	External exposure, inhalation of Rn-222	0,6—1,0	1,4—1,8
Administrative staff	External exposure	0,1—0,3	0,3—0,5

The above results show that the main sources of exposure at the PChP industrial site are buildings (for workers inside), areas with high background radiation (hot spots), residues of contaminated infrastructure and tailings with insufficient protective barriers.

The highest exposure risk is associated with the potential long-term occupancy of personnel inside contaminated premises of uranium ore processing facilities. The main contribution to the radiation dose inside contaminated buildings is the inhalation of radon. However, external exposure from contaminated structural elements and equipment in some cases has a significant effect on doses. External radiation is a major factor in the doses received from the surfaces of contaminated soils (e.g. tailings and contaminated sites).

Preliminary dose estimates contain significant uncertainties related to the temporal and spatial variability of the radiation monitoring data used in dose estimation. In addition, conservative assumptions have been used in the development of exposure scenarios, while human behaviour is difficult to predict and may lead to adjustments to the dose (both increase and decrease).

Dose assessments conducted within ENSURE-I and ENSURE-II projects did not address a number of specific situations (e.g. removal of contaminated soil, dismantling of contaminated buildings, or emergency situations that may occur during restoration work) at the PChP site).

Assessment of impacts on the population and the environment

Residents of Kamianske (Zavodsky rayon) and the surrounding settlements of Karnaukhivka, Taromske, Svitle, Gorky and Ordzhonikidze are in the area of influence of the main uranium PChP facilities in one way or another. The map-scheme of location of these settlements and information on the number of residents are shown in Fig. 59.

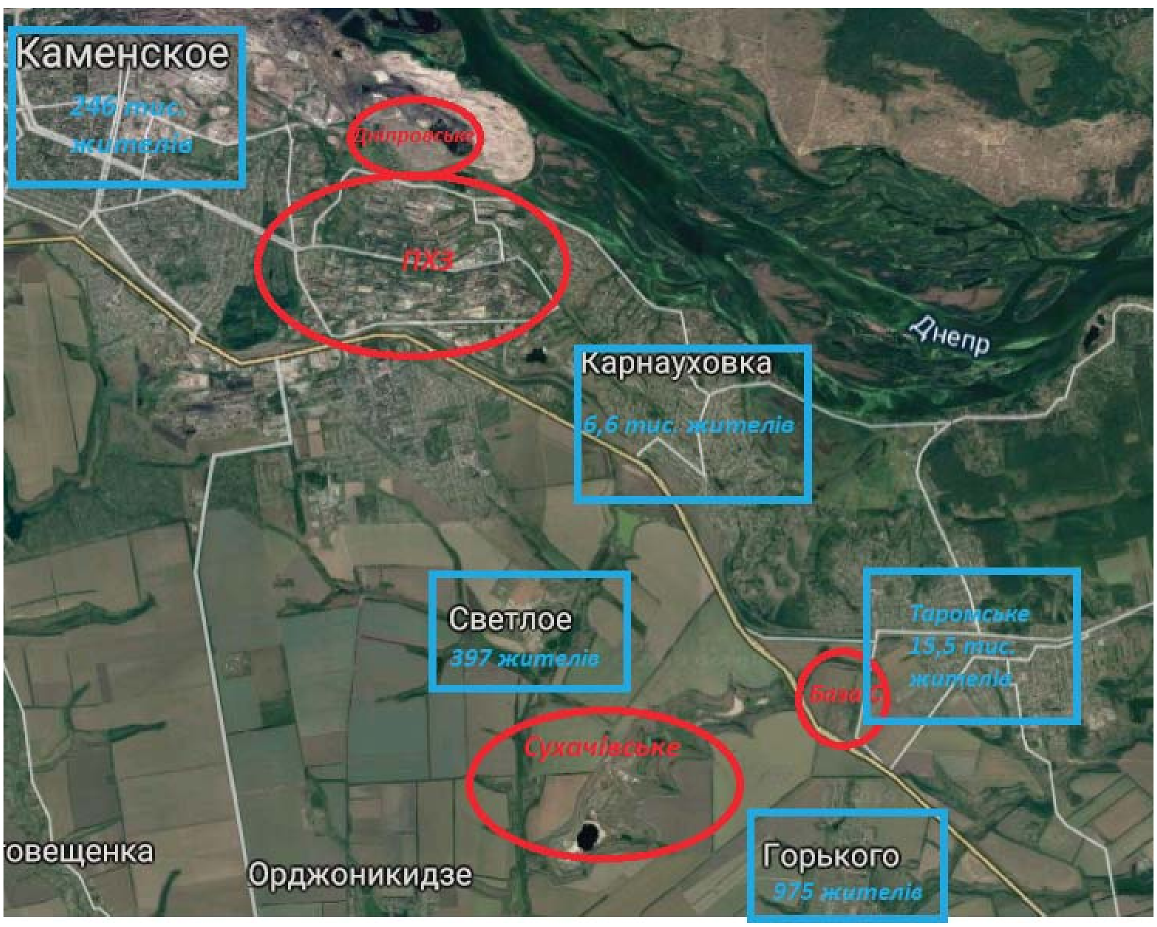


Fig. 59. Map of location of settlements in the area of influence of uranium objects of PChP

The main ways of exposure of the population are:

– inhalation of radioactive aerosols and air contaminated with toxic substances;

– Radon breathing;

– consumption of contaminated agricultural products and fish from surrounding water bodies;

– stay in places with high radiation background.

Within the framework of the ENSURE-II project, the potential impact on the population has been estimated at the cost of the above mentioned factors, both directly for the industrial site and for the Sukhachivka site

For example, in the event of 100% destruction of the tailing storage facility Zakhidne, for Kamianske residents the doses due to radon exhalation are estimated to be very low (5.4 x 10 4 μSv/year) and do not pose a significant radiological risk. Air transport of radionuclides associated with dust particles from potential sources of the Sukhachivka site (Base C and section 1 of the Sukhachivka tailing storage facility) was calculated in 2009. Two assumptions were used in the assessment. First, the calculations took into account the resuspension and wind transfer of dust particles smaller than 10 μm (i.e., inhaled particulate pollutants), which determine the inhalation load of radionuclides for humans. Secondly, the calculations were performed for continuous wind flow conditions for 5 days with two characteristic speeds of 4 and 12 m/s. The results of the calculations indicate that the wind transfer of radioactive particulate pollutants at a speed of 4 m/s does not significantly affect the radiation conditions near the site. The simulated concentrations of radionuclides in the air at a distance of 100-200 m are less than the allowable levels of PCBinhal by 4 orders and at a distance of 1000-2000 m by 5 – 6 orders (for ^{238}U).

At a wind speed of 12 m/s, the radiation situation is deteriorated by the approaching (but not exceeding) of the concentrations of radioactive particulate pollutants to the permissible levels of PCBinhal. Therefore, in the conditions of strong winds, there are certain risks of radioactive exposure for residents of nearby settlements. Calculations of the radiation dose due to the transfer and inhalation of dust from Base C to nearby villages indicate that at a wind speed of 12 m/s, the maximum inhalation doses in the villages of Taromske, Sukhachivka and Gorkogo are up to 50-70 μSv (within a 5-day period). At a wind speed of 4 m/s, the estimated radiation doses are lower by about an order (5-7 μSv within a 5-day period). The potential impact of the beaches of Section 1 of Sukhachivka tailing storage facility on the settlements of Taromske and Gorkogo in the scenario of unfavourable meteorological conditions is somewhat higher than in the case of Base C. Thus, at a wind speed of 12 m/s, the maximum integral inhalation doses in the villages of Taromske and Gorkogo are 85-100 mSv (within a 5-day period). At a wind speed of 4 m/s, the radiation doses are estimated to be lower by about an order (8-10 μSv within a 5-day period).

Estimates of radiation doses due to contamination of agricultural products to the public in the PChP uranium tailings area were conducted by the Ukrainian Institute of Agricultural Radiology. The results of conservative modelling estimates showed that PChP uranium tailings did not significantly increase the content of radionuclides in the arable soil (compared to the natural background content) of farmland located near tailings (contamination gain less than 0.01% compared to 0.01% year-on-year). . Thus, uranium tailings do not contribute to root uptake and aerial contamination of crops and livestock products.

Estimates of radionuclide intake by local residents through consumption of agricultural products and appropriate radiation doses (Table 17) show effective doses of PCP tailings that are 7.3 μSv/year, well below the dose quota established by SRSU-97 for current uranium ore processing enterprises (0.12 mSv/year).

Table 17. *Maximum calculated values of annual radionuclide uptake by adults in the PChP tailing areas and corresponding effective doses of internal irradiation*

Radionuclide	Annual average consumption of radionuclides through food, Bk					Annual average effective dose, μSv/year
	Root crops	Grain	Milk	Vegetables	Sum	
^{238}U	<3	<2	<1	<3	<7	<0,3
^{226}Ra	<4	<18	<1	<2	<25	<7
					Total	**<7,3**

Groundwater contamination by uranium tailings

For tailings located at the PChP site, the primary radiological hazards are associated with the migration of uranium into groundwater. The concentrations of uranium in porous solutions in the body of the uranium tailings exceed the permissible concentration in drinking water according to SRSU-97 by 1-2 orders of magnitude (for example, concentrations of ^{234}U + ^{238}U reached 1068 Bq/l in 2005 in Zakhidne tailing storage facility). At the time of the research (2005-2009), radioactive contamination spread from the waste to unsaturated soils and the horizon of sedimentary rocks below the tailings body and, in some cases, uranium migrated about 100 meters downstream from the tailing storage facilities. in alluvial deposits.

Apart from radioactive contamination, significant contamination of groundwater by chemicals is observed. Concentrations of chemical elements such as nitrates, sulphates, chlorine, sodium and potassium exceeded the norm for drinking water by 1-2 orders of magnitude. Groundwater contamination with heavy metals (lead, manganese, etc.) was also observed.

The level of contamination of the groundwater of the aquifer in alluvial deposits between the tailing and the discharge circuit (Konoplyanka river) is such that it makes it unsuitable for drinking and domestic use. The groundwater horizons between the West and Central Yar reservoirs are polluted by chemical pollutants along the entire length from the source (tailing) to the discharge circuit in the Konoplyanka River. In the future, it is expected that radioactive plumes will spread from tailings to surface water tanks (Konoplyanka and Dnipro rivers). It should be borne in mind that groundwater contamination of the aquifer in alluvial sediments downstream of tailings at the PChP site may pose a threat to the local population if contaminated groundwater from that aquifer is used as drinking water or for domestic use.

The monitoring data do not show the impact of the Sukhachivka tailing on groundwater contamination of the lower sandy aquifer in the Neogene sediments (used as a source of drinking water downstream from the site). At the same time, the groundwater monitoring system of the Sukhachivske Tailing is unsatisfactory and requires significant improvements, including the installation of additional monitoring wells.

According to previous studies, PChP tailings can be divided into two groups:

- tailings, which are a significant source of radioactive and chemical contamination of groundwater. Zakhidne, Dniprovske and Centralnyi Yar tailings belong to this category and need more attention in terms of development of groundwater monitoring system and rehabilitation analysis;
- relatively safe areas where engineering and geological barriers at the time of exploration provide sufficient groundwater protection against radioactive pollutants. This category includes the South-eastern (Pivdenno-Skhidne) Tailings, Sections 1 and 2 of the Sukhachivske tailings and Base C.
- To address the problems of radioactive and chemical contamination of the groundwater of the PChP site, experts have recommended a controlled natural attenuation strategy adapted to local conditions, based on the recommendations of the IAEA document [11], namely:
- departmental control and restrictions on the use of water from the aquifer of alluvial deposits and water from the Konoplyanka River in the area of impact of tailings;
- awareness-raising among the local population to prevent inadvertent exposure from contaminated water and fish;
- covering the tailings with engineering protective coatings in order to minimize the penetration of atmospheric precipitation into the tailings;
- monitoring of natural processes (sorption, dispersion, etc.) of radionuclides and chemicals in the surface environment;
- periodic updating of groundwater modelling forecasts and revision of PChP source management strategies as needed.

8. ROAD MAP TO PCHP SAFEGUARDING

As of now, sufficient positive experience in the rehabilitation of uranium sites has been accumulated in the world and in Europe in particular. First of all, it is the rehabilitation work carried out at the former joint Soviet-German enterprise "Bismuth" for the extraction and processing of uranium ores.

Established in 1953, Bismuth was the third largest uranium producer in the world, producing 231,000 tonnes over the period. Intensive mining activities carried out for over 40 years have led to significant man-made radioactive contamination of the densely populated areas of Saxony and Thuringia. In December 1990, it was decided to terminate the enterprise. In 1991, the German Parliament passed a law (WISMUT Act), which initiated the rehabilitation of contaminated territories, for which the Federal Government of Germany has allocated 6.2 billion euros. Guided by the principle of optimization, in agreement with regulators, rehabilitation was carried out in two scenarios:

– restoration of territories to the state of "green lawn";

– restoration of the territories to the state of brown lawn.

The restoration of the territories to the state of green lawn (the main scenario) involved the reclamation of land to the extent of unrestricted use. This required the removal of surface soils with a contamination level exceeding 0.2 Bq/g (at radio-226), as well as the implementation of landscape design of the terrain, restoration of soil productivity and control of their erosion. The restoration of certain areas to brownfield conditions implied limited use of land on which industrial and industrial premises could be located. Criteria for limiting land use were determined by the radioactive contamination of soil with radium-226, which should not exceed the standard of 1 Bq/h, provided that the radioactively contaminated materials were completely removed from the territory [12]. The modern appearance of the territories where previously depleted ore dumps and tailing storage facilities of the Bismuth enterprise is shown in Fig. 60.

Reclamation works at the tailing of uranium ore waste dump in Sillamäe, Estonia

The uranium plant of the Soviet Union military-industrial complex (Combine No. 7) was built in Sillamaye in 1948. In 1948-1953, uranium production was organized from extracted on-site raw materials (uranium deposits in shale). In 1953-1977, the plant processed uranium raw materials that were imported from both the Soviet Union republics and other countries of the so-called Eastern bloc.

The tailing is located in the western part of Sillamäe in the Ida-Viru district, directly on the Gulf of Finland. The storage area is over 50 hectares. The amount of accumulated waste is 8 million m^3, or 12 million tons.

Fig. 60. Modern view of the territories where previously depleted ores and tailing storage facilities of the Bismuth Enterprise (photo by Ch. Kunze, Wisutek, Germany)

Fig. 61. General view of a reclaimed tailing storage facility and a rebuilt maritime port terminal, Sillumiye, Estonia

The tailings contain uranium raw materials with a predominant content of uranium, thorium and other radionuclides, as well as heavy metals and other toxic chemical elements and substances. In addition, shale ash from the thermal power plant was stored in the storage facility. The thickness of the waste layer is about 20 m.

The Ministry of Environment of the Republic of Estonia was one of the initiators and organizers of the remediation project. The total cost of the tailings remediation project was over € 21 million (CZK 330 million). The project was funded by the European Union through the Phare program, the NEFCO Nordic Environmental Fund and the Baltic countries: Denmark, Norway, Finland and Sweden. The Estonian state financed the project from the state budget and through the Environmental Investment Center.

The Estonian Tailings Reclamation Project is the largest conservation project in history. Preparatory and design work began in 1997. Construction work was carried out from 1998 to 2008 under the direction of a specially created private-state structure of the joint-stock company "Ekosil" (Eston. ÖkoSil).

The general view of the reclaimed tailing storage facility and the rebuilt port terminal is shown in Fig. 61.

FOR REFERENCE:

<u>The "Phare" program</u> (Poland and Hungary: Aid for Restructuring of the Economies) is one of the financial instruments of the European Union aimed at assisting candidate countries from Central and Eastern Europe in preparing for EU accession.

<u>Ecosil Joint-Stock Company</u> (Eston. ÖkoSil) is an enterprise operating in the industry of protection of the environment. The share capital of Ekosil is 7.8 million kroons, of which 35% is owned by the Republic of Estonia and 65% by the joint stock company Silmet Grupp. The mission of this enterprise is to manage major environmental projects, including the Sillamäe Uranium Tail Reclamation Project, as well as environmental management and monitoring services. The Company's technical base is located in Sillamäe.

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One of the latest examples of approaches to addressing the rehabilitation of uranium heritage sites is the Strategic Master Plan for Environmental Reclamation at Uranium Heritage Sites in Central Asia, developed by the Coordination Group on Former Uranium Objects, presented at events held in as part of the 61st session of the IAEA General Conference in September 2017 The Working Group includes representatives of the European Bank for Reconstruction and Development, the European Commission, the IAEA, the Russian Federation, Kyrgyzstan, Tajikistan and Uzbekistan.

The total cost of the reclamation works involved in the master plan, together with the support activities, is estimated at around 210 million euros. Certainly, a large part of this amount (around EUR 180 million) is earmarked for reclamation works, around EUR 17 million for integrated risk assessment and remediation options on site and about EUR 15 million for supporting capacity-building and other activities, deemed necessary to ensure the success of the remediation activity.

In all cases, the planning of recovery strategies began with political decision-making and dialogue with the public, determining the end result and criteria for achieving the ultimate goals of rehabilitation, which were legislated at the level of local and state authorities. Decisions were then taken to ensure sustainable funding for the programs, and the responsibility of regulators and operators for their implementation was established. Then began the process of finding ways to reach the goal.

In the preparatory phase, detailed safety assessments were carried out, criteria and requirements for procedures and contractors were developed. The best options for engineering solutions were chosen based on the priorities of the analysis of monitoring data and safety assessments, including feasibility studies for each variant of the chosen strategy and environmental impact assessment. The projects underwent multi-stage approval and adoption – only after that the implementation of engineering measures began. Radioecological monitoring, technical and regulatory oversight services operated in parallel, and institutional control procedures and mechanisms were developed [12].

As of now, there is no formalized long-term strategy in Ukraine to bring the PChP site to an environmentally sound state. The lack of an approved strategy for bringing PChP to a safe state has led to inefficient use of so little budgetary resources and to the lack of continuity of program-to-program activities. The draft of such a long-term strategy, based on the best European experience, was first developed during 2015-2016 by the Consortium comprising: Facilia AB, WISUTEC GmbH, WISMUT GmbH, C&E GmbH, within the framework of the European Commission project U4.01/10G "Development of a method (strategy, technology) for the reclamation of the territory of the former uranium object" Prydniprovsky Chemical Plant ". At present, the strategy has been approved by the project beneficiary, the Ministry of Energy and Coal Industry, but has not yet been implemented as a government decision.

According to the best world practice, the strategy should include decontamination and dismantling of the processing plant itself (production infrastructure of the uranium enterprise), reclamation of contaminated territories and tailing storage facilities, restoration of groundwater status to acceptable conditions (if necessary) and long-term monitoring and institutional control. . The levels of radiation, health and safety of personnel and the general public must be monitored and appropriate records maintained. Access to radiation contaminated sites and equipment must be controlled. The process of bringing the site of the inheritance to a safe state requires considerable time and expense. According to the draft strategy, the total cost of PCP rehabilitation work, including the cost of rehabilitation waste management infrastructure, is approximately € 250 million over 10 years.

A thorough review of all stages of direct rehabilitation work is not covered by this review, and a roadmap at the project implementation stage is a necessary and useful tool.

Full-scale and successful rehabilitation work at the PChP site, in line with global best practice, should be preceded by a significant amount of preparatory and support work and activities, namely:

a) renewal of the radio-ecological monitoring network;

b) a detailed characterization of waste contained in contaminated buildings and areas;

c) development of a Waste Management Program;

d) study of geo stability and radiation status of tailing storage facilities (Zakhidne, Pivdenno-Skhidne, Centralnyi Yar, Dniprovske);

e) creation/rehabilitation of rehabilitation waste management infrastructure;

e) development and approval by the regulatory body of rehabilitation criteria;

f) development and approval of the Rehabilitation Program.

The details of actions and events are more described below:

a) The renewal of the radio-ecological monitoring network shall consist of:

– development of the Program and regulation of radioecological monitoring both at the site and in the area of influence of future rehabilitation works;

– arrangement of a network of observations by type of automated radiation monitoring system.

b) The detailed characterization of waste contained in contaminated buildings and areas should include:

– complete inventory of contaminated equipment and radioactive materials contained in main production buildings (buildings 1-6, buildings 1A, 1M, 2B, 103 and 104);

– determination of radiation characteristics of equipment, radioactive materials and structures of buildings;

– clarification of radiation contamination of the territory of the southern part of the industrial site and the territory of the former base C uranium ore composition (detailed dosimetric survey with sampling of the soil through the established network). The total area is about 150 hectares;

– analytical processing of received materials, mapping.

c) Development of a Waste Management Program. The program should contain:

– waste classification and volume;

– identification of waste streams;

– waste sorting procedures according to the classification.

d) Rehabilitation of tailing storage facilities (Zakhidne, Pivdenno-Skhidne, Centralnyi Yar, Dniprovske, Sukhachivske, 1 section):

– carrying out works on the study of the geo stability of the enclosure dams and the condition of the protective cover of the tailings

– ensuring constant technical supervision over the condition of the tailing storage facilities.

e) Establishment of rehabilitation waste management infrastructure should include the following measures:

– construction of a sanitary pass for personnel and a point of deactivation of vehicles;

– construction of contaminated equipment decontamination site;

– arrangement of a temporary platform for storage of heavily contaminated equipment;

– development of the project of overhaul of the Sukhachivske Tailing, Section 2;

– execution of works on overhaul of the Sukhachivske Tailing, Section 2 and putting it into operation.

f) Development and approval by the regulatory body of rehabilitation criteria.

At present, there are no criteria for the rehabilitation of uranium heritage sites in Ukraine.

g) Development and approval of the Rehabilitation Program for the southern part of the PChP site and the Base C storage site, including.

In accordance with the requirements of Art. 12 of the Law of Ukraine "On mining and processing of uranium ores", the Program of rehabilitation of the southern part of the PChP industrial site and the territory of the storage of Base C should provide for the environmental impact assessment and to pass the state nuclear and radiation safety examination and other state examinations in accordance with the legislation of Ukraine.

Certainly, the above works and activities will be possible, effective and successful in the case of:

– approval of a state-level strategy for bringing the PChP site to a safe state;

– regulation at the legislative level of the rights and obligations of all economic entities at the uranium heritage site, regardless of their ownership;

– identifying a stable and sufficient source of funding for the works;

– definition of a site operator provided with sufficient financial and human resources.

9. AFTERWORD

Object status

In the period from 1949 to 1991 the main activity at the production association "Prydniprovsky Chemical Plant" was the processing of uranium raw materials in order to obtain a concentrate of natural uranium for the needs of the military-industrial complex of the former USSR. Due to the collapse of the Soviet Union and subsequent decentralization processes, PA PChP ceased operations.

However, the PCP did not pass the decommissioning and liquidation stage as a uranium facility with all safety stages and requirements. The decommissioning of the main facilities of the former uranium cycle was accomplished by dismantling the most valuable equipment and decontamination of some buildings and territories. These works were motivated, above all, by economic interests, without due regard for compliance with the radiation safety requirements of employees and the environment.

In the conditions of the insolvency of PA PChP, a restructuring procedure for the plant was introduced, which was carried out against the background of its bankruptcy, with the subsequent privatization and commercialization of certain objects. In some radiation-contaminated territories and in the former workshops of the plant, various economic activities were introduced, not peculiar to the uranium object, and production or commercial activities were carried out without observing the basic requirements for radiation safety.

Radiation threats to the personnel, the general public and the environment

In 2000, in order to ensure the safety of activities in the territory and facilities of the former PA PChP, a specialized State enterprise ”Barrier” was set up. Such hazardous uranium facilities as 5 tailings with uranium ore wastes and individual, most polluted industrial buildings (workshops) used in the uranium production chain were transferred to this SE. It should be noted that SE ”Barrier”, as a licensee in the field of uranium ore processing, ensures compliance with the radiation safety requirements only of the objects that have been transferred to it. The rest of the objects remain uncontrolled.

Moreover, the site as a whole is not under the regulatory control of the State Nuclear Regulatory Inspectorate. In practice, this results in a lack of oversight of compliance with the radiation protection requirements of on-site personnel. Only employees of the

SE ”Barrier” (approximately 10-20 persons out of 1000 at different times) belongs to the ”staff” category. In such a situation, and in the context of over-pollution of most of the site and buildings of the former uranium processing cycle, more than 1000 workers of PChP are at risk of undue exposure. The estimated radiation doses of non-radiological workers exceed the established limit for the population of 1 mSv/year.

Exposure risks also persist for the population living in the area of exposure to uranium objects, especially in the Sukhachivka site area. Groundwater of the drinking horizon and surface water in the area of influence of uranium objects are polluted beyond the established norms in terms of both radiation and chemical parameters. The groundwater hydrogeological network constructed in the early 2000s is in a state of neglect, which does not allow proper monitoring of the groundwater status.

As a result of the financial inability of the operator of the site of SE “Barrier”, the work on radio-ecological monitoring is practically not implemented. The technical condition of the tailing storage facilities, contaminated buildings and structures is not properly monitored. The condition of the dams, in terms of their geotechnical stability, especially the largest and most dangerous tailings Dniprovske and Sukhachivske, as well as in section 2, has not been determined. None of the existing tailing storage facilities have sufficient protective cover, adapted to best international practice, and are therefore a permanent source of radon in the environment.

Results of the state programs

Measures taken under state programs to bring the site to an environmentally safe state were ineffective and did not improve the situation. They were of primary/stabilization nature and emergency focused. Rehabilitation activities, as such, were practically not envisaged by the programs. Funding of state programs was carried out on a residual basis and did not exceed 40-50% of the planned, even extremely limited, funds.

It is the lack of an approved strategy for ecological safeguarding of PChP that has resulted and results in an inefficient use of the limited amount of budgetary resources, and the lack of continuous activities from program to program. Program interruptions and unstable funding, together with other management weaknesses, also made it impossible to carry out continuous radioecological monitoring as a basis for further management decisions on rehabilitation work.

Based on the above, it is considered appropriate to:

- change the ideology of developing government programs to ecological safeguarding the PChP site and introduce a new approach based on the government-approved PChP rehabilitation strategy as a uranium heritage site;
- Significantly improve the status of operation with involvement of the international donor assistance.

International programs and perspectives

Starting from 2016, thanks to the implementation of EC project U4.02/16B1 "Implementation of emergency measures at the Prydniprovsky Chemical Plant", systematic preparatory work was started at the PChP site, which should be preceded by full-scale rehabilitation activities, namely:

- stabilization of radiological risks (enclosure of the most contaminated territories and objects, in order to limit uncontrolled access, isolation of contaminated buildings in order to prevent leakage of pollutants outside);
- construction of a storage facility for the localization and temporary storage of contaminated sites, in large quantities (more than 200), located on open areas within the PChP;
- removal of the above listed objects;
- development of the capacity of the site operator.

Under favourable political conditions and strong financial participation of Ukraine supported by the developed projects, construction works on the site at the expense of the EC project can be implemented in the II quarter of 2020.

However, the possible progress towards the implementation of further preparatory and direct rehabilitation works at this time is not fully defined and will depend, first of all, on the demonstration of intentions by the Ukrainian side to support these projects, as well as on further financial support from the EC.

According to the strategy developed under the previous project, the estimated total cost of rehabilitation works, including the cost of rehabilitation waste management infrastructure, is approximately € 250 million over 10 years.

In such circumstances, any financial support from European donors, environmental organizations, etc. will be extremely beneficial and will help to maintain a positive pace in addressing one of the most pressing environmental problems in Ukraine.

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