

Uranium Mines In Bulgaria - Analysis Of The State 30 Years After Their Closure

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Abstract. Uranium mining in Bulgaria dates back to 1939 and was made a historical aspect of uranium mining in Bulgaria until its liquidation in 1992. The measures taken under Decree No. 74 / 27.03.1998 to liquidate the consequences of mining and processing are described of uranium and the omissions to be made. eliminated in this regard. Until the end of uranium mining in 1992, the annual production of uranium was 660-680 t, of which 430 t was obtained by geotechnical method - drilling with sand-type uranium drilling. They are poor in uranium (below 0.05%), but with several times cheaper yields (average \$40/kg for 1970-1990). The problems related to the reclamation of lands around uranium deposits and enterprises are shown. The condition of the terrain around the mines and the results of the samples from 2000 and 2010 have been analysed and recommendations for improving the condition and subsequent investigation of the condition of the adjacent terrain have been identified.

Keywords: mines, mining, reclamation, results, samples, uranium, uranium processing.

I. INTRODUCTION

Uranium mining in Bulgaria has a 47-year history (1945-1992) and is one of the earliest in Europe. Uranium deposits in Bulgaria (48 in number - Fig. 1) include diverse genetic and industrial types [1], [2]. 48 mines were extracting uranium according to Decree No. 74 of the Council of Ministers from 1992, with which the government of Philip Dimitrov decided to liquidate uranium mining, and another 30 were in the stage of exploration and trial exploitation.

Many experts believe that the liquidation of uranium mining in our country in 1991. was carried out hastily, as a result of which in a number of sections complete technical solutions for this activity have not been implemented. Adequate measures have not been taken for

full reclamation of the areas surrounding the uranium mines and uranium processing plants [3], [4]. [5]

World practice indicates that no country, except for Bulgaria, has protected its uranium deposits without them being completely exhausted, and even then it extracts uranium from the old embankments around the mines. And no country liquidates its uranium production if it has nuclear plants. However, Bulgaria closed uranium mining in 1992 and spent over 50 million BGN from the budget and a lot more on the Phare program for the liquidation of mines and land reclamation [6].

The purpose of the research is to analyze the situation near the uranium mines and processing plants that were closed in 1992 and to track the change in radiation pollution in these areas. Such research was done at the end of the 20th century under the PHAR program and in 2010-2011 by the University of Plovdiv. There was an idea to start a follow-up study in 2020, but the Covid epidemic thwarted the start of this study, and therefore the results shown are partial and incomplete for now, but with the normalization of the situation, we hope to complete this started study. This will be very important for the development of municipalities, tourism, local business and the livelihood of the population.

II. MATERIALS AND METHODS

A. Development of uranium mining in Bulgaria

a) Historical overview of uranium mining in Bulgaria

The Germans were the first to start extracting uranium in Bulgaria - in 1938 in Buhovo. Already in the first year they extract 100 tons of metal. In 1939, with the beginning of the war, they stopped. After the end of the Second World War, uranium mining was resumed in strict secrecy, but now by the Soviet-Bulgarian Mining

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Company [1], [7], [8]. It existed until 1956, when the "Rare Metals" union, which was called "a state within a state", was created as a cap of uranium mining. 13,000 people worked in it. It controlled the geological exploration, extraction, processing and export of the resulting uranium concentrate. The rest of the enterprises were also under his umbrella: "Buhovo", "Trakia" - Plovdiv and "Vazkhod" - Smolyan. The Bulgarian product is called "triuranium osmoxide" (or oxide-oxide).

The classic technology of mining uranium ore is at a loss. This is an expensive process, but due to the strategic production of the raw material, it is still supported in a number of mines [2], [9].



Fig. 1. Gallery in a uranium mine [bta]

The other scheme is the geotechnological one. It is clean and very cheap. There are only two uranium ore processing plants - "Eleshnitsa" and "Buhovo" - with tailings storage facilities. Modern technology allows uranium to be extracted from much poorer ores, and uranium can again be extracted from the tailings in both tailings. The yellow cake - the commercial product with a uranium content of 30% to 60% was obtained after processing at the Eleshnitsa plant, and in Buhovo it was further baked and a concentrate with a uranium content of about 80% was obtained. From there it was transported in containers to the Soviet Union, where the nuclear fuel was produced and returned to our Kozloduy NPP [10].

According to genetic types, the uranium deposits in Bulgaria are magmatic, hydrothermal and exogenous (sand and infiltration type). As industrial types, they refer to small (stocks up to 1000 t) and medium (up to 10,000 t) deposits. Magmatic deposits are associated with alkaline and acidic magma masses and are characterized by high contents of radioactive elements (uranium and thorium). They are not of industrial interest. However, the deposits associated with primary enrichment of uranium in the leptitoid gneisses (the Narechen and Zdravets deposits from the Narechen ore district) can be attributed to them. The infiltration deposits formed as a result of uranium enrichment of the weathering crusts developed on granites are also connected with them (Igralishte, Senokos, Selishte, Smilyan-Lipets, Beslet, etc.).

The group of hydrothermal deposits is comparatively the largest. In terms of age, they are old-mid-alpine, located in the Balkan and Srednogorsk zones (Buhovo, Proboynitsa, Kurilo, Sliven, Rosen) and young-alpine - in the Rilo-Rhodope region (Partizanska polyana, Beli Iskar, Kostenets, Dospat, Chetroka, Samitsa, Planinets and dozens of ore occurrences. Common characteristic features of this type of deposits are: strict structural control of the ore; relatively large vertical range (up to

600-1000 m); close mineral associations - nasturane-quartz-carbonates, often also zeolites [3], [11], [12].

Another, equally large group are the exogenous (sandstone) deposits of Paleogene age, located in the peripheral and internal graben basins of the Rilo-Rhodope massif: Upper Thrace (14 deposits - Momino, Belozem, Haskovo, Maritsa, Okop, Tenevo, etc.), Mestenskii (Eleshnitsa) and Strumski graben (Simitli, Melnik, Zlatolist). Only the uranium deposits of the Smolyanovtsi and Vinishte deposits (Montansko) are associated with unoxidized Upper Permian sediments.

The explored and proven reserves in the entire history of uranium mining in Bulgaria are 35,374 t [1]. The amount of uranium extracted from them is 16,255 t by the classical (mining) and geotechnological method. As of 1992 (the year of cessation of uranium mining activity), residual reserves and resources of 19,748 t are distributed in 31 deposits, referring to two genetic types - endogenous (hydrothermal) and exogenous (sandstone and infiltration). Then the Proboynitsa, Smolyanovtsi, Simitli and Gabra deposits were studied and prepared for mining. The exploitation of the deposits from the Buhovo and Smolyan ore fields, Eleshnitsa and Sborishte, as well as a large part of the deposits from the Thracian-Tundzhan region [13], [14] was incomplete.

Currently, based on geological, ecological, economic, infrastructural and other considerations, 14 studied and partially exploited deposits of exogenous (sandstone) type from the Thracian-Tundzhan uranium ore region are of industrial interest. They are located in 3 geographical areas: Plovdivski, Haskovski and Yambolski and are localized in permeable rocks (sandstones), limited in section by marglite. As a result of the research and geological exploration works in the period 1970 - 1985, paleo-channel (Mominska, Marishka, Sokolishka, Tundzhanska) and paleolagun (Iztochnomarishka) structures were established in these areas (Fig. 2) [2]. Proved reserves and resources of these deposits are 10,384 t, of which 6,750 t are potentially recoverable. The industrial interest in them is determined by the proven possibility of applying the geotechnological method of extraction (drilling variant), one of the most progressive and ecological methods of extracting minerals in the world. Currently, 45% of the world's uranium mining is done by this method [15], [16].



Fig. 2. Measurement of the radioactive background next to a mine in the Eastern Maris region [nova tv]

The Eleshnitsa, Smolyan and Simitli deposits, exploited so far by the classical (mining) method, with total reserves and resources of 7828 t of uranium, may in the future be exploited by the so-called combined method.

b) Brief geological-economic evaluation

The uranium deposits on which uranium mining is supposed to be organized are of the sandstone type, from which 430 t of uranium was obtained by the geotechnological method in 1988. The cost of the mined concentrate at this period did not exceed \$40/kg of metal. The area on which the deposits for geotechnological uranium mining are located is ~11,700 decares on the territory of the Thracian-Tunjan uranium region [1], [5].

After the cessation of mining (1992-1994) and the technological liquidation, technical and biological reclamation, all exogenous (sandstone) deposits are at the stage of explored reserves and resources and the beginning of mining construction, including the construction of a new re-extraction plant to obtain finished product "yellow cake" - ammonium uranyl tricarbonate (AUTC) [2], [4].

Expert estimates, including the 7 exogenous deposits of this uranium region, show that the production cost of the uranium concentrate will be between \$60 and \$80/kg (average \$70/kg). With the price of uranium concentrate currently averaging ~\$100/kg (according to Ux Consulting Company, LLC), mining in this area will be efficient. This cost price includes all the necessary costs for ecology and reclamation of the worked areas on the deposits. The annual yield can reach 200-350 t, an amount that would fully satisfy the needs of Bulgaria's nuclear power industry [7]. To this quantity will be added the extracted uranium concentrate (AUTC) as a result of the purification of mine waste water from the Kutina uranium mining sites (Iskra site), the Chora mine from the Bukhovo ore field, the Byalata Voda mine, as well as in perspective, construction of new sorption installations on shaft No. 9 of the Eleshnitsa deposit, shaft No. 93 of the "V-th shaft" section of the Seslavsko deposit, shaft No. 1 of the "Selishte" section, vert. shaft No. 3 from the "Izgreve" section of the Dospat ore field, etc. This is, in fact, a roadside extraction of uranium concentrate, obtained mainly as a product of the purification of mine waste waters, contaminated with radionuclides and, in particular, with natural uranium dissolved in them [2], [16].

In the scope of the classic, underground mining mines ("Druzhba" mine 1 and 2 in Eleshnitsa, the Smolyan and Bukhovo ore fields, the Narechen ore area, etc.) after the liquidation and reclamation activities have been completed, huge amounts of mine water are currently accumulated, as a result of the stopped water outflow in the mines after the cessation of uranium mining and the natural restoration of the pressures and SVN (static water level) in the sites. Only in the "Druzhba" mine 1 and 2, about 42-45 million m³ of mine water accumulated, which flooded all the mining areas with residual and off-balance sheet stocks. Through shaft No. 9, the mine waters with the uranium dissolved in them come to the surface under pressure. The construction of a water pumping installation (mobilization of mine waters), through which instead of 10-20 l/sec, 200-300 l/sec will pass, will increase the yield of AUTK to 20-25 t per year only from the Druzhba mine area " 1 and 2. If installations at the Bukhovsko, Narechensko ore field and other classical mines are equipped in the same way, the output can reach 50-60 t AUTK per year only from the accumulated mine waters and their passage through

batteries of sorption columns. Such is the practice in Germany of the main mine in the Königstein deposit, where the annual production together with the other two large deposits Lichtenberg and Rönenburg is ~200-250 t AUTC [2], [17].

This approach to building similar facilities for mining only from mine waters also has a certain ecological effect, because sooner or later the mine waters come to the surface and create a potential danger of contamination of the surface waters with radionuclides 2-3 orders of magnitude above the PDL (maximum permissible norms).

As a second stage, projects will be developed for the implementation of the so-called combined mining of uranium deposits located in hard rocks, with explored and blocked reserves, similar to the Byalata voda and Zdravets deposits, such as e.g. Gerzovitsa deposit (Smolyansk ore field) and/or Proboynitsa and Smolyanovtsi, which have completed the stage of detailed exploration [3, 18]. The project estimates for the possible extraction of uranium (concentrate) from the mine waters and the combined extraction in perspective for a period of 10 years are in an estimated amount of ~200-250 t.

The calculations made for the operating costs for this combined extraction are based on the currently operating re-extraction line (line for regeneration purification of ion-exchange resins - LROYS) in the village of Eleshnitsa and the production of the so-called "yellow cake" from the uranium-contaminated mine waters show that for the extraction of ~200 t of uranium the costs will not exceed BGN 10-15/kg. Along with the mining in this area, it will be necessary to build a suitable site for an installation for the re-extraction of the uranium-enriched resin and obtaining "yellow cake" as a finished product.

Mining and processing will create ~1,000 jobs, as well as ancillary industries with ~3,000 jobs. Sulfuric acid production will resume at ~50,000 t/year.

Prospects for discovering new uranium deposits in Bulgaria are mainly of the sandstone type and in the metamorphic rocks and granitoids of the Central Rhodopes. In both directions, it concerns uranium deposits with low uranium contents (0.02-0.05%), but with possibilities for applying a geotechnological extraction method in the drilling version and combined mining [1], [11].

In the Thracian-Tundzhan region, the prospects for discovering new deposits are in the pre-Abonoligocene sandstones, conglomerates and volcanoclastic rocks lying below the Neogene. In them there are established and partially exploited deposits and ore occurrences - Navusen, Troyan, Maritsa, Trud, Chirpan. Uranium resources can be increased as a result of applying technologies for extraction from greater depths (up to 600-650 m), which in world practice is already successfully applied.

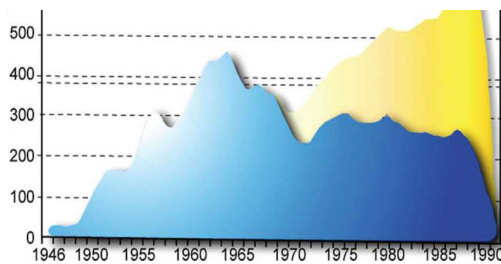


Fig. 3. Uranium extraction in Bulgaria for the period 1946-1991 (in blue - mining method; in yellow - geotechnological through chemical extraction) [2]

There are also prospects for discovering new sandstone deposits in the Strum basin, in the southern parts of the Mesten basin and in the so-called Jebel sandstones in the Eastern Rhodopes.

Some metamorphic rocks - the leptitoid gneisses from the Narechen region in the Central Rhodopes - are also of proven industrial interest. The 50-80 m thick gneiss pack has almost universal anomalous radioactivity and a uranium content of 0.01 to 0.03%. It covers an area of >200 km² and in its northwestern part, the "Zdravets" geotechnological site for combined mining began to operate in 1991 [2].

There are prospects for uranium mining with the application of a combined mining method in the Central Rhodopes in the Smilyan granites ("Lipets" section) and in Southwestern Bulgaria (Igralishte and Senokos deposits).

After the start of mining activity and conducting geological surveys in the above-mentioned areas, the uranium resources in Bulgaria will be able to increase by 40-50,000 t [3].

III. RESULTS AND DISCUSSION

After the cessation of uranium mining and uranium processing, a number of biological reclamation activities were carried out in all sites. They include reclamation activities to restore the soil fertility of the agricultural lands within the boundaries of the geotechnological sections. In total, for the period 1997-2002, ~11,700 decars of arable land were recultivated and returned to the owners within real limits with restored soil fertility [4], [19].

The control in the MoEW system of the radiation status of the environment near former mines with uranium extraction includes field radiometric measurements and laboratory analyzes of soils, waste products in tailings and landfills, bottom sediments, underground and surface water. The radiological parameters of soils, bottom sediments and waste materials are assessed by means of analysis of samples from the EIA Network for Control of Potential Contaminants. The water samples are analysed radio chemically with regard to the indicators laid down in BDS 2823 "Drinking water" - total beta radioactivity, uranium content and radium content [5].

With the entry into force of PMS No. 74/27.03.1998 for the liquidation of the consequences of the mining and processing of uranium raw material, "Ecoengineering - RM" EOOD is assigned to organize and control the activities of technical liquidation, technical and biological reclamation, cleaning of also leads the implementation of

complex departmental monitoring of the components of the environment. Despite the existence of a legal basis, monitoring networks have not been built and operated at all sites, according to the "Instruction for the organization of a monitoring system, design, construction and operation of environmental monitoring networks in the affected by uranium industry regions" [4].

The decommissioning of any mine begins with the closure of the shafts and horizontal galleries. The entrances are blocked with concrete walls, the above-ground bunkers and buildings are simultaneously demolished, and then technical and biological reclamation of the affected lands is undertaken.

In parallel with the above-mentioned activities, since 1998 and at the present time, radiation monitoring of waters is carried out in all sites to assess the qualities of underground and surface waters, the impact of uranium mining activities, as well as the results of biological reclamation. Water quality and radionuclide content as a consequence of uranium mining have been tracked over time through monitoring [3], [20].

Water pollution with natural radionuclides throughout the survey period was registered mainly in the sites with classical extraction. In them, a combined geotechnological method for uranium extraction with acid leaching or treatment with soda solutions is additionally applied. Contamination in and around these sites is mainly from mine runoff, self-flow drilling, open-pit drainage, and tabanized low-level ore bodies.

All sites from the geotechnological mining of uranium are classified by the NCRZ to the Ministry of Health in the category "Objects with a low radiological risk for the waters". In the former geotechnological sites "Tsarimir", "Trilistnik", "Belozem", "Momino" and "Debar" and approx. among them, there are no registered over-normative contaminations with radionuclides of underground water, both in PTV and in soils. In the "Navasen", "Orlov dol", "Trojan" and "Vladimirovo" sections, the values of natural uranium in surface water, in water from pumping stations used for drinking and domestic water supply, local water sources, etc., organized as currently operating monitoring points, are significantly below the PDN according to Ordinance No. 1/15.11.1999.

What does the situation look like in the areas of the former uranium deposits to date.

The overall process of rehabilitation of these areas and their conservation has not been fully completed, despite worsened millions of BGN from our government and PHAR program and funds allocated by other countries and institutions. This arouses great concern both among specialists and among the local population, because it has a direct impact on their daily life, livelihood, livelihood and life. For the most part, these are mountainous areas and the population is mainly engaged in the production of plant and animal products and tourism. It is extremely worrying that there is no marking or it is not in good condition in these places, and they are located near tourist routes, eco-trails, populated areas, etc.

After the liquidation, some of the mines "resurrected" with new functions. The closed uranium mine in the Rhodope village of Barutin, for example, was turned into

a regional waste dump for 4 municipalities - Devin, Borino, Dospat and Satovcha. Near Kostenets, there is also an idea to use a closed uranium mine as a garbage dump. Under conditions defined by law, mines could be used as landfills or quarries. All sanitary requirements and norms for preventing incidents related to the past of these objects must be observed.

Many people from the region of the Iskar Gorge, including from Svoge, worked in the uranium mine near Lakatnik. For its time, the mine was the newest and most modern uranium mine in Bulgaria. In search of ore, more than 600 meters of underground galleries and shafts were excavated. The area was thoroughly explored, probed and high hopes were placed on the "Balkan" mine, as it was once called, says Vasil Chaney, director of the state-owned company "Ecoengineering RM", liquidating and recultivating uranium mines in Bulgaria. According to the plan, more kilometers of galleries had to be excavated, even the bed of the Probnoynitsa river was diverted and pushed through an underground channel. However, it never got to the actual deposits and mining. Ore was extracted, but in small quantities, from the gravel when the galleries were dug, and now uranium can only be found in the soles around it. Thus, the still unfinished mine went directly into a process of technical liquidation, and later also of technical and biological reclamation, and finally, to arrive at... its current semi-legal operation. Semi-legal, because according to residents in the area, inert materials are still used in the construction of roads and railway embankments from the uranium embankments from the former mines. And it is even used in construction [1], [6].

To the south of Melnik are the villages of Lozenitsa and Vinogradi. It is very curious for random people that 10 meters from the bus stop between the villages there is the shaft of the old "Melnik" mine. Those waiting here know about her, but she is not visible to the unknown passers-by, she does not bother anyone. Accidental passers-by on this road also do not pay attention to it, since there is no marking indicating an increased radiation background. And there is one.

At the foot of Western Pirin there are other uranium deposits - Brezhani, Senokos, Simitli, Eleshnitsa, Igralishte. Instead of a desolate and ominous place, a lunar landscape with contours of concrete, iron and ugly embankments, I saw a beautiful area with which the mine has merged - from the concrete on the shaft there is a beautiful view of the Melnik Pyramids in the foreground and the snowy peaks of Pirin in the background, the shaft is surrounded by fertile gardens and of course vineyards.

The mine was even useful to someone - the fittings from its concrete "plug" were stolen for secondary raw materials.

The Melnik mine was closed half a century ago and was therefore not considered too dangerous in the 1990s, when the list of mines for technical liquidation was determined. However, it is among the thirty sites designated by a government decree at the end of 2007 that are subject to risk assessment.

Some of the richest uranium mines in Bulgaria were located 25 km from our capital, in the immediate vicinity

of the town of Buhovo. The first uranium mining activities in this area date back to 1938, when the Germans began mining this valuable raw material. Later, a plant was built there for processing the mined ore and extracting uranium and a tailings repository for it. For the reclamation of the tailings storage facility and its adjacent areas, more than 6 million BGN have been allocated under the PHAR program, the necessary measures have been taken and the necessary information has been placed in prominent places. But no one can prevent the local population from passing through these territories, growing fruits and vegetables near the reclaimed areas and feeding their animals from the pastures around the settlements.

In the immediate vicinity of the Seslavtsi neighborhood of Sofia, there are some of the richest uranium mines in Bulgaria. They are located next to the settlement itself and the end houses border the territory of the uranium mining enterprise. Even the fences of many of the houses are made of blocks from the former mines, the wind constantly blows radioactive dust, and the water flowing after rain floods the yards with "enriched" material. Unfortunately, the millions of leva given for the reclamation of the uranium massifs have not been able to reach this remote area of our country.

The problem with uranium mines in Bulgaria has existed for a long time and the measures taken to solve it are not effective enough or the result is not satisfactory.

In the area of the village of Eleshnitsa is the famous area for the processing and mining of uranium ore. There is also a tailings storage facility near the "Zvezda" processing plant. It is said that Eleshnitsa is the best rehabilitated area compared to the others in the country and perhaps with the most invested funds. However, there are reports of stolen funds and incomplete rehabilitation leading to landslides and leakage of water from the tailings storage facility into the Maritsa River. Regarding the measured values of the surface, they are around the norms.

It is not the first time that the issues of uranium resources and uranium mining activity in the Republic of Bulgaria have been addressed. It has been emphasized every time that the facts such as reserves and resources of uranium ores and the most modern mining technologies used (geotechnological drilling option and combined geotechnological) for decades in the last century are the most serious arguments for the restoration of this activity in the country.

No matter how much alternative sources of energy production are emphasized, humanity will solve and go hard to solve its energy problems by using nuclear energy. Uranium is needed for energy development. Nuclear energy guarantees long-term independence, even more so if it is tied to the resumption of uranium mining in Bulgaria.

After the closure of the uranium mines and our two uranium processing enterprises under the PHAR program at the end of the last century, measures were taken to restrict access to the mines and recultivate the lands around them. At the beginning of the 20th century, a study of the condition of the soils near the mines and enterprises was carried out, and the results obtained and the analysis

of them showed gaps and measures were identified to overcome them. Measures were taken by the enterprises responsible for the storage of the objects to limit the negative impacts.

In 2010-2011, Plovdiv University, under a program with the United Institute for Nuclear Research in Dubna, took samples from potentially dangerous areas and performed spectroscopy for the presence of radioactive isotopes. The obtained results were close to those of the previous study, but in individual mines, where underground water passes through their galleries and comes to the surface, an increased level of certain radioisotopes is reported. Such deviations are observed in Barutin, Borino, Smolyan, Proboynitsa and others, for which specific proposals have been made to limit pollution.

After that, a new study was not done, and we at the Vasil Levski National Military University in 2019 prepared a project to carry out a new study of the problem areas, monitoring the condition of the mines and adjacent territories. This research will provide up-to-date data and will enable tracking the development of the environmental clean-up process in these areas. This will give information to the local authorities and the population, with which they will be able to develop the regions, tourism, agriculture and their livelihood. The availability of up-to-date information will be of great importance for the Rilo-Rhodope region.

IV. CONCLUSIONS

1. Government documents were adopted to deal with the problems of the consequences of priority liquidated uranium mining and uranium processing sites, which were updated until the beginning of the 20th century, but after that things were left almost to fate. Complete studies were carried out under the PHAR Program at the end of the 20th century and in 2010-2011 by the University of Plovdiv together with the United Institute for Nuclear Research in Dubna. These investigations found gaps in the sealing of the uranium mines and the subsequent control. There are open areas with an increased radioactive background and corresponding prescriptions have been written, but there is a lack of longer control;

2. Some sites of uranium mining and uranium processing have no established monitoring networks for radiation control and do not conduct departmental monitoring, there are no warning signs and no explanatory work is carried out among the local population. Humans and animals are allowed in unsecured and unexplored areas near the uranium deposits. There is uncontrolled groundwater and surface water discharge from the closed mines, which may contain elevated levels of radioactive substances;

3. Already completed liquidation and reclamation works have been compromised due to their poor design and/or implementation and insufficient technical support of already built facilities. A part of the equipment has been destroyed, and under the influence of time, another part of it does not fulfill its purpose. Vandalism of destruction or theft of safety equipment has also been observed, and no measures have been taken to repair the damage. There is an unclear status and responsibility for

the control and monitoring of the condition of the objects under consideration;

4. There is a radio-ecological risk due to unresolved problems with the management and complex cleaning of waters contaminated with natural radionuclides, flowing from the uranium mining sites.

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