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The article was received
2019.01.29

UDC 613:614.876:340.13(477) https://doi.org/10.26641/2307-0404.2019.1.162313

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IMPROVING THE SYSTEM OF RADIATION AND HYGIENIC MONITORING OF ENVIRONMENTAL OBJECTS IN THE AREAS OF OBSERVATION OF UKRAINIAN NUCLEAR POWER PLANTS AS A FUNDAMENTAL OF RADIATION SAFETY

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Цитування: Медичні перспективи. 2019. Т. 24, № 1. С. 80-86
Cited: Medicni perspektivi. 2019;24(1):80-86

Key words: *nuclear power plants, observation area, environment, levels of pollution, radionuclides, radiation-hygienic monitoring*
Ключові слова: *атомні електростанції, зона спостереження, навколишнє середовище, рівні забруднення, радіонукліди, радіаційно-гігієнічний моніторинг*
Ключевые слова: *атомные электростанции, зона наблюдения, окружающая среда, уровни загрязнения, радионуклиды, радиационно-гигиенический мониторинг*

Abstract. Improving the system of radiation and hygienic monitoring of environmental objects in the areas of observation of Ukrainian nuclear power plants as a fundamental of radiation safety. Khomenko I.M., Zakladna N.V. *The relevance of the work is determined by the absence of documents on the problems of observation areas of nuclear power plants, including the organization and monitoring of environmental objects in Ukraine. The*

purpose of the study was to assess the state of radioactive contamination of the environmental objects of the observation area of the Zaporizhzhia nuclear power plant. To accomplish the tasks, we analyzed the data of the laboratory control performed by the external radiation monitoring laboratory of the Zaporizhzhia nuclear power plant and the data of the State Institution «Zaporizhzhia Regional Laboratory Center of the Ministry of Health of Ukraine». The obtained results allow us to draw the conclusions that in the environmental objects (water of the Kakhovsky reservoir, atmospheric air, soil, drinking water) of the observation area of the Zaporizhzhia nuclear power plant, the main dose-forming radionuclides were identified. It is established that their levels are not uniform, and the revealed instability testifies to the need for continuous laboratory monitoring of the content of cesium and strontium and the need for monitoring the impact on health of the residents of the observation area. It is necessary to improve radiation monitoring through the development and implementation of new methodological documents and regulations on the organization of laboratory control, justification of its frequency and the required amount of laboratory research, which will allow to establish the true impact on public health in these areas.

Реферат. Усовершенствование системы радиационно-гигиенического мониторинга объектов окружающей среды в зонах наблюдения атомных электростанций как основа радиационной безопасности. Хоменко И.М., Закладная Н.В. *Актуальность работы определена отсутствием в Украине документов по проблемам зон наблюдения атомных электростанций, в том числе организации и осуществления мониторинга объектов окружающей среды. Цель исследования заключалась в проведении оценки состояния радиоактивного загрязнения объектов окружающей среды зоны наблюдения Запорожской атомной электростанции. Для выполнения поставленных задач, были проанализированы данные лабораторного контроля, выполненного лабораторией внешнего радиационного контроля Запорожской атомной электростанции и данные ГУ «Запорожский областной лабораторный центр МОЗ Украины». Полученные результаты позволяют сделать выводы о том, что в объектах окружающей среды (вода Каховского водохранилища, атмосферный воздух, почва, питьевая вода) зоны наблюдения Запорожской атомной электростанции выявлены основные дозообразующие радионуклиды. Установлено, что их уровни неравномерны, а выявленная нестабильность свидетельствует о необходимости осуществления постоянного лабораторного контроля за содержанием цезия и стронция и необходимости мониторинга воздействия на здоровье жителей зоны наблюдения. Необходимо усовершенствование радиационного мониторинга путем разработки и внедрения новых методических документов и регламентов по организации лабораторного контроля, обоснование его периодичности и необходимого объема лабораторных исследований, что позволит установить истинное влияние на здоровье населения этих зон.*

According to the Energy Strategy of Ukraine for the period up to 2030, the main conditions for the development of nuclear energy in Ukraine for a specified period are unconditional compliance with all norms and safety requirements to the nuclear-energy complexes, including nuclear power plants (NPPs), and limiting their possible impact on the population and the environment (E) [3].

In the conditions of rapid development of modern technologies and industry, an integral part of which are enterprises of the atomic industry and the widespread use of sources of ionizing radiation in many spheres of human activity, the question of the impact of radiation objects on the health of the population living in observation areas (OA), together with the monitoring of environmental objects in these areas becomes of particular relevance [4, 9].

Separate documents of the state level [6] rule that all nuclear power plants should be equipped with automated radiation control systems (ARCS), which are continuously monitoring the radiation state at the industrial site of NPP, in the sanitary protection zone and OA of the NPP.

In 2002 for the first time in the CIS, at the Zaporizhzhia NPP (ZNPP), which is the largest nuclear power plant in Europe, the information measuring system "ring", with the radius of 30 km to control the radiation situation, was put in operation. In the OA the network of specially equipped posts located in settlements of the OA of the ZNPP [5] was created. Today all Ukrainian NPPs are equipped with ARCS [1, 7].

The purpose of the work was to assess from the hygienic position the state of radioactive contamination of the environmental objects of the observation area of the Zaporizhzhia Nuclear Power Plant.

MATERIALS AND METHODS OF RESEARCH

The research was based on the analysis of the results of field observations on the content of the main dose-forming radionuclides ^{137}Cs and ^{90}Sr in the objects of the environment (soil, air, water of Kakhovsky reservoir, drinking water). The observation time is 10 years (2006-2015).

The data of researches carried out in the laboratory of external radiation control (LERC) of ZNPP in the settlements of Zaporizhzhia (v. Michurine, Vodyane, Prymirne, Samara, Kamianka-Dniprovska, Ivanivka, Velyka Znamenivka) and Dnipropetrovsk region (cities of Nikopol and Marganets) were used. In particular, they contained information on the content of radionuclides (^{137}Cs and ^{90}Sr) in samples

of water of surface water reservoirs (Kakhovsky reservoir), soil, in the air and drinking water. The task of controlling the content of radioactive substances in the environment is to obtain data for the assessment of radiation doses from the effect of the ZNPP for the population in order to confirm the justification of emissions and discharges, as well as the quality of their control.

Also, there was carried out the analysis of radiation-hygienic monitoring performed by SE "Zaporizhzhia Regional Laboratory Center of the Ministry of Health of Ukraine". The measurement error according to certification scope of the laboratory was determined, depending on the type of radionuclide which content was studied. The size of the measurement error for the study of ^{137}Cs and ^{90}Sr in the water of the Kakhovsky Reservoir was – 21.4% and 6.9% respectively. Sampling was carried out once a year.

In the course of the study, bibliographic, analytical, hygienic, mathematical-statistical methods and observation method were used.

RESULTS AND DISCUSSION

For radiological control of the surface watercourse, probe sampling of the surrounding area of Kakhovsky reservoir (v. Vodyane of K-Dniprovsk district of Zaporizhzhia region) as well as on the opposite bank of Kakhovsky reservoir in the area of cities Nikopol and Marganets of the Dnipropetrovsk region was performed by LERC of ZNPP. The content of the studied radionuclides in the water, surface water, carried out by LERC of ZNPP is presented in table 1 and the results of similar studies conducted by "Zaporizhzhia Regional Laboratory Center of Ministry of Health of Ukraine" (control point - v. Vodyane of K-Dniprovsk district of Zaporozhzhia region) are in table 2.

According to the measurements of the "zero background", the voluminous activity of radionuclides in the water of the Kakhovsky reservoir before setting in operation of the NNPP was: ^{90}Sr – (24.3±1.2) ^{137}Cs – (2.6±0.8) Bq/m^3.

Table 1

Content of ^{90}Sr and ^{137}Cs in the water of Kakhovsky reservoir, Bq/m^3

Control points	2007		2009		2011		2013		2015	
	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr
v. Vodyane	<4.0	27	<4.4	32	<4.4	36	<4.4	32	<4.4	19
Water intake Nikopol	<4.0	27	<3.6	27	<4.3	31	<4.7	32	<4.0	14
Water intake Marganets	<4.5	32	<3.8	23	<4.0	27	<5.2	28	<4.2	15

Drinking water research was carried out by LERC of ZNPP, samples for research were taken directly in the laboratory room. Water supply with drinking water of OA of the ZNPP (in particular, Zaporizhzhia part of it) is carried out at the expense of underground sources (artesian wells), and water supply of the cities of Nikopol and Marganets, Nikopol and Tokmak districts is carried out by water intakes from the Kakhovsky reservoir and requires additional water cleaning.

The results of the research of the drinking water are presented in table 3.

Table 2

Content of ^{90}Sr and ^{137}Cs in the water of Kakhovsky reservoir, Bq/m^3

Water intake	2007		2009		2011		2013		2015	
	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr
Kakhovsky reservoir	60±12.8	50±3.45	19±4.06	30±2.07	3.7±0.79	53±3.66	5±1.07	40±2.76	3.6±0.77	32±2.48

Table 3

Content of ^{137}Cs and ^{90}Sr in drinking water, Bq/m^3

Control point	2007		2009		2011		2013		2015	
	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr
c. Energodar	<4.1	12	<3.8	9.7	<4.7	4.8	<4.4	5.9	<4.3	3.2

The content of ^{137}Cs and ^{90}Sr in samples of the drinking water meets the requirements of the Hygienic Standard of the HN 6.6.1.1-130-2006 "Permissible levels of radionuclide content of ^{137}Cs and ^{90}Sr in food and drinking water", according to which the permissible content of the above radionuclides is 2 Bq/l or 2000 Bq/m^3 [2].

According to multi-year reports of the ZNPP in the course of its operation, gaseous, solid and liquid products containing radionuclides, i.e, radioactive isotopes of chemical elements are formed. Radiation influence on atmospheric air is connected with the release of these radionuclides in the environment. Control over the content of radioactive substances in the air is carried out in 12 points of stationary observation, located with account of wind rose. The volumetric activity of radionuclides ^{137}Cs and ^{90}Sr in the atmospheric air over 30 years of observations did not exceed the normative values according to NRSU-97. For radionuclides ^{137}Cs and ^{90}Sr, the values of the concentration measured before the setting in operation of the ZNPP and currently are practically at the level of values measured in the first years of operation of the ZNPP [5]. According to the annual report of the ZNPP in 2011 (April-May), there was observed the increase in volumetric activity of ^{137}Cs as a consequence of the accident at the "Fukushima-1" NPP. Data from laboratory studies are presented in tables 4, 5.

Table 4

Content of ^{137}Cs in the atmospheric air, μBq/m^3

Settlements (control points) OA of ZNPP	2007	2009	2011	2013	2015
Zaporizhzhia region					
v. Michurine	1.4	1.1	5.6	1.41	1.4
v. Vodyane	1.4	1.1	6.1	1.09	1.1
v. K.-Dniprovska	2.1	2.3	10.2	1.81	1.5
v. V.Znamianka	1.7	1.5	9.0	2.35	1.3
Dnipropetrovsk region					
c. Nikopol	1.1	1.2	4.5	<1.0	1.0

Before setting in operation of the ZNPP, specific activity of radionuclides in the atmosphere corresponded to the global levels of radionuclide content and was:

^{137}Cs – (2.22±0.74) μBq/m^3;

^{90}Sr – (11.10±5.92) μBk/m^3.

The research of soils of OA of the Zaporizhzhia NPP was carried out at the control points of Zaporizhzhia (Michurin village, Vodyane village, Kamianka-Dnipropetrovsk village, the village of V. Znamianka - K-Dniprovsky district) and Dnipropetrovsk region (Nikopol city). Soil contamination is caused by radionuclides ^{90}Sr and ^{137}Cs. The content of the main dose-forming radionuclides ^{137}Cs and ^{90}Sr by the data of the conducted research is presented in Figures 1, 2.

Table 5

Content of ^{90}Sr in the atmospheric air, μBq/m^3

Settlements (control points) OA of ZNPP	2007	2009	2011	2013	2015
Zaporizhzhia region					
v. Michurine	**0.2**	**0.1**	**0.1**	**<0.1**	**<0.1**
v. Vodyane	**0.1**	**0.1**	**0.1**	**<0.1**	**<0.1**
v. K.-Dniprovska	**0.1**	**0.2**	**0.1**	**<0.1**	**<0.1**
v. V.Znamianka	**0.1**	**0.2**	**0.1**	**<0.1**	**<0.1**
Dnipropetrovsk region					
c. Nikopol	**0.3**	**0.4**	**0.2**	**<0.1**	**<0.1**

Specific activity of radionuclides before setting in operation of the Zaporizhzhia NPP in the surface layer of soil was:

^{90}Sr – (0.89±0.41) kBq/m^2;

^{137}Cs – (1.18±0.52) kBq/m^2.

The results of our previous researches on the study of their content in the main food products are evidenced by the intake of the main dose-forming radionuclides ^{137}Cs and ^{90}Sr in the objects of the environment during the operation of the ZNPP [8].

According to modern studies [1], normative legal documents, as well as methodological regulations on the organization and conduct of radiation control at Ukrainian NPPs, do not fully correspond to the current scientific understanding of the problems of ensuring radiation safety of the NPP. The control points over radiation situation in the locations of the Ukrainian NPPs do not reflect the actual state of the environment and do not provide the same exact results, while ARCS do not provide the necessary information on the radiation influence of the NPP on the environment at the expense of placement of posts on the territory of settlements of the observation area. Radiation control systems are constructed without taking into account ecological features in the location areas of NPP. Therefore, it is impossible to assess the radiation state of the environment and to predict the radiation dose for the population, which, accordingly, makes it impossible to develop optimal environmental safeguards.

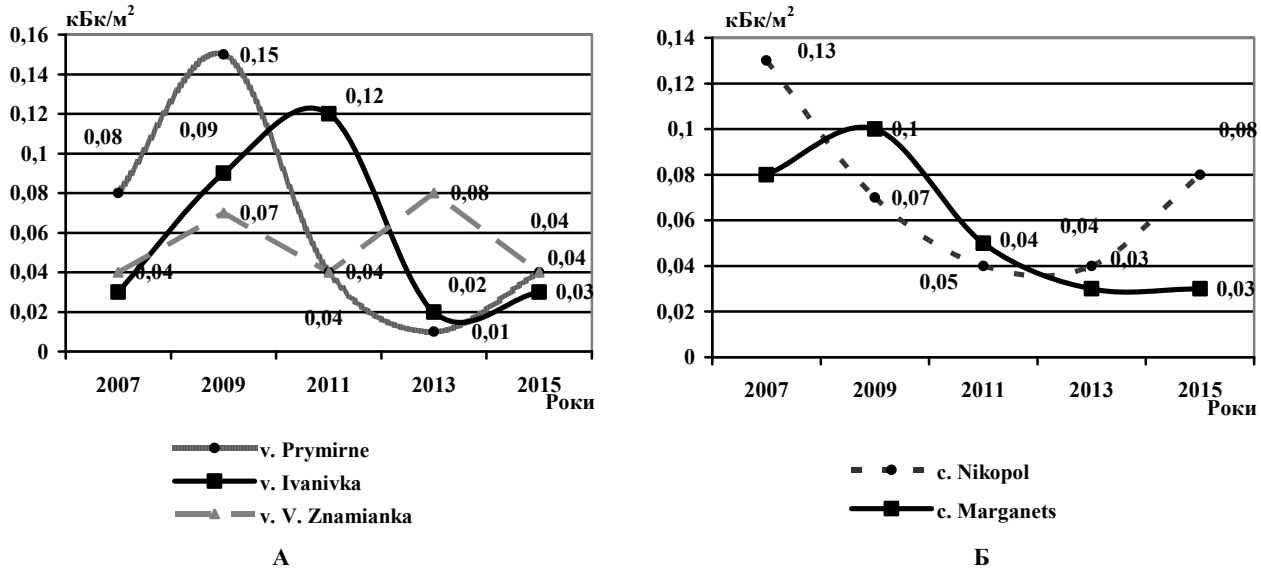

Fig. 1. Content of ^{90}Sr in the surface layer of Zaporizhzhia (A) and Dnipropetrovsk (B) regions, observation areas of Zaporizhzhia NPP in 2007, 2009, 2011, 2013 and 2015, kBq/m^2 of dry mass

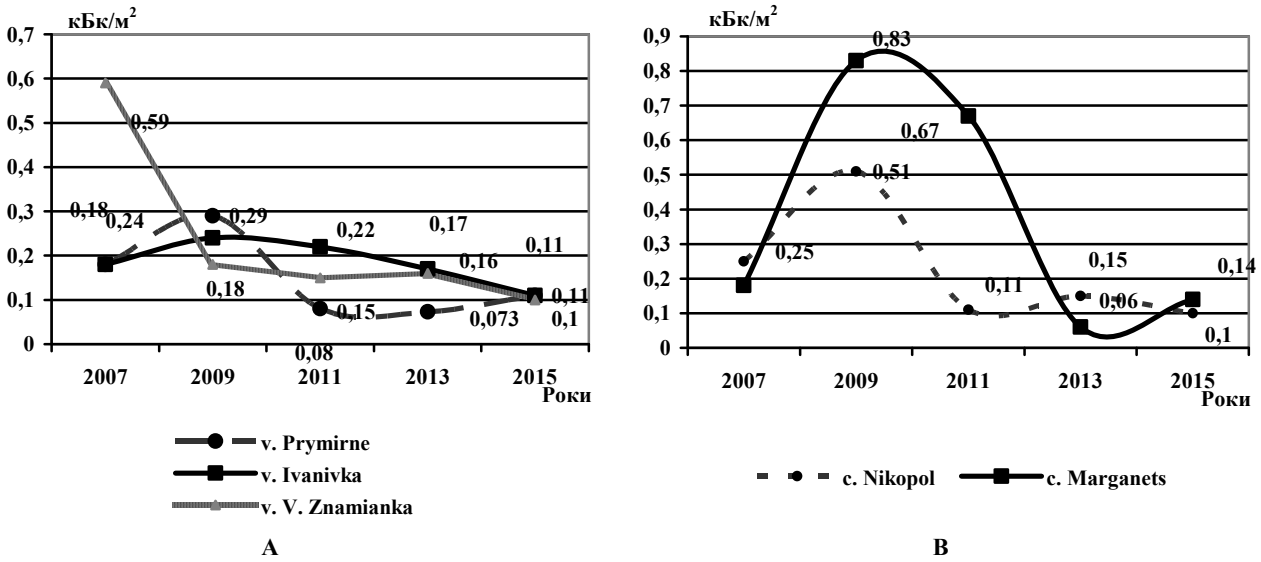

Fig. 2. Content of ^{137}Cs in the surface layer of Zaporizhzhia (A) and Dnipropetrovsk (B) regions, territorial parts of the observation area of Zaporizhzhia NPP in 2007, 2009, 2011, 2013 and 2015, kBq/m^2 dry mass

CONCLUSIONS

1. The presence of the main dose-forming radionuclides ^{137}Cs and ^{90}Sr in the atmospheric air, water of the Kakhovsky reservoir and soils testifies that the discharge of these radionuclides into the environment occurs during the operation of the Zaporizhzhia Nuclear Power Plant.

2. It was established that the content of ^{137}Cs and ^{90}Sr in the water of Kakhovsky reservoir is higher than those before the setting in operation of the Zaporizhzhia nuclear power plant. The detected levels of these radionuclides are uneven and have a territorial difference. Despite the fact that the nuclear power plant is located in the Zaporizhzhia region, the levels of these radionuclides in the soil are more pronounced in the Dnipropetrovsk region.

3. For more complete information it is necessary to improve radiation and hygiene monitoring (in particular, the development, introduction of regulations and methodological documents on organization, periodicity, determining of the required volume of laboratory research) and, accordingly, conducting research of indicators in a larger time interval of observations, which will allow to comprehensively assess the degree of safety of dwelling in the observation areas of nuclear power plants and to determine the possible impact on the health of the population.

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The article was received
2019.02.05