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URANIUM MINING AND ASSOCIATED ENVIRONMENTAL PROBLEMS IN UKRAINE

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The problem of uranium industry development for the period of 2004–2013 is review. The latest data on uranium extraction in the world and Ukraine are analyzed. Environment impact and reducing of uranium mining negative effects are examined taking into account nature protection measures complex.

Keywords: uranium extraction, uranium mining impact, environment protection.

Розглянуто розвиток урановидобувної галузі за період 2004–2013 рр. Проаналізовано новітні дані щодо видобування урану в світі та Україні. Досліджено проблеми впливу галузі на навколишнє середовище та визначено комплекс заходів щодо його зниження.

Ключові слова: видобування урану, вплив урановидобувної галузі, захист навколишнього середовища.

Introduction

Ukraine is heavily dependent on nuclear energy — it has 15 reactors generating about half of its electricity. The mining and milling of uranium is the first step in the production of nuclear energy. Ukraine is known to be among a few “uranium” countries in the world. On one hand increasing of uranium extraction volumes will lead to economic benefits. But on the other hand, negative environmental effects are unavoidable. It is obvious that development of uranium mining should be supported by environment protection measures, and the topic of research is of current interest and importance for Ukraine from the point of its supply with nuclear fuel and nature protection measures development.

The goal of this paper is to analyze uranium industry of Ukraine in comparison with the world’s uranium giants and to consider the main environmental challenges for Ukraine.

Problem formulation

The concept of uranium mining and the associated environmental challenges are widely described in the world’s scientific literature. But there is a recognized need in improving the environmental component in uranium industry in Ukraine. That is why it is important to provide comparative analysis of the industry development in the world and in Ukraine to show the necessity of providing nature protection measures.

Uranium reserves and recent publications analysis

Ukraine is considered as a uranium-mining country with Europe's largest resources. According to the Energy Strategy up to 2030, the country is planning energy production at the expense of nuclear power. For implementation of this strategy, the capacity of uranium production should be increased through improving the existing production potential. According to the World Nuclear Association (WNA), about 64 percent of the world's production of uranium from mines is from Kazakhstan, Canada and Australia — world leaders in the industry. Ukraine occupies the 11th position in the list of top uranium-mining countries [1]. According to V. Biletskiy [2] Ukraine has the largest resources in Europe, most of which are located on the territory of the Ukrainian shield. There are 17 deposits with reasonably assured uranium reserves “on balance”: 14 in Kirovograd oblast’, 2 — in Mykolaiv oblast’, and 1 — in Dnipropetrovs’k oblast’. The part of Ukraine in world’s resources is 1,8 %. Among 15 nuclear units at four power plants there are 13 units with VVER-1000 and 2 units with VVER-440 new generation. The total installed capacity of operating power units is 13 835 MW [3]. Ukraine has modest recoverable resources of uranium — 225,000 tU according to IAEA Red Book 2011 [4]. Uranium mining began in 1948 at Pervomays’ke deposit, and 65,000 tU was produced so far. Current production is about 1000 tU/yr. The Eastern Mining and Ore Dressing Enterprise (VostGOK) is the biggest in Europe and the only enterprise in Ukraine that extracts and processes uranium ore, and produces uranium concentrate). The enterprise expects increasing production in 2015.

According to B. Kornilovich [5], the main sources of environmental pollution during uranium extraction are mine waters and solid disperse wastes.

Uranium extraction for the period 2006-2013

Uranium deposits are characterized by a low content of uranium. Nevertheless developed infrastructure of their mining and uranium concentrate production along with big sizes of uranium deposits, high thickness of uranium-containing rocks, relatively low water content in mining tunnels, relatively simple measures of radiation protection (because of low content of uranium in ores) — all these facts provide competitive capacity for the uranium concentrate on the market [3]. So, the production rate is not that high in comparison to world's leaders — Kazakhstan, Canada and Australia.

The production of uranium in these countries is in dozens times higher than in Ukraine (Table 1, Fig. 1 according to WNA data [1]).

Table 1

World's uranium extraction

Country	2006	2007	2008	2009	2010	2011	2012	2013
Kazakhstan	5279	6637	8521	14020	17803	19451	21317	22451
Canada	9862	9476	9000	10173	9783	9145	8999	9331
Australia	7593	8611	8430	7982	5900	5983	6991	6350
Niger (est)	3434	3153	3032	3243	4198	4351	4667	4518
Namibia	3067	2879	4366	4626	4496	3258	4495	4323
Russia	3262	3413	3521	3564	3562	2993	2872	3135
Uzbekistan (est)	2260	2320	2338	2429	2400	2500	2400	2400
USA	1672	1654	1430	1453	1660	1537	1596	1792
China (est)	750	712	769	750	827	885	1500	1500
Malawi				104	670	846	1101	1132
Ukraine	800	800	801	830	837	873	1012	1075
South Africa	534	539	655	563	583	582	465	531

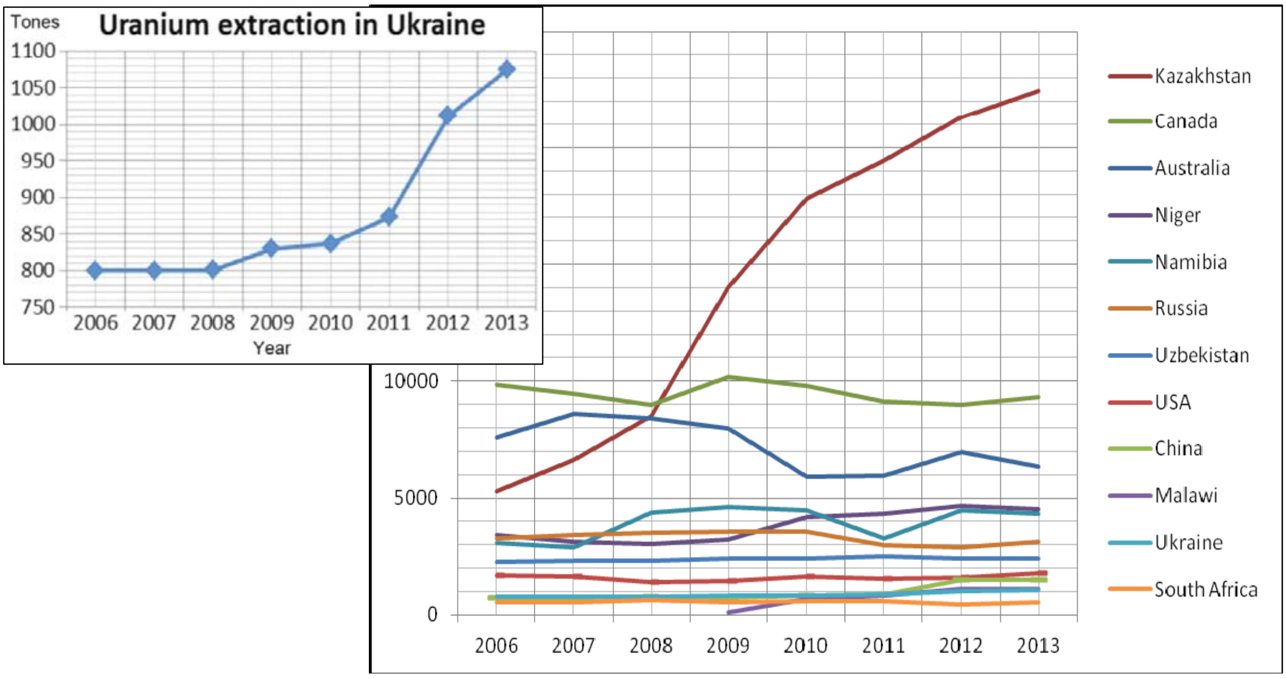

Fig. 1. The place of Ukraine among the world's U-mining countries

In Ukraine the uranium production is provided by metasomatite deposits of the alkaline albitite type developed within zones of deep faults of the Ukrainian Shield. The origin of uranium mineralization is associated with sodium metasomatism superimposed on granite-gneiss basement within an area of tectono-magmatic protoactivization occurred at the end of the Ukrainian Shield orogenesis [6]. The deposits of hydrothermal and metasomatic type of sodium-uranium formation are genetically associated with the final stage of ultra-metamorphism of uranium-containing rocks. The uranium ores are considered to be complicated for technological processing because of their matter and chemical composition and wide range of ore mineralization. Brannerite along with iron hydroxides and their thin intergrowth of uranium and dark-colored minerals make it complicated when ore processing through autoclave sulphuric leaching (Table 2).

Linear trend equation:
$y = 35{,}3x – 70053$ ($R^2 = 0{,}7992$);

Calculation of prognosis data for 2014 year:
$y_1 = 35{,}3*2014 – 70053 = 1076{,}5$;

Calculation of prognosis data for 2015 year:
$y_2 = 35{,}3*2015 – 70053 = 1111{,}8$;

Calculation of prognosis data for 2016 year:
$y_3 = 35{,}3*2016 – 70053 = 1147{,}1$;

Calculation of prognosis data for 2017 year:
$y_4 = 35{,}3*2017 – 70053 = 1182{,}4$.

The accuracy of the prognosis is higher, if the error value is lover. Error shows the difference between the prognosticated data and fact value of researched data.

To evaluate the accuracy of the prognosis based on the linear trend, it was necessary to calculate the confidence intervals, which we may see on the Fig. 2, Table 3.

Table 2

Uranium extraction in Ukraine in 2005-2013

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013
Tones	750	800	800	801	830	837	873	1012	1075

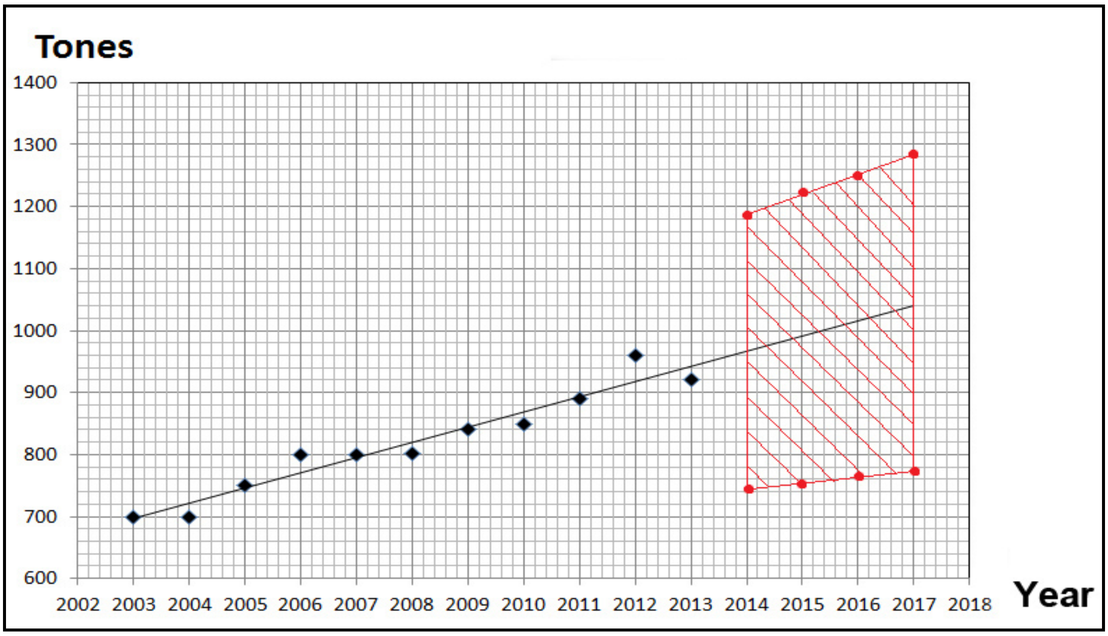

Fig. 2. Linear trend of U-mining development in Ukraine

Table 3

Prognosis of uranium extraction for 2014-2017

Year	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Tones	750	800	800	801	830	837	873	1012	1075	1076,5	1111,8	1147,1	1182,4

Environmental challenges in uranium mining

The environmental impacts of uranium mining and milling activities are severe. These impacts range from the creation of massive stockpiles of radioactive and toxic waste rocks and sand-like tailings to serious contamination of surface and underground waters with radioactive and toxic pollutants, and releases of conventional, toxic and radioactive air pollutants. In fact, the impacts of uranium mining have been so severe, that many jurisdictions around the world have adopted bans on the establishment of new uranium mines. It is known a prominent example in Nunavut where any proposal for a future uranium mine must be approved by referendum. There are many ways how to summarize the uranium mining impact on the environment. The authors follow generalization mentioned below.

Impact from uranium mining includes:

1) ***waste rock*** — which may contain radioactive and hazardous contaminants, dust containing radionuclides, heavy metals and particulate matter (PM);

2) ***risk of acid mine drainage*** resulting in acidification of surface water and ground water and releases of conventional and radioactive contaminants, radon releases from waste rock;

3) ***tailings***, those are acidic in most cases, in large volume, which contain radionuclides and hazardous contaminants. Tailing brings the risk of ground water and surface water contamination; releases of dust containing radionuclides, heavy metals, and PM; risk of catastrophic tailings containment failure;

4) ***ground and surface water contamination***, meaning: groundwater contamination from tailings and waste rock sites; surface water contamination - from discharges of mine water and process waters, and surface drainage from tailings, waste rock, and general run-off; disruption of surface water and groundwater flows; discharges from milling processes;

5) ***atmospheric releases*** (radon in ventilation air being discharged from underground mines, radon releases from surface mining, VOCs, radionuclides, PM, NO_x and SO_x emissions from milling operations and acid plants, GHGs, particulates, NO_x and SO_x emissions from equipment and vehicles, milling and tailings management activities, PM, heavy metals and radionuclides in dust from surface mine sites, waste rock and tailings areas;

6) ***water impact***, including: groundwater contamination from tailings and waste rock sites; surface water contamination — from discharges of mine water and process waters, and surface drainage from tailings; waste rock and general run-off; disruption of surface water and groundwater flows, discharges from milling processes;

7) ***landscape and ecosystem impact*** (land footprint of mines, facilities, tailings and waste rock storage facilities; increased concentration of radioactive material and heavy metals in flora, fauna and food chain near mines;

8) ***occupational and community health*** (occupational health — exposure of mine workers to radiation and mining safety hazards; community health — direct radiation exposure, inhalation of particulates and ingestion of radionuclides through food chain.

Reducing negative environmental impact from uranium mining activity

To reduce the wide negative influence of uranium mining activity it was offered to consider a complex of nature protection measures (Fig. 3).

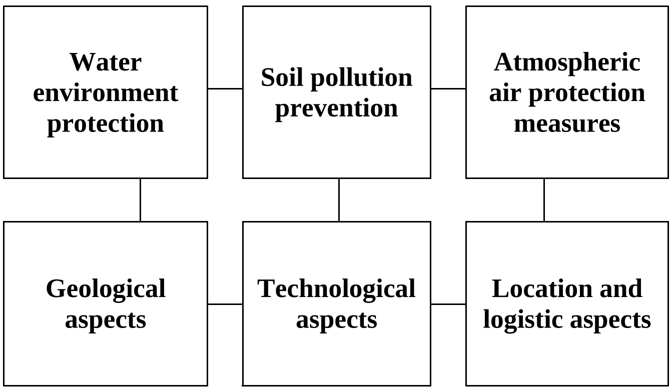

Fig. 3. Nature Protection Measures Complex

Water environment protection

To prevent adverse effects on groundwater and surface water during exploration works the following measures have to be provided. The area reserved for the construction of wells should be shielded with ditch and walls, which prevents the ingress of water into the territory of the drilling platform during melting of snow and raining; to prevent penetration into the soil of leachate drilling fluid, fuel, chemicals, waste water and to prevent their falling into surface streams during platforms drilling, aggregation and pump block, block preparation solution, composition of chemicals etc. should be provided waterproofing coating (concrete or metal base plate); collecting of contaminated rainwater and waste water from drilling platforms; cleaning, disinfection, neutralization and utilization of sludge waste;

To reduce and prevent the negative impact on groundwater and surface water at development and processing of deposit it should be considered following measures: at the design stage it must be rationally located infrastructure and mine dumps based on hydrological network; organization of runoff system at the mine (to prevent ingress of untreated industrial waste water in the soil and then in hydrological network); placement under the whole territory of the heap of sorption or waterproof barrier to prevent penetration of filtrates in underground aquifers; prevent the discharge of non-purified mine water in surface waters and on relief; should be provided measures to prevent flooding of the mine by surface and atmospheric waters; prevention of flooding of the working mine; providing the monitoring of the level and composition of groundwater in the area of exposure to the mine.

Soil pollution prevention

Measures to prevent and reduce harmful effects on soils: to reduce and prevent the negative impact on soil during construction of exploratory wells should be provided following activities: storage of topsoil in places of its storage; area reserved for the construction of wells, should be shielded with ditch and walls, which prevents the ingress of water into the territory of the drilling platform during melting of snow and raining; to prevent penetration into the soil of leachate drilling fluid, fuel, chemicals, waste water and to prevent their falling into surface streams during platforms drilling, aggregation and pump block, block preparation solution, composition of chemicals etc. should be provided waterproofing coating (concrete or metal base plate); installation of reinforced concrete trays for drains around the perimeter of the concrete pad from the aggregate and pumping units, with longitudinal slope > 5 ° to place of collection; collecting of contaminated rainwater and waste water from drilling platforms; containers for collection of municipal solid waste and next taken of it to the landfill of solid waste utilities; cleaning, disinfection, neutralization and utilization of sludge waste; recultivation of disturbed lands after the construction of the well.

To reduce and prevent the negative impact on soil at development and processing of the deposit also should be considered following measures: at the design stage should be used correct approach for the question of location of facilities and infrastructure heaps, they must be placed in terms of minimum occupation of fertile soil; placing of heaps should be provided taking into account the probability of occurrence and strength winds, severe side to the windward side, to reduce swelling intensity of dust particles from the heap to soils; placing wind protection screens, or green plantation directly on heap to reduce the force of the wind, which is in contact with the rock; organization of runoff at the mine, to prevent ingress of industrial waste water in the soil and then in hydrological network; placement under the whole territory of the heap of sorption or waterproof barrier to prevent penetration of filtrates in underground aquifers; installation of air filters at the output of the ventilation shaft; optimal organization of transport processes, both in the mine and for ore export to enrichment plants; prevention the discharge of mine water into the relief to prevent salinization and soil contamination.

Atmospheric air protection measures

The main sources of air pollution include: special equipment, vehicles, tractor equipment, diesel generators, boiler room. In developing of uranium deposits emitted dust and radon from ventilation of the mine. Measures for the protection and prevention of air pollution: storage of fuels and lubricants in pressurized tanks equipped with breathing valves; installation of air filters at the output of the ventilation shaft; it should be choose the best mode of transportation operations at the mine; installation of hard coating on the mine; placing wind protection screens, or green plantation directly on heap to reduce the force of the wind, which is in contact with the rock;

Geological environment

To reduce and prevent the harmful effects development and processing of the deposits on the geological environment should provide the following activities: construction of wells should be provided in accordance with technological requirements; construction of wells should provide safe process, namely the prevention of erosion wellhead isolation and groundwater due to the descent direction to a depth of 12 m and descent conductor to a depth of 150 meters, in order to overlap the upper aquifer and protect them from contamination with mud filtrate drilling in the intermediate column; to prevent overflows of fluids and formation water in the space of all cement casing rises to the well bore; given the hydrogeological conditions of the site for the construction of wells (physical and mechanical properties of soils, soil filtration coefficient), you must choose the optimal conditions and modes of production wells and the passage of core; to prevent the flow of groundwater and wastewater between the horizon and the water content of the ore body with oxygen-containing waters further possibility of leaching of uranium is necessary to tamping completed exploration wells.

The main requirements for the protection of natural resources, put forward in passing and development of uranium deposits is state control over rational use and protection of subsoil (and establish procedures for its implementation), compliance with the established procedure approved standards governing the terms of mineral resources, air, land , forests, waters. Also, should provide the following conservation measures: passing shafts and mine horizons should be made taking into account the geological, hydrogeological characteristics of the deposit, as well as with regard to the location field tectonics areas; passing shafts and mine horizons should be in strict accordance with the laws, rules and special rules and regulations for highly qualified personnel; should provide for measures to prevent flooding of the mine surface and atmospheric waters; in places where it is needed, should be provided ceiling mounting openings, despite the fact that the working place in crystalline rocks; has held control over the movement and use of explosives; prevent flooding of the mine working groundwater; monitoring of geological environment, particularly in the areas of faults and fractures.

Technological aspects for drilling rigs should be used technological solutions and liquids that are environmentally friendly or which have minimal polluting properties.

During drilling it is created significant anthropogenic pressure on objects hydrosphere, lithosphere and biosphere. In areas of mass drilling a threat of environmental stress, leads to disruption of the natural ecological balance, falling of resource potential of biogenic biosphere, degradation of components of the environment (a sharp decrease in fish stocks, pollution of soil and water facilities etc.). This is caused by: low environmental security processes; lack of consciousness of contractors; unsatisfactory control of pollution from environmental services; low economic and moral responsibility for nature caused damage.

Design, construction, reconstruction and operation of mines should be conducted in compliance with the Law of Ukraine “On Labor Protection”, “On sanitary and epidemiological welfare”, “On compulsory state social insurance against accidents at work and occupational diseases that caused disability”, “On environmental Protection”, “On an increased risk”, Mining Law of Ukraine and other legal acts.

Location and logistics aspects

At the design stage must reasonably accommodate infrastructure and mine dumps based hydrological network; at the design stage to correctly approach the question of accommodation facilities and infrastructure heaps, they must be placed in terms of minimum occupation of fertile soil; placing piles should be taking into account the probability of occurrence and strength winds, severe side to the windward side, to reduce swelling intensity of dust particles in soils with a heap; optimal organization of transport processes, both in the mine and ore for export at enrichment plants.

Conclusion

Comparative review of the world’s and the Ukrainian potential in the sphere of uranium mining industry was presented. On the basis of the WNA statistical data, it was provided prognosis of U-mining development in Ukraine for the next three years using the method of linear trend line construction. Prognosis shows that uranium extraction will be growing in the next few years, and so the negative loading on the environment will too.

There are a lot of ways in which uranium mining industry spreads its negative effect on the environment. Among them the following were specifically considered: geological environment; aquatic environment; soils; atmosphere pollution; technological aspects and logistics.

On the basis of the world’s experience, it was considered nature protection measures complex covering all components of the environment. The implementation of these nature protection measures can bring a serious reduction of the environment stress while uranium mining.

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