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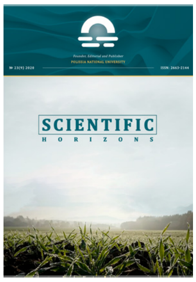

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The Influence of the Radiation Background of City-Forming Settlements with NPPs on Public Health and the Environment

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Abstract. The radioactive decay of elements as a result of a nuclear reaction is a powerful source of energy used in the production of electricity and heat in cities close to NPPs. The problem of using this kind of energy is the danger of radiation exposure. The production of nuclear energy has many advantages, including the profitability of the final product and its low cost; on the other hand, the half-life products of radionuclides in the composition of gas-aerosol emissions from ventilation pipes settle in the environment on the territory of city-forming nuclear power plants. The duality of the problems of the impact of radiation background on the urban areas near NPPs has become the purpose of this study. It is necessary to investigate the negative effect of radioactive waste emissions during the normal operation of nuclear power plants. For this purpose, the method of a project experiment was used, during which, using laboratory monitoring of external radiation safety and an automated radiation monitoring system, indicators of exposure dose capacities were collected from points in the 30-kilometre zone around the NPP. As a result of the monitoring of radiation samples from soil, atmospheric air and precipitation, and reservoirs, it was revealed that the natural radiation background is insignificant; the probability of harm from radiation exposure is small and insufficient for the development of radiation sickness. However, potentially unsafe sources of radiation exposure have been identified, such as natural radiation – the consumption of contaminated food, solar and cosmic radiation from radioactive elements present in the bowels of the earth; radionuclides, whose emissions uncontrollably occur into the atmosphere; radioactive waste, the disposal and storage technology of which is economically costly. Therefore, it is justified to conduct regular design experiments to check the operability of automated radiation monitoring systems. The materials of the study are of practical value for chemists, environmentalists, and ecotechnologists working at NPPs that monitor safety for human health and environmental protection in the field of atomic energy use

Keywords: nuclear energy, nuclear power plants, radiation, exposure dose indicators

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INTRODUCTION

Ionising radiation enters the environment from various sources – streams of photons or other elementary particles capable of ionising matter. In the process of a nuclear chemical reaction, radioactive elements are released, the energy of which is converted into other types of energy, such as heat or electricity. The background radiation can come from both natural and artificial sources. Unfortunately, the half-life products of artificial nuclei, when ingested into the human body, replace living cells, destroying tissues from the inside (Environmental Safety Report, 2020).

P. Pereira *et al.* (2022) in their study provide reports on how some radionuclides affect the human body. Thus, the radionuclide Caesium-137 causes sarcoma, Strontium-90 replaces calcium, causing leukaemia, bone and breast cancer; Krypton-85 leads to skin cancer. The main organs and parts of the human body that take on radiation in the first place: skin, bone tissue, bone marrow, lungs, stomach, intestines, inguinal zone; the thyroid gland and spleen are the next to be exposed to radiation; the trachea and liver are the last. The changes in the environment that the radiation background produces are caused, firstly, by the extraction of raw materials, during which the ecosystem of soil and vegetation is destroyed, the atmosphere and the aquatic environment are polluted by radioactive and chemical products. Secondly, the reproductive capacity of flora and fauna is reduced, and species mortality and morbidity are increased. The risks lie in the fact that environmental pollution by city-forming nuclear power plants entails an accelerated process of extinction of mankind, since by consuming contaminated food and water, humans and animals expose themselves to radiation from the inside, thereby accelerating the process of spreading the radiation background.

The amount of the dose received, the duration of exposure to radiation, and the state of human health and wildlife are the factors that affect the nature of the course of radiation sickness or death. The power of the absorbed dose of 10,000 rad on the human body is fatal within a few hours or days (depending on the degree of damage). The indicator of natural radiation that a person acquires from terrestrial radiation is 0.1 rad (Pereira *et al.*, 2022).

Modern studies by Ukrainian (Hromyka, *et al.*, 2020; Zabulonov, *et al.*, 2021) and Western European researchers (Partanen *et al.*, 2020; Oe *et al.*, 2021; Boldsaikhan, & Juyoul, 2021) indicate that nuclear power has been firmly embedded in the industry of the world economy. V. Burtniak *et al.* (2018) and O. Trofymchuk *et al.* (2021) cite the following statistics in their papers. To date, 31 countries of the world produce electricity and heat with the help of nuclear power plants, and 73 energy facilities are being developed in another 15 countries. 140 surface and submarine ships use nuclear reactors, and in the last century, Soviet and American design engineers used nuclear reactors in spacecraft that are still in Earth orbit. In connection with the facts presented, the thesis that humanity will soon abandon nuclear energy is questionable. Moreover, the search for alternative energy sources is a complex and lengthy process with high resource costs and low performance forecasts. Therefore, the preservation of wildlife and the reduction of human morbidity associated with the effects of radiation on the body is a promising plan for the development of energy technologies of international atomic protection organisations (Shielding radiation…, 2020; Gender + Radiation Impact Project, 2022). The World Nuclear Association (WNA, 2020), analysing trends in the global nuclear industry, notes that compliance with technological standards for the operation of nuclear power plants reduces the risks of environmental pollution, in turn, opponents of such an energy source cite evidence of a threat to human life and natural resources.

This study is aimed at investigating the indicators of the automated radiation monitoring system (ARMS) using the indicators of EDR (exposure dose rate). *The purpose of the study* is to investigate the influence of the radiation background of city-forming nuclear power plants on public health and the environment.

MATERIALS AND METHODS

The study was conducted from January 2020 to December 2021. The following methods were used in the process. The theoretical ones include the analysis and synthesis of academic literature on ecology, biology, chemistry, physics, and nuclear energy. The concretisation and synthesis of theoretical data showed the relevance of the problem under study and allowed setting a goal and objectives. A comparative analysis of the achievements of world scientists in the nuclear power industry was carried out using the method of analogies. An approach to investigating the influence of NPP radiation on the adjacent territories of settlements and wildlife is theoretically modelled. For this purpose, a diagnostic evaluation of the determination of the exposure dose rate was carried out. The empirical study started with the analysis of the experience of energy generating companies of the present and past years, regulatory and educational documentation, and reports on environmental safety. The main experiment took place in three stages: ascertaining, formative, and control. Methods of mathematical statistics and graphical representation (figures, tables, diagrams) were used to summarise the results and generate conclusions. The experimental base of the study was the Scientific and Production Association "Typhoon".

During the first, ascertaining stage, after analysing the necessary scientific and methodological literature, it was decided to investigate the annual indicators of the results of determining the exposure dose rate. A laboratory experiment to control the radiation situation was carried out on the territory of the Khmelnytskyi NPP, on the shore of the Netishinskyi reservoir of the Hnylyi Rih river. The industrial site of the Khmelnytskyi NPP accommodates 2 departments of reactor power units and workshops of construction and installation organisations. The city-forming settlements of residential areas of the Khmelnytskyi NPP form the territories of the Khmelnytskyi (part of the Shepetivskyi district) and Rivne (part of the Rivnenskyi district) oblasts. The release of radionuclides is carried out through ventilation pipes as part of gas-aerosol waste coming from each power unit.

Soil sampling was carried out 1 time a year at 8 radiation monitoring stations. Using the envelope method, 5 soil samples 5 cm deep were excavated in each square with 10 × 10 m sides. Water samples were taken from the nearby Hnylyi Rih river water reservoir. Several samples were taken: one from the basin of the cooling reservoir of the Khmelnytskyi NPP and the second from the water area of the fishing station.

During the next, formative part of the study, in the 30-kilometre zone of the Khmelnytskyi NPP, exposure dose indicators were taken from sensors of the automated radiation monitoring system located at radiation monitoring points at different distances from the NPP. With the help of dosimeters, the indicators of annual dose absorption in settlements were measured. Summing up the above indicators, conclusions were drawn about the state of the radiation background in the atmosphere, soil, and reservoirs. The EDR measurement was carried out with a DRG-01 T dosimeter.

At the final, control stage, after analysing all the data obtained from the annual survey of radiation background indicators from all points on the territory of the 30 km zone of the NPP, it turned out that the indicators of radionuclide emissions increased, but are within acceptable limits. As in general, the data of the dosimeter of the calculation of the EDR, which ranged from 0.09 to 0.16 mSv/h. The sums of all other sample indicators are presented in the following sections using mathematical and graphical methods of providing information.

RESULTS AND DISCUSSION

The industrial site of the Khmelnytskyi NPP is a sanitary zone where any economic activity and permanent residence of people are prohibited, but temporary stay of workers of category A (personnel who work directly with artificial sources of ionising radiation) and B (personnel who do not work directly with artificial sources of ionising radiation, but their workplaces are located in the zone impacts) is allowed. The time spent at the industrial site is limited to 180 days per year. The dose loads on the territory of the sanitary protection zone were estimated from external (emissions of radioactive clouds and their deposits in the soil) and internal (inhalation of atmospheric air and consumption of contaminated food) exposures. Outside the 30-km zone, the radiation background in residential areas of the Khmelnytskyi NPP is determined by the values of the total safety factor on the ground, equal to the ratio of the annual radiation dose to the permissible dose limit.

The population density near nuclear power plants within a radius of 3 km to 10 km is very high and is about 316 people/km^2 at the expense of the urban population, and the density of the rural population in this radial interval is 70 people/km^2. In general, in the 30-km zone around the Khmelnytskyi NPP, the population density is 134 people/ km^2. Currently, the NPP region is densely populated with a fairly high level of industrial and agricultural development, where industrial and transport companies are located. In agriculture, the 30-kilometre zone is an area of intensive agriculture with developed animal husbandry, dairy, and vegetable growing areas.

During the formative experiment, the authors of the study investigated the contribution of various radiation sources to the collective radiation dose of the population of the Netishynskyi district in the vicinity of the NPP (Fig. 1). It can be seen that the main dose of radiation the population of the district receives from enterprises with sources of ionising radiation (65%) and from natural sources (35%). These indicators are different for each of the regions and are not constant over time.

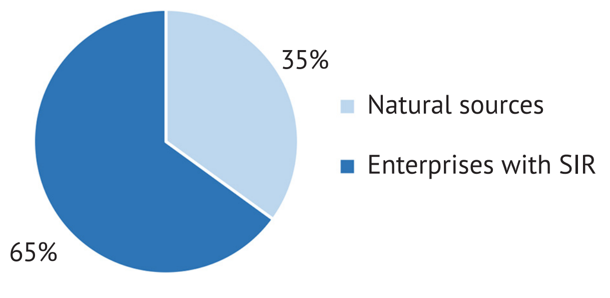

***Figure 1**. The results of the study of the general effect of background radiation from various sources on the regions adjacent to the NPP territory*

Proponents of nuclear energy claim that the described radiation doses are too low to cause any "proven" harm, however, the results of research (Arguments against nuclear energy, 2020) indicate that among children and pregnant women, leukaemia diseases and disorders of the nervous system are associated with doses that are within the levels "background" radiation, which is claimed by the industrial industry. Low doses of radiation can cause serious oncological diseases, including blood diseases (leukaemia) and diseases not related to oncology, for example, diseases of the cardiovascular system, genetic damage to the DNA of reproductive cells, deterioration of the development of the nervous system, and many other diseases that may manifest several years after exposure. This phenomenon has been called the "delayed action" of radiation.

Table 1 shows the average monthly values of EDR indicators of surface and atmospheric air, soil and water samples obtained during the formative stage of the experiment.

***Table 1**. The results of the study of the average monthly and average annual indicators of the radiation background samples of the residential area of the city-forming Khmelnytskyi NPP*

Month	EDR indicators (mSv/h)	Ground air (10^{-5}Bq/m^3)	Atmospheric precipitation (Bq/m^3)	Soil samples (kBq/ m^3)	Water samples (mBq/l)
January	0.09	27	0.47	0.12	88
February	0.12	20	0.54	0.15	78
March	0.12	22	0.50	0.17	69
April	0.13	13	0.49	0.19	245
May	0.10	10	0.46	0.18	264
June	0.11	26	0.52	0.13	235
July	0.15	15	0.45	0.11	246
August	0.17	17	0.56	0.24	267
September	0.11	21	0.84	0.10	92
October	0.09	12	0.73	0.20	152
November	0.12	18	0.82	0.22	105
December	0.11	16	0.67	0.21	211
Average for the year	0.85	18.9	0.58	0.16	171

After analysing the data on the ARMS of the reception and transmission points of the average monthly values of EDR in the 30-km zone for 2021, the authors of this study note that there were no significant deviations from the radiation background in the surveyed area. The average annual rate of 0.85 mSv/h is within the fluctuations of the global background and does not exceed the normative indicators for the territory. The average annual radioactivity of the surface layer of air is $18.9 \cdot 10^{-5}$ Bq/m^3, which is 2.9 times lower compared to the surveys for 2020, which were analysed by P. Pereira *et al.* (2022). High precipitation rates are observed for the period from September to November, which affected the average annual value of 0.58 Bq/m^3. Table 1 shows that the average annual value of the background radiation in these territories is 0.16 kBq/m^2. The average background radiation in the cooler basin is 3 times higher than in the riverbed – 171 mBq/l. It follows from this that the increased content of radionuclides in cooling basins does not affect their content in rivers.

The state of radiation activity in samples of agricultural products is significantly lower than the permissible specific activity of radionuclides: meat – 0.70 Bq/kg, milk – 0.35 Bq/kg, vegetables and cereals – 0.35 Bq/kg. Meat and milk sampling was carried out 1 time a year in the summer. Vegetables, root crops, and grains were sampled during the seasonal harvest. The planned catch of fish was carried out to take samples to study the activity of radionuclides in fish products. The samples were also taken once a year, the indicator is 0.70 Bq/kg per year. The number of radionuclides identified on the territory of the Khmelnytskyi NPP and adjacent territories included: ^{51}Cr, ^{59}Fe, ^{58}Co, ^{64}Zn, ^{89}Sr, ^{95}Zr, ^{103}Ru, ^{131}I, ^{141}Ce, ^{144}Ce. The data indicators collected on the territory of the Khmelnytskyi NPP are 0.91 mGy. As a result, it can be argued that the average annual total risk of radiation exposure for the population in the area near the NPP is equal $8.6 \cdot 10^{-7}$, directly on the territory of the Khmelnytskyi NPP it is equal $5.6 \cdot 10^{-7}$, which is 65% of the total percentage of radiation occurring in the surveyed area.

In addition, according to the authors, the use of new equipment, the closure of reactors and the abandonment of nuclear power facilities that have exceeded their service life can reduce the dose of human radiation exposure, and avoiding the consumption of food produced in contaminated areas naturally leads to a decrease in collective radiation doses. However, according to J. Perkins, *et al.* (2019), many people carry artificial radiation in their bodies as a result of the work of nuclear technologies, especially emissions that occurred as a result of atomic bomb tests and accidents at nuclear power plants. The largest of them are: the accident at the Mayak plant, 1967 (Chelyabinsk Oblast, Russia); Windscale, 1957 (Scotland, UK); Three Mile Island, 1979 (USA); the accident at the Chornobyl NPP, 1986 (Ukraine); and in 2011, Fukushima (Japan) (Nuclear reactors…, 2020; Fukushima catastrophe at 6…, 2019). The consequences of these accidents have caused irreparable harm to the world's population and their natural environment (Rowlatt, 2020).

J.F. Barquinero *et al.* (2021) noted that changes in radiation emissions into the environment should be made considering comprehensive assessments of the risks existing in the region, and the mandatory establishment of appropriate priorities. This approach allows focusing only on those problems that require attention. However, M. Partanen *et al.* (2020) consider the transition to an ecocentric approach in the field of ethics of relationships with nature, which are not found or very rarely found in the industrial sector, to be a priority. Having investigated the experience of Western European countries (Kosovets, 2015; Chumak et al, 2016) on the assessment of background radiation control in (Table 2), the authors of this study presented the main observations obtained from this information.

***Table 2**. Examples of automated radiation monitoring systems in some countries of the world*

Country	Controlled territories	Technological support of NPPs	Features of the application of ARMS	Availability
Finland	Scandinavian countries, 20 stations in the Leningrad NPP district	290 stations across the country	The results are entered into the National Data Bank.	To the authorities. In real time
Bulgaria	Monitoring centre indicators from 35 stations across the country	Gamma background control system	The indicators are transmitted to the control and response centre	To the authorities. In real time
United Kingdom	94 posts across the country (with a large location in the coastal area)	RIMNET – national network for analysing the dose rate of gamma radiation in the atmosphere	It mainly tracks the consequences of foreign nuclear accidents.	UK National Nuclear Database
Belgium	212 measuring posts across the country	TELERAD – a system of 4 rings around nuclear power plants	Automatic registration of artificial radioactive isotopes, consisting of 10-30 m. masts of stations for mobile measurement	Official website, freely available
Japan	19 prefectures and 217 posts	Computerised dose determination system	The system of forecasting the radiation situation, observing weather conditions near radiation-hazardous enterprises	On the official website, freely available

The studies by O. Hromyka *et al.* (2020) and J. Rowlatt (2020) show that mainly developed countries define ensuring safety from radiation catastrophe as a priority area of policy (Table 2). ARMS will not protect from radiation, but it will allow taking timely measures to prevent a man-made disaster. Adopting the experience of developed countries, it is possible to organise a single automated network with the countries of the second and third world at the international level. F. Krasnogorova (2015) has revealed that on the territory of the city-forming enterprises of the Khmelnytskyi NPP there are radionuclides that are of natural origin and can be isolated as a result of chemical reactions at an industrial site. By their nature, such radionuclides are unpredictable and, without constant monitoring and compliance with safety measures, can cause harm even during normal operation of power plants. For example, the main radionuclides are presented in Table 3.

***Table 3**. The main radionuclides formed as a result of the operation of nuclear power plants*

Source of radiation	Main features	Radiation doses
Tritium	Hydrogen isotope	Beta particles have an energy charge of 18.6 keV 65 % – in the world ocean 27 % – in the biosphere 8 % – in the atmosphere 0.01 % – in the human body
Carbon – 14	Beta particles with emitted energy	Particle energy – 155 keV
Potassium – 40	Natural mixtures of potassium isotopes 30 Bq	Content in marine biota – 90-100 Bq/kg The human body contains 0.23% of the total body weight
Radon	Half-life products	50-60 Bq/m^3 indoors

O. Trofymchuk *et al.* (2021) argue that technogenic tritium formed as a result of nuclear fuel reprocessing at nuclear power plants depends on the type of reactor and its parameters. Tritium fills the biosphere as a by-product of the use of atomic energy, the isotope actively affects natural processes, genetic structures, as it is easily assimilated in water, turning it into tritiated water. Its half-life is 12.3 years. Thermonuclear explosions led to an increase in the concentration of tritium in the stratosphere for 1 year, most of which settled in the Northern hemisphere, since almost all tests were conducted in this area. Concentrating in atmospheric precipitation, tritium decay products began to move closer to the equator (Krasnogorov, 2015). This is conditioned by the process of global warming. Tritium ions enter the human body in a matter of minutes, assimilating with the liquid in the human body, they are also quickly excreted. In this regard, this radionuclide does not pose a danger to public health and the environment. Technogenic Carbon-14 is formed as a result of nuclear weapons tests at the enterprises of the nuclear complex. It takes 5,730 years for the decay products to fully decompose.

The third largest radionuclide-causing radiation in the Earth's biosphere is Potassium-40. A. Chumak, *et al.* (2016) noted that the presence of this radionuclide is concentrated mostly on the Earth's surface. The accumulation of Potassium-40 in the bowels of the Earth leads to an increase in the natural heat of the planet. As already noted, radionuclides increase their concentration when they enter water. Thus, in the waters of the world ocean, the concentration of Potassium-40 is 12 Bq/kg, and in the cells of the body, its amount is 30 times higher than outside the cells. With age, its concentration decreases. Of all the listed radionuclides, Radon has the shortest half-life – 92 days. During its half-life, it is able to irradiate the largest number of living organisms. Its concentration in the atmosphere is 5,200 PBq, which is 5 times higher than the concentration from nuclear tests. The greatest amount of radiation a person receives in residential premises. Assimilating with water, the Radon concentration is 0.05 Bq/l. In production, when generating 1GW of electricity, the Radon background radiation is 0.03%. Thus, the safety of emissions does not exceed the values of the norm obtained by radiation exposure. In fact, the emissions of all controlled radionuclides are 4.0% of the permissible. The release of radionuclides with wastewater at the Khmelnytskyi NPP is carried out in cooling reservoirs and spray pools located on the territory of the NPP industrial site. The cooling pond is used at the Khmelnytskyi NPP for the organisation of technical circulating water supply. The maximum values of radiation indicators were recorded at the northern border of the sanitary protection zone. When calculating the concentration of radionuclides, all pathways of infection, including food chains, were considered. The distribution of emissions of ionising radiation sources outside the industrial sites does not exceed 1 m^3/year. The heterogeneous nature of local maxima near the sanitary protection zone is associated with changes in climate, wind direction, precipitation, changes in these factors are beyond human control.

Only 3% of the world's population receives a radiation dose of 1 mSv/year, another 1.5% – 1.4 mSv/year, the remaining 95% – 0.3-0.6 mSv/year. Low radiation dose rates and short-time influence reduce the likelihood of serious consequences. Being near a radiation source with low indicators for a long period of time increases the risk of diseases that may manifest themselves in years and decades (Arguments against nuclear energy, 2020). The likelihood of such risks increases for children, adolescents, pregnant women and their unborn children. According to the World Nuclear Association (2020), from 1 to 8, and from 25 to 40 weeks of pregnancy, there is no risk of radiation to the fetal brain even with indicators of 100 mSv and higher. However, the risk of developing cancer in the foetus is equivalent to the risk of developing cancer in an early child. Terrestrial animals receive the most external radiation. The dose of internal radiation depends on the content of radionuclides in the local components of the environment. The increased radiation dose of terrestrial plants in comparison with animals is most likely due to a number of the following factors: the presence of 40K in the plants themselves; dust and fragments of rock settle on the leaves; rhizome and young shoots are in close contact with the soil. Accordingly, invertebrates and microorganisms, in contact with the settled half-life products in the soil, receive high doses of radiation. A. Chumak, *et al.* (2016) claim that simple microorganisms, unicellular plants, animals, and bacteria are also sensitive to radiation doses. However, they are also more stable, as they are adapted to aggressive environmental conditions. For example, bacteria form spores, in this state their metabolism stops, and they withstand lethal doses of radiation. Invertebrates are also resistant to ionising radiation 1,000 times higher than the lethal dose for humans. For example, the DNA of water bears contains the Dsup protein, which forms the protection of genes from various damages.

CONCLUSIONS

The analysis of the influence of the radiation background in residential areas of settlements of city-forming NPPs on public health and the environment showed that with the normal technical condition of the system and elements of nuclear power plants important for safety, the risks of radiation contamination are reduced – 0.85 mSv/h (65%). While natural radiation (30%) and medical radiation (5%) are no less dangerous for the population and the environment.

Radiation acting on a living organism from the outside can be harmful because it affects DNA, cells, tissues, and organs of a person. Ionising radiation leads to the formation of free radicals and ions, which, in turn, destroys the structure of cells and tissues of the body. Such processes usually take place irreversibly, without the possibility of regeneration of the systems of a living organism, and improper restoration of cells leads to various diseases. However, it is possible to stop the harmful effects by protecting from external radiation or avoiding its effects. However, if a person consumes radioactively contaminated food or inhales radioactive air, radionuclides still enter the body. This is a serious problem because the human body mistakenly perceives these radionuclides as natural elements. Thus, radioactive isotopes are deposited in bones and muscles, irradiating a person from the inside, for a long time. This process is called internal irradiation. It is more dangerous than external exposure due to the long period of exposure. Summarising the results of the study of the impact of atomic radiation on the environment, the authors came to the conclusion that nuclear energy is not capable of causing serious harm if handled reasonably.

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Вплив радіаційного фону міських поселень з атомними електростанціями на здоров'я населення та навколишнє середовище

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Анотація. Радіоактивний розпад елементів в результаті ядерної реакції є потужним джерелом енергії, що використовується при виробництві електричної та теплової енергії в містах, наближених до АЕС. Проблемою використання такого виду енергії є небезпека радіаційного опромінення. Виробництво ядерної енергії має багато переваг, серед яких рентабельність кінцевого продукту і його низька собівартість, з іншого боку, продукти напіврозпаду радіонуклідів у складі газоаерозольних викидів з вентиляційних труб осідають в навколишньому середовищі на території містоутворюючих АЕС. Двоїстість проблеми впливу радіаційного фону на міські території поблизу АЕС стала метою даного дослідження. Необхідно дослідити негативний вплив викидів радіоактивних відходів при нормальній експлуатації атомних електростанцій. Для цього було використано метод проектного експерименту, під час якого за допомогою лабораторного контролю зовнішньої радіаційної безпеки та автоматизованої системи радіаційного моніторингу були зібрані показники експозиційних дозових потужностей з точок 30-кілометрової зони навколо АЕС. В результаті моніторингу радіаційних проб ґрунту, атмосферного повітря та атмосферних опадів, водойм встановлено, що природний радіаційний фон незначний, ймовірність шкоди від радіаційного опромінення невелика і недостатня для розвитку променевої хвороби. Разом з тим, визначено потенційно небезпечні джерела радіаційного опромінення, такі як природне випромінювання - споживання забруднених продуктів харчування, сонячне та космічне випромінювання від радіоактивних елементів, присутніх в надрах землі; радіонукліди, викиди яких неконтрольовано відбуваються в атмосферу; радіоактивні відходи, технологія захоронення та зберігання яких є економічно затратною. Тому проведення регулярних розрахункових експериментів з перевірки працездатності автоматизованих систем радіаційного моніторингу є виправданим. Матеріали дослідження мають практичну цінність для хіміків, екологів та екотехнологів, що працюють на АЕС, які здійснюють контроль за безпекою для здоров'я людини та охороною навколишнього середовища у сфері використання атомної енергії

Ключові слова: ядерна енергетика, атомні електростанції, радіація, показники експозиційної дози