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RADIATION PROTECTION AT THE IRON MINES IN THE CONDITIONS OF TECHNOGENICALLY INCREASED SOURCES OF NATURAL ORIGIN

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ABSTRACT. The Purpose of the Research. *To draw up a system of measures for radiation protection at the iron ore mines to facilitate the control of the natural exposure component of miners and to ensure that the established dose criteria are not exceeded.*

Methodsand Materials. *During the development of the measures, the results and conclusions of the radiation-hygienic study of the Kryvyi Rih Agglomeration iron ore mines, the territory of which was identified as radon-dangerous with the presence of man-made sources of natural origin, were used. The measurements were made on the selected network of control points at the horizons of the mines. For analysis, the system was used to measure the volumetric activity of radon and its subsidiary decay products in the mine atmosphere, the dose rate of gamma radiation in mines, the content of natural radionuclides in the ores, the dustiness of the mine atmosphere. At the same time, they were guided by the main regulatory and methodological base.*

Results and Conclusions. *The main stages of the developed system of radiation protection at iron ore mines in terms of technogenic-enhanced sources of natural origin are: radiation-hygienic examination, radiation control, protection measures for normalization of radiation situation, control of the effectiveness of radiation prevention, preventive protection. The decision on the need for radiation monitoring and the implementation of radiation protection measures for iron ore mines is made on the basis of the preliminary survey, which determines the categories of the mine and the type of control. On the basis of the conducted research of iron ore mines of Kryvyi Rih Agglomeration, a system of radiation protection was developed and ordered, the sequence of implementation of measures of radiation examination, radiation control and normalization of radiation situation was substantiated. The measures developed need to be consistent with the recommendations of the International Commission on Radiation Protection regarding radiological protection against radon exposure in the workplace.*

Key Words: *iron ore mines, radiation protection, radiation control, radon, man-made sources of natural origin, miners.*

Introduction. The technogenic load on the natural environment of the territory of Ukraine is 4-5 times higher than the similar indicator for the developed countries [1]. Thus, the activities of enterprises for the development and extraction of minerals have led to a large-scale destruction of natural landscapes, the formation of man-made sources of natural origin (MMSNO), which led to changes in the volume of receipt and release of radioactive radon gas in natural ways. Thus, in large volumes, the release of radon accompanies, above all, the extraction of uranium [2], coal, gas and iron ore.

The development and production of iron ore on the territory of Ukraine has been going on since 1865, the center of which is the Kryvyi Rih Agglomeration. The impact of this production on the environment and human health is combined. The first to be exposed to the impact of harmful factors are miners. The most common dangerous factors are dust, noise, vibration. Natural sources of ionizing radiation, natural radioactive radon gas and its decay products (DPs) are also dangerous factors. Miners are exposed to radon both in the workplace and at home [3], where high levels of radon have been detected. Particularly negative is the situation where in coal mining settlements the houses are located along the waste heaps (slagheaps), and in the case of iron ore mines in sanitary protection zones above the mine workings. Radon and its DPs contained in the air in the work area of mines and in the air of living quarters can cause lung cancer [4]. Epidemiological studies of miners have become a major source of information on the risks of lung cancer associated with radon exposure [4].

An increased incidence of bronchial cancer was observed among different groups of personnel in underground works, which are exposed to radon during the stays below ground[5]. In particular, epidemiological studies of radon-exposed working uranium mines show a clear correlation between the doses of radon radiation and an increase in the incidence of lung cancer, which cannot be explained by the influence of other factors. This is confirmed by experimental data from

radon-irradiated animals.The first study by E.S. London on the toxic effects of radon on animals in 1904 found that their death in the early stages after inhalation of radon was caused by respiratory apparatus damage by radium emanation. Radon DPs caused lung cancer in rats, histologically similar to human lung cancer [6]. The original experimental data are given in the work of N. Rayevsky and others, when the authors placed animals in a mine at the miners' workplaces. Of the 88 mice dead in two years tumors were detected in 18 of them: cancer and lung adenoma, thyroid adenoma, generalized lymphangiomatosis.

The risk of lung cancer [7] by inhaling radon DPs is the accumulation of dose in the corresponding lung tissues and depends on the length of stay in this area and age [8].

In the course of the previously conducted radiation-hygienic study at Kryvbas iron ore mines [9], the presence of natural radiation sources found in iron ore and accompanying rocks has been determined, which defines the Kryvyi Rih iron ore basin as the territory of MMSNO, where radon is the main dosage factor. The study of morbidity, its relationship with working conditions, the analysis of radiation status, the study of the content of air in the working zone of radon and its DPR have established the presence of a link between lung cancer and upper respiratory tract with the accumulated dose in these organs. By regulating the radiation situation in mines, the incidence of lung cancer among miners can be significantly reduced. That is why it is necessary to develop and systematize radiation protection measures at iron ore mines.

The Aim of the Research. To establish a system of measures for radiation protection at iron ore mines based on the conducted radiation and hygiene study in the Kryvyi Rih Agglomeration in order to control the natural constituent of the miners' irradiation and to provide appropriate conditions to prevent exceeding of the established dose criteria.

Methods and Materials. During the development of the system, the results and conclusions of the radiation and hygiene examination of the Kryvyi Rih region were used. According to the results of studies [9, 10], the territory of the Kryvyi Rih Agglomeration was identified as radon-dangerous with the presence of MMSNO. The measurements were made on the selected network of control points at the horizons of the mines. For analysis, the system was used to measure the volumetric activity of radon and its DPs in the mine atmosphere, the dose rate of gamma radiation in the mine, the content of natural radionuclides in the ores, the dustiness of the mine atmosphere. The decision on the need for radiation control and the implementation of radiation protection measures for iron ore mines is made on the basis of the preliminary survey, which determines the category of the mine and the type of control. At the same time, they were guided by the main regulatory and methodological base [11–14].

Results and Discussion. The sources of radiation hazard in iron ore mines are the natural radionuclides of uranium and thorium, which are found in iron ore and surrounding rocks. The annual effective irradiation dose of iron ore workers is determined by the following components: annual effective doses from external gamma radiation, irradiation by radon and thoron decay derivative products, aerosols of long-lived alpha-emitting radionuclides of uranium and thorium series, respectively. The gamma radiation of ores and rocks creates an external exposure to the miners' body. As a rule, gamma radiation is not an influential radiation factor in iron ore mines because the content of uranium and thorium in ores and associated rocks in most cases does not go beyond the fluctuations of the natural background.

The developed system of measures (Fig.) of radiation protection at iron ore mines consists of the following stages: radiation-hygienic examination, radiation control, protection measures for normalization of radiation situation at iron ore mines, control over the effectiveness of anti-radiation measures aimed at improving the radiation situation in iron ore mines, measures of medical and preventive protection.

Radiation hygiene inspection at iron ore mines includes: preliminary examination; detailed examination; current survey. The purpose of the preliminary survey is to classify iron ore mines according to the level of cumulative influence of radiation-hazardous factors (RHF) (preliminary dose assessment) and the justification of the composition and volume of control of the radiation situation at the mine.

The objectives of the preliminary survey are: to determine the content of natural radionu-

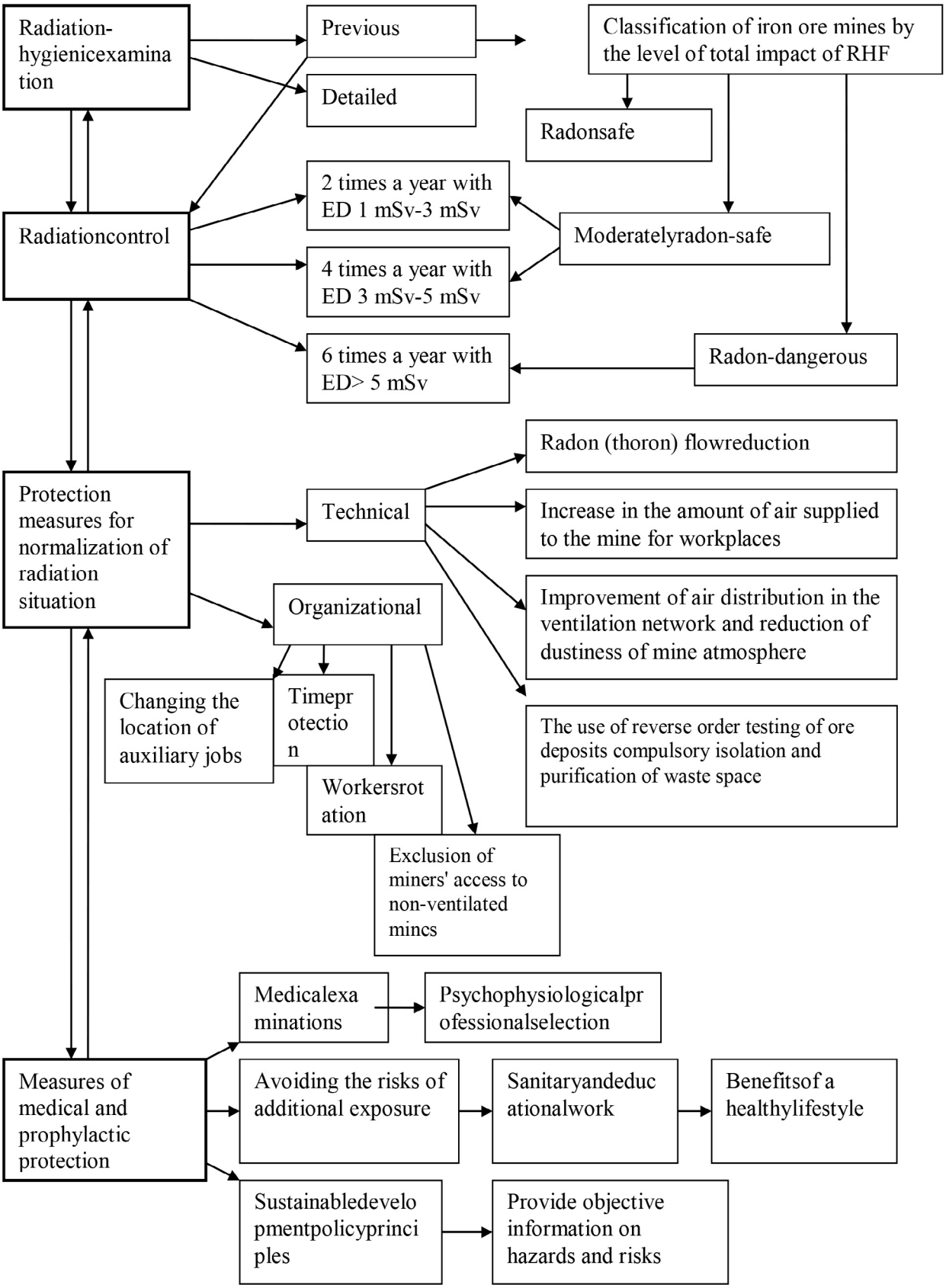

Fig. Stages of radiation protection system at iron ore mines

clides (NRNs) in iron ore and host rocks; determination of the content of long-lived NRNs in the mine atmosphere (taking into account the air dust data) at the main underground workplaces and transport facilities; measurement of the power absorbed by the air dose of gamma radiation at the main workstations or its calculation taking into account the content of NRNs in the ore and the host rocks; determination of the content of radon and its DPs, the derived products of thoron in all inlet and outlet air streams of the mine, at the main workplaces;the calculation of effective doses of radiation from the total impact of RHF in the main workplaces; assessment of the radiation status of the mine as a whole, preparation of proposals for the organization of dosimetric control and improvement of the efficiency of the use of protection means.

A detailed examination of the radiation situation is carried out if, according to the results of the preliminary examination, it is established that the annual effective dose for miners exceeds 5 mSv. In this case it is obligatory to carry out: measurement of RHF levels at all workplaces and in transport workings and calculation of radiation doses of individuals (workers) taking into account the route of their movement in workplaces; identify sources of radioactive contamination of the atmosphere; study of radioactivity of all types of mine water; development of a rational set of protective measures to minimize radiation doses; development of proposals for adjusting the volumes and regulations of current radiation control. Repeated detailed examination of the radiation situation makes it possible to evaluate the effectiveness of the implemented safety measures.

According to the results of radiation-hygienic examination, the distribution of iron ore mines is divided into categories by the degree of radon danger and the identification of sites with high radioactive contamination of the atmosphere (air of the working area) and the radiation situation is monitored.

The amount of radiation control at iron ore mines depends on the radiation situation at the enterprise. The decision on the need for radiation monitoring is made based on the results of a preliminary survey, which determines the category of the mine and the type of control. For a mine where the category of «radon-safe» is installed, an unscheduled inspection in the volume of the previous one is carried out in cases of the mine ventilation change; the commissioning of new horizons or blocks with parameters other than those previously set in the mine for iron ore and rocks; combining or decoupling mining fields and changing the ventilation parameters and layout.

For iron ore mines, a typical set of technical and organizational protective radiation measures is recommended. Technical measures to normalize the radiation situation at iron ore mines to reduce the content of radon and its DPs and prevent them from entering the body of workers include: 1. Reducing the flow of radon (thoron) and ventilated volume by: isolating areas that have lost their production value; intensification and concentration of mining operations; changing the way the mine is ventilated. 2. Increasing the amount of air supplied to the mine on the working horizons and sections by reducing air leaks in surface structures; maximizing the use of the main ventilation system; reconstructing the mine ventilation system. 3. Improving of air distribution in the ventilation network and reduction of dust in the mine atmosphere, which is achieved by rational distribution of air between sections of the network; stabilizing of the ventilation mode; increasing the efficiency of the use of dust control. 4. Applying the reverse order of the ore deposit with the mandatory isolation of the spent cleaning space.

Organizational measures: 1. Transfer of auxiliary workplaces to the area with low atmospheric pollution. 2. Maximum reduction of people's time spent in workings with high levels of atmospheric pollution. 3. Rotation of workers performing work in conditions with high radioactive contamination of the atmosphere. 4. Exclusion of people's access to unventilated workings.

According to preliminary estimates, the effectiveness of worker protection is sometimes around 20-40%, including worker rotation of 30%, the transfer of auxiliary jobs to dangerous areas of approximately – 70%.

Measures for preventive protection of miners consist of high-quality examinations; undergoing psychophysiological examination of the suitability of workers to perform their professional duties in the face of high risk, the determination of contingents and properties of the organism (state of individual sensitivity, state of adaptation). Formation of the workers'

response to avoid the risk of additional radiation through sanitation, in particular: promoting the benefits of a healthy lifestyle, the use of bioprophylaxis (individual and / or collective), improving the quality of life. Application of the principles of sustainable development policy, namely: providing objective information on radon hazard, providing complete information on available protection measures with the involvement of occupational safety, radiation hygiene professionals, scientists of this profile. Bringing reliable information to the workers and the need to follow the instructions on radiation and radon protection, possible risks. In addition, radon policy can have a positive effect on addressing other public health issues such as smoking and indoor air quality [4]. Although the absolute risk of lung cancer due to radon irradiation is significantly higher for smokers than for non-smokers, the International Committee on Radiation Protection recommends that no distinction be made between these categories of people when performing radiation protection.

Thus, in the mines of radon irradiation and its DPs refers to the situation of existing irradiation, because the source is unchanged concentrations of NRNs in the rocks. Human production activity alters radon supply volumes increases its activity in the work area air (and as a consequence, also in the air of residential dwelling adjacent to mines), compared to the background value outdoors. Radon is unlikely to lead to an emergency situation [4], but an excessively high volumetric activity requires an effective protective system. In Ukraine, in the presence of operating iron ore mines in the air of which the natural factors of radon and its DPs are revealed, the developed radiation protection system needs to be improved and harmonized with the recommendations of the International Commission on Radiation Protection regarding radiological protection against radon radiation.

Conclusions

A system of radiation protection at iron ore mines was created and organized.

1. The basic stages of the radiation protection system at the iron ore mines are determined and the sequence of implementation of the measures of radiation examination, radiation control and normalization of the substantiated radiation situation.

2. Measures of preventive health protection of miners are harmonized with the requirements for professions with dangerous working conditions, using methods and techniques of sanitary and educational work, principles of sustainable development policy.

3. Further work on radiation protection measures at iron ore mines under conditions of technogenically enhanced sources of natural origin requires immediate compliance with the recommendations of the International Commission on Radiological Protection against radon irradiation.

The autors declare that there are no conflicts of interest.

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РАДІАЦІЙНИЙ ЗАХИСТ НА ЗАЛІЗОРУДНИХ ШАХТАХ В УМОВАХ ДІЇ ТЕХНОГЕННО-ПІДСИЛЕНИХ ДЖЕРЕЛ ПРИРОДНОГО ПОХОДЖЕННЯ

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РЕЗЮМЕ. Мета досліджень. *Створити систему заходів з протирадіаційного захисту на залізорудних шахтах для сприяння здійсненню контролю природної складової опромінення гірників і забезпечення неперевищення встановлених дозових критеріїв.*

Матеріали і методи дослідження. *При розробці заходів були використані результати та висновки радіаційно-гігієнічного дослідження залізорудних шахт Криворізької агломерації, територія якої ідентифікована як радононебезпечна з наявністю техногенно-підсилених джерел природного походження. Виміри проводилися за обраною мережею контрольних точок на горизонтах шахт. Для аналізу при створенні системи бралися показники об'ємної активності радону та його дочірніх продуктів розпаду в рудничній атмосфері, потужність дози гама-випромінювання в гірських виробках, вміст природних радіонуклідів у рудах, показники запиленості рудникової атмосфери. При цьому керувалися основною нормативно-правовою та методичною базою.*

Результати досліджень і висновки. *Основними етапами розробленої системи протирадіаційного захисту на залізорудних шахтах в умовах дії техногенно-підсилених джерел природного походження є: радіаційно-гігієнічне обстеження, радіаційний контроль, заходи захисту для нормалізації радіаційної обстановки, контроль за ефективністю протирадіаційних заходів, спрямованих на поліпшення радіаційної ситуації, заходи медико-профілактичного захисту. Рішення про необхідність проведення радіаційного контролю і впровадження заходів протирадіаційного захисту залізорудних шахт приймається за результатами попереднього обстеження, де встановлюються категорії шахт і вид контролю.*

На підставі проведеного дослідження залізорудних шахт Криворізької агломерації розроблено і впорядковано систему протирадіаційного захисту, обґрунтовано послідовність виконання заходів радіаційного обстеження, радіаційного контролю і нормалізації радіаційної обстановки. Розроблені заходи потребують узгодження з рекомендаціями Міжнародної комісії з радіаційного захисту у частині радіологічного захисту від опромінення радоном на робочих місцях.

Ключові слова: *залізорудні шахти, протирадіаційний захист, радіаційний контроль, радон, техногенно-підсилені джерела природного походження, шахтарі.*

РАДИАЦИОННАЯ ЗАЩИТА НА ЖЕЛЕЗОРУДНЫХ ШАХТАХ В УСЛОВИЯХ ДЕЙСТВИЯ ТЕХНОГЕННО-УСИЛЕННЫХ ИСТОЧНИКОВ ПРИРОДНОГО ПРОИСХОЖДЕНИЯ

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РЕЗЮМЕ. Цель исследований. *Разработать систему мероприятий по радиационной защите на железорудных шахтах для осуществления контроля природной составляющей облучения горняков и обеспечения не превышения установленных дозовых критериев.*

Материалы и методы исследования. *При разработке мероприятий были использованы результаты и выводы радиационно-гигиенического исследования железорудных шахт Криворожской агломерации, территория которой идентифицирована как радоноопасная с наличием техногенно-усиленных источников природного происхождения. Измерения проводились по выбранной сети контрольных точек на горизонтах шахт. Для анализа при составлении системы брались показатели объемной активности радона и его дочерних продуктов распада в рудничной атмосфере, мощность дозы гамма-излучения в горных выработках, концентрация радона в рудничных водах, содержание естественных радионуклидов в рудах, показатели запыленности рудничной атмосферы. При этом руководствовались основной нормативно-правовой и методической базой.*

Результаты исследований и выводы. *Основными этапами разработанной системы противорадиационной защиты на железорудных шахтах в условиях действия техногенно-усиленных источников природного происхождения являются: радиационно-гигиеническое обследование, радиационный контроль, меры защиты для нормализации радиационной обстановки, контроль за эффективностью противорадиационных мероприятий, направленных на улучшение радиационной ситуации, меры медико-профилактической защиты. Решение о необходимости проведения радиационного контроля и внедрении мер противорадиационной защиты железорудных шахт принимается по результатам предварительного обследования, где устанавливается категория шахты и вид контроля.*

На основании проведенного исследования железорудных шахт Криворожской агломерации разработана и упорядочена система противорадиационной защиты, обоснована последовательность выполнения мероприятий радиационного обследования, радиационного контроля и нормализации радиационной обстановки. Представленные мероприятия требуют согласования с рекомендациями Международной комиссии по радиационной защите в части радиологической защиты от облучения радоном на рабочих местах.

Ключевые слова: *железорудные шахты, противорадиационная защита, радиационный контроль, радон, техногенно-усиленные источники природного происхождения, шахтеры.*

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