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RADIATION-ECOLOGICAL MONITORING OF COAL MINES OF NOVOVOLINSK MINING AREA

Abstract. The recent restructuring of the mining industry causes a significant detrimental effect on environment and population. Operating of coal mining enterprises of the Lviv-Volyn coal basin and the restructuring of the mining industry led to the accumulation of waste possessing technogenically-increased natural radioactivity. Radiation safety on these coal mines is associated with natural radionuclides in coal and associated rock (γ-rays). The main contribution to the radiation dose of underground workers and the general radiation background.

Keywords: restructuring, radon, uranium, thorium, monitoring of radioactivity.

Introduction. Sustainable socio-economic development of modern society is impossible without an assessment of the technogenic impact on the environment. Nowadays, the peculiarities of development of various regions of Ukraine are the course of anthropogenic processes that lead to environmental pollution. Particular attention needs to be paid to the study of the regions where the coal industry is developed.

During the period of coal mining and coal processing in the territory of the Lviv-Volyn coal basin, the geoecological environment has undergone significant changes. This is primarily due to the change in the natural landscape, the impact of coal-processing waste on the environment, as well as the change in the geochemical indicators of the environment as a result of additional inflow of chemical and mineral compounds into it [1, 2].

One of the main sources of ecological danger for the region are dumps of mine rocks. Thus, during the extraction of coal from the rock mass that enters the surface, more than 75% of the raw material goes into the waste. In this regard, an important issue when developing environmental measures to minimize the impact of dumps mine rock to the environment is a reliable assessment of their toxicity [3].

Novovolynsk mining area belongs to the Lviv-Volyn coal basin, which is located on the border of the Lviv and Volyn regions of Ukraine and covers the right and left banks of the Bug. The total geological coal reserves are estimated at 2 billion tons, while the balance reserves are 1.4 billion tons [4]. In the landscape of the investigated area the arable land occupies more than 60% of the territory, in the north the surface is hilly, with a height of 244-270 m, which contains many ravines and beams. On its territory 28 mine dumps are formed (figure 1).

Along with weathering, which is widespread in the outer part of shaft waste heaps, because within them there are favorable conditions for oxidation and subsequent burning. The leading role in this belongs to the activities of microorganisms. The study of the conditions for the development of microorganisms in the zones of oxidation of sulfide deposits shows their stability at temperatures from 2 to 70 ° C, and pH of the medium - from 1 to 8. In this, the development of bacteria occurs in conditions of high humidity of the rock mass. In support of these findings, the fact that within the boundary parts of the mine waste dumps there are local focal ignition and there is a selection of vaporous sulfate acid [5-7].

The oxidation and burning of the waste heaps described above is accompanied by a significant evolution of water vapor, which is a mineral-forming medium for most of the minerals: sulfates, hydrocarbons, carbonates, phosphates, arsenates. In addition, oxidation produces carbon dioxide, nitrogen

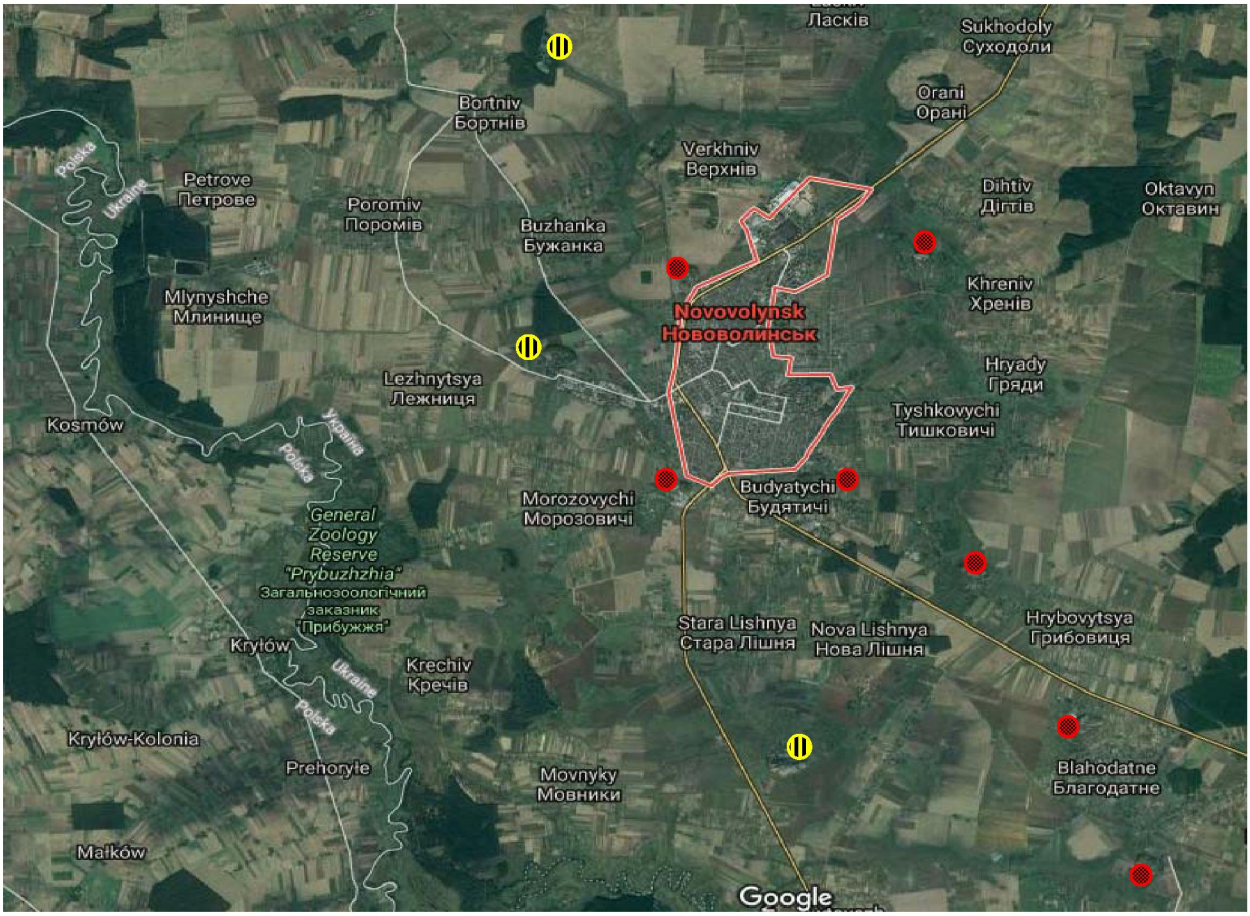

Figure 1 – Satellite image mines on the territory of Novovolynsk mining area (Ukraine).
Legend: yellow tag producing mines, red tag recultivated or under recultivation

oxide (IV), which forms nitric acid with water. In the absence of oxygen in the burning cells in the vapor-gas emissions contain hydrogen sulfide, hydrocarbons, ammonia, carbon monoxide (II). When leaving the surface of the rock dump form raids, crystalline or spherulite aggregates of new minerals, which predominate sulphates, sulfides and carbonates. The other part of the oxidized compounds evaporates into the atmosphere, filling it with harmful substances [9-11].

Modern mining operations are accompanied by an intense change in natural energy and mass transfer, as huge deposits of coal, rocks and underground water reach the surface of the earth causing the development of many negative phenomena that leads to environmental degradation of the region. For the Novovolynsk mining area, a significant transformation of the hydrogeology conditions, the change in the balance and regime of groundwater, the subsidence of the earth's surface, the formation of highly mineralized acid waters are characteristic [12, 13].

Purpose, tasks and methods of research. The purpose of this investigation is measurement of radiation background of mining waste heaps by MKS–05 "TERRA" dosimeter-radiometer. The permissible dose of background radiation is 0.3 μSv/h.

According to the purpose the following tasks are set: currently there are only few investigations made on coal mines, although they are extremely important for monitoring the health of mine personnel, as well as for the analysis of the radon level. The change of radon content may signal a fire breaking-out in the unworked coal.

The change of radon content may signal a fire breaking-out in the unworked coal. Presently 3 mines are operating on the territory of the Novovolynsk Mining Area, one is being built and 7 mines are being reclaimed or recultivated.

Radiation safety on these coal mines is associated with natural radionuclides in coal and associated rock (γ-rays). The main contribution to the radiation dose of underground workers and the general radiation background is made by radon products, as well as radionuclides of uranium and thorium series, and the radioactive isotope of potassium - 40, which are present in the form of aerosols in mine atmosphere. As is commonly known, gamma rays has a high penetrating power and therefore creates an external irradiation of the body of miners. Gamma-radiation intensity is directly proportional to the content of γ-emitting radionuclides in the walls of mining workings [14-16].

The greatest amount of radon emission is observed in areas where rocks contain high concentrations of uranium. Migration of radon is facilitated by long term deformation of rocks, vertical fault zones and porosity of rocks. It is believed that the greatest intensity of migration of radon from rocks can be expected in conditions of combination of geological factors such as the presence of a rock enriched with uranium; intense deformation of sub-vertical rocks that don't contain quartz, carbonate or clay, and a soil cover consisting of gravel or sandy eluvium.

Results and their discussion. The radiation situation in the coal mines of the Novovolynsk mining area depends on the intensity of its ventilation. Most coal mines are intensively ventilated (the time of air exchange is more than 2500 seconds), the average content of uranium and thorium in coal and rocks rarely exceeds 40 Bq/kg^{-1}. If such mines adhere a standard for dust contamination (10 mg/m^{-3}), then the average level of total radionuclides exposure on the lungs is within the range of 0.5– 0.7 exposure limit for miners of non-uranium mines and the radiation state is quite favorable. The annual dose for these categories of workers is 5mSv/year.

Mining conditions in coal mines, as a rule, differ significantly from the conditions for the ore deposits. Coal mines are characterized by a narrower range of the content of radium – 226 (Ra^{226}) and thorium – 232 (Th^{232}), coal and enclosing rocks, a small number of horizons that are in operation, shallowness of coal beds and the release of methane. Taking into account these differences, one can make the following assumptions about the radon emission features in the coal mines of the Novovolynsk mining area:

1. radon emission per unit volume or per unit surface of mine working is more or less uniform throughout the mine;
2. high intensity of radon emission may occur in the places with significant amount of methane released, as well as in mine workings, adjacent to the abandoned place;
3. on mines with a exhaust ventilation, higher radon emission should be expected, especially at a shallow workings;
4. radon emission intensity will be higher compared to the wingway due to the radon filtration release from the coal bed between them.

During complex studies in the region it is determined that the most dangerous for the environment are the workings in coal beds with radioactivity of 0.01-1.3 mSv/year (an average of 0.06 mSv/year), and for field workings of 0.05-0.8 mSv/year (an average of 0.12 mSv/year). The significance of such doses can be estimated by comparing them with the average external radiation dose obtained during the year by the staff working in the premises on the surface (0.23 mSv), with the average external radiation dose by the natural background of 0.8 mSv/year [17, 18].

It can be expected that the annual average external dose of staff in a coal mine will be 2.4 times less than the dose received during the same period by the workers on the surface and 6.12 times less than the annual dose due to the average value of the natural rediation background on the surface. From the foregoing, it follows that external gamma radiation is not a significant radiation hazard and that systematic monitoring and accounting of external doses of underground workers is required only in mines where the average content of natural radionuclides exceeds the content of radium (Ra^{226}) - 200 Bq/kg^{-1}, and thorium (Th^{232}) - 150 Bq/kg^{-1}. Measurement of the exposure-dose rate of photon-ionizing radiation in coal mines of the investigated area was carried out only in the producing mines.

As a result of the measurements of photon-ionizing radiation in the cities of Lviv-Volyn coal basin and in the coal dumps, it was established that:

1. The exposure-dose rate of photon-ionizing radiation in the Novovolynsky mining area is higher than in other cities of the basin.
2. The results of radioecological investigations have shown that the concentration of cesium - 137 in coal mines is 18-55 kBq/m^2 (0.5-1.5 Ci/km^2). The usual concentrations of cesium - 137 for this area are

0.1-0.2 Ci/km². Thus, the level of exposure dose of mining objects in the area exceeds the background in 1.2-1.6 times. The average index of radioactive contamination of 137Cs is higher than the background in 1.3-1.7 times, and 90Sr - in 2.0-5.0 and this causes their high concentrations in food in the area. In mines, the average content of natural radionuclides is: Ra^{226} - 3240 Bq/kg, Pb^{210} - 930 Bq/kg, Po^{210} - 1700 Bq/kg, Th^{232} - 1700 Bq/kg, Th^{228} - 1100 Bq/kg, Pa^{230} - 1300 B/kg.

3. The content of radon in the air of coal mines reaches 0.3-6.0 Bq/m³ (background content), high values of radon content are observed in the places of the former settling basins of the mine (on the surface of 22-35 Bq/m³, and at a depth of 0.3 m to 180 Bq/m³), and in the places of sediment ponds in the mine field, the radon content reaches several hundred Bq/m³ (MPC per radon of 100 Bq/m³ for mine production facilities) (figure 2).

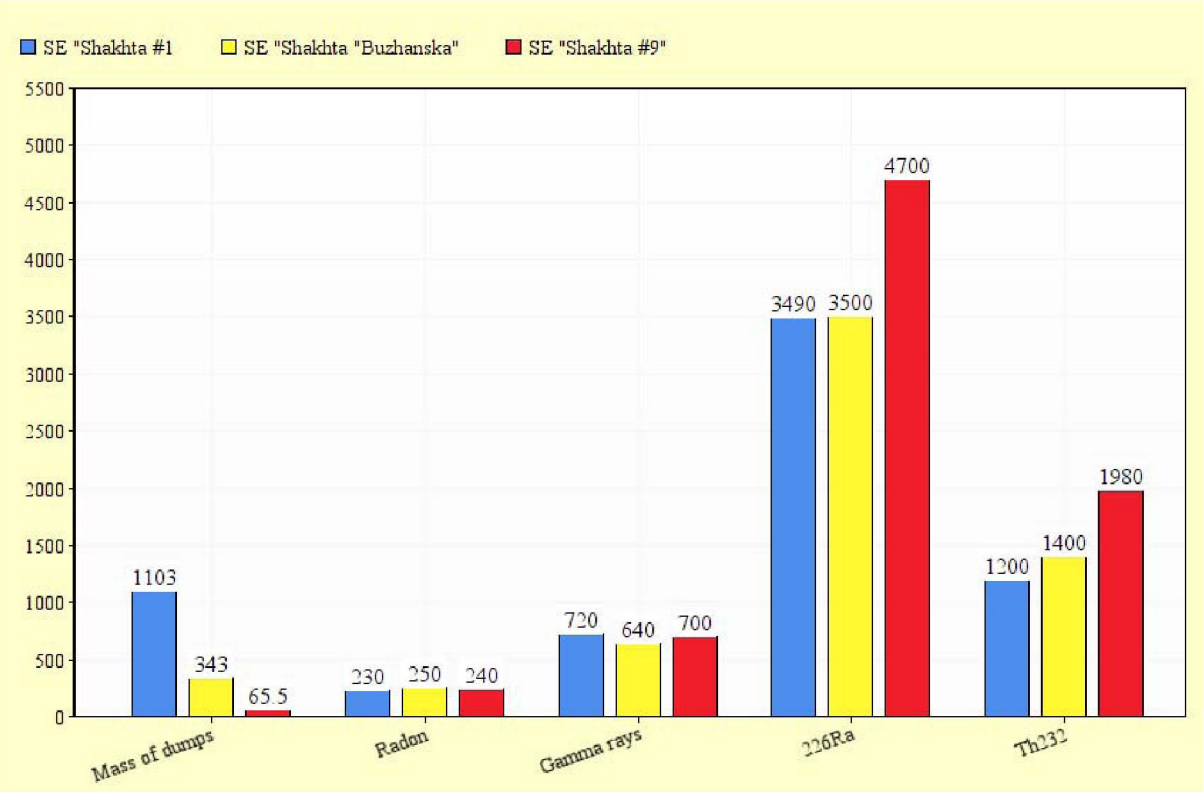

Figure 2 – Graphic representation of the radioactivity level (^{226}Ra and Th^{232}) on the producing coal mines of the Novovolynsk mining area

^{226}Ra, Th^{232}, specific activity of rocks does not exceed 4900 Bq/kg. High radioactivity is observed in loamy-sludge sediments of sediment ponds of coal mines. Here, the rate of gamma radiation dose from the surface is 640-720 mR/g, at the depth this index is 750 mR/g. The density of beta-rays from the surface - 80 cpm/cm², and alpha-rays 4 cpm/cm². It was established that in other mines of the area, the gamma-rays exposure rate does not exceed the values of 21-25 μR/g. The total specific activity at more than 90% is determined by the presence of ^{226}Ra and is equal to 3490-13000 Bq/kg.

Conclusions. It should be emphasized that the control of the concentration (volume activity) of radon in the atmosphere, which is necessary for determining the sources of its emission, the calculation of the needs of the mine in the air and the rational distribution of the latter. In the mine roadway mines of Novovolynsk mining area, the assessment of radioactive contamination of residential and industrial premises, measurements of individual expositions, plays a special role in ensuring radiation safety of the area. Ways of radioactive wastes burial are developed in the special literature and based on the requirements of "Norms of radiation safety of Ukraine". Now the main goal of radioactive waste burial is to reduce the total dose of all radiation sources to a rate that does not exceed the maximum allowable dose for the environment and population of the city (region). Therefore, this topic is worth special attention and further monitoring.

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НОВОВОЛЫН ТАУ-КЕН ӨНЕРКӘСІБІ АУДАНЫ КӨМІР ШАХТАЛАРЫНЫҢ РАДИАЦИЯЛЫҚ ЭКОЛОГИЯЛЫҚ МОНИТОРИНГІ

Аннотация. Соңғы кездегі тау-кен өнеркәсібін қайта құрылымдау қоршаған ортаға және халыққа зиянды әсер етуде. Львовск көмір өндіруші кәсіпорындарының жұмысы- Волын көмір бассейні мен тау-кен өнеркәсібін қайта құрылымдау техногендік жоғары табиғи радиоактивтілігі бар қалдықтардың жиналуына әкелді. Радиациялық қауіпсіздік бұл көмір шахталарында көмірдегі және байланысты жыныстардағы табиғи радионуклидтермен (γ-сәулелер) байланысты. Радон өнімдері, сондай-ақ бірқатар уран, торий радионуклидтері және калий-40 радиоактивті изотопы, -аэрозоль түрінде пайда болған шахталық ауадағы радионуклидтер аясында пайда болады. Львовско-Волын көмір бассейнінің мәселелері қоршаған ортаны Нововолин тау-кен өнеркәсіб ауданында көмір шахталарын жабу, жұмыс істеп тұрған шахталардың экологиялық және радиациялық қауіпсіздігін арттыру кезінде сақтау жолдарын зерттеу қажеттілігінен туындады.

Түйін сөздер: қайта құрылымдау, радон, уран, торий, радиоактивтілік мониторингі.

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РАДИАЦИОННО ЭКОЛОГИЧЕСКИЙ МОНИТОРИНГ УГОЛЬНЫХ ШАХТ НОВОВОЛЫНСКОГО ГОРНОПРОМЫШЛЕННОГО РАЙОНА

Аннотация. Недавняя реструктуризация горнодобывающей промышленности оказывает значительное пагубное воздействие на окружающую среду и население. Работа угледобывающих предприятий Львовско-Волынского угольного бассейна и реструктуризация горнодобывающей промышленности привели к накоплению отходов с техногенно повышенной природной радиоактивностью. Радиационная безопасность на этих угольных шахтах связана с естественными радионуклидами в угле и связанных породах (γ-лучи). Продукты радона, а также радионуклиды ряда урана, тория и радиоактивный изотоп калия-40, присутствующие в форме аэрозолей, образуются на фоне радионуклидов в шахтном воздухе. Проблемы Львовско-Волынского угольного бассейна обусловили необходимость изучения путей сохранения окружающей среды при закрытии угольных шахт, повышения экологической и радиационной безопасности действующих шахт Нововолынского горнопромышленного района.

Ключевые слова: реструктуризация, радон, уран, торий, мониторинг радиоактивности.

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