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APPROACHES TO BUILDING A NETWORK OF AUTOMATED RADIATION MONITORING POSTS IN THE TERRITORY OF UKRAINE

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The article describes the conceptual approach to building a network of automated monitoring posts of the Integrated Automated Radiation Monitoring System of the environment in the territory of Ukraine. To solve this task, it is proposed to take as a basis the network of posts of existing object automated systems and the network of non-automated posts of radiation monitoring of atmospheric air of the Ukrainian Hydrometeorological Center, with further work on optimizing the number of posts of the Hydrometeorological Center and their automation, and then integrating all posts into one system. It is proposed to form an integrated network of observation posts taking into account the ecological and hygienic principle.

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The issue of the creation of the State Automated Radiation Control System (SARCS) in Ukraine was raised at the republican level almost immediately after the Chernobyl accident, in 1989, that is, during the times of the USSR. Information about such work in Ukraine and related projects can be found in the monograph [1]. But SARCS was never created.

After that, for many years, in independent Ukraine there were many discussions and discussions about the creation of SARCS. Many different decisions, resolutions, and orders were adopted. The last discussion of the problem took place in 2011–2012 after the accident at the nuclear power plant in Japan. The issue was brought to a meeting of the National Security Council, after which the Cabinet of Ministers of Ukraine (CMU) issued Order No. 44-r on January 25, 2012 "On the approval of the plan of measures for the creation of a unified automated system for monitoring the radiation situation for the period until 2015". However, after the well-known events that began in Ukraine at the end of 2013, the process of creating a state system of radiation control of the country's territory stopped again until 2022. In April 2022, the CMU approved the Strategy of the integrated automated radiation monitoring system for the period until 2024, which (the system) is planned to be created with the support of the European Commission.

It should be noted that, if earlier in the regulations of the CMU it was about the creation of SARCS, now – about the State Automated Radiation Monitoring System (SARMS), or more precisely – the Integrated Automated Radiation Monitoring System (IARMS) of the territory of Ukraine.

The author considers it necessary to explain the difference between the concepts of "control" and "monitoring", which, in particular, are used in this article. The recommendations of the international Standard ISO 4225-80 "Air quality. General aspects. Terminology", Law of Ukraine "On Environmental Protection" dated 06.26.1991, No. 1268-XII, "Basic sanitary rules for ensuring radiation safety of Ukraine", approved by Order of the Ministry of Health of Ukraine dated 02.02.2005, No. 54 and registered in the Ministry of Justice of Ukraine on 20.05.2005 under No. 552/10832, and the IAEA explanation.

Summarizing the recommendations of the ISO 4225-80 Standard, the Law of Ukraine and the Basic Sanitary Rules, we can say that according to these documents, under **monitoring**, including radiation means a system of observation, collection, processing, preservation, analysis of information about the state of the environment, forecasting its changes due to the influence of anthropogenic factors, and the development of scientifically based recommendations for making effective management decisions.

The main task of **control** in the field of environmental protection is to ensure compliance with the requirements of environmental legislation by all state bodies, enterprises, institutions and organizations, regardless of the forms of ownership and subordination. As far as **radiation control** is concerned, it is interpreted as "control within the framework of practical activities in compliance with the Radiation Safety Norms of Ukraine, the Basic Sanitary Rules for Ensuring Radiation Safety of Ukraine and other regulatory documents, as well as obtaining information about the level of exposure of people, the radiation condition at objects and in the environment". That is, "control" is the observation and evaluation of received information from the point of view of the level of impact on the natural environment and people, while "monitoring" also includes elements of information analysis, forecasting and development of recommendations for making management decisions.

The IAEA in its Glossary of Nuclear Security and Physical Security [2], which defines and explains technical terms used in IAEA Safety Standards and IAEA Nuclear Security Guidelines, as well as in other IAEA security-related publications, and provides information on their use, interprets the concept of

"**radiation monitoring**" as "measurement of dose level, dose rate or activity to **assess or control** exposure due to exposure to radiation or exposure from radioactive substances, as well as interpretation of the results".

"**Assessment**" means "obtaining information that serves as a basis for making a decision as to how satisfactory the subject matter is," i.e., how satisfactory the levels of exposure or contamination are compared to standards or criteria.

"**Control**" is the function of management, regulation, or limitation that forms the basis of decision-making and forecasting regarding dose loads and pollution levels.

Thus, the IAEA defines "monitoring" as evaluation and control on the basis of which decisions are made.

That is, the concepts of "control" and "monitoring" are treated almost identically in the above documents.

Further in the article, concepts related to obtaining information about the radiation situation and performing appropriate actions with it are used in the sense described above.

It is well known that the basis of both ARCS and ARMS is a network of observation posts (control, monitoring), which consists of posts at on which the strength of the exposure dose (ED) of gamma-radiation is measured, placed in the area is measured. In addition, for a reliable assessment of the situation, both systems must be supplemented with sensors that measure meteorological parameters, based on the readings of which the state of the atmosphere is determined; technological sensors of a radiation-hazardous object (RHO), designed to determine the parameters of the release of a radioactive impurity into the atmosphere; software that makes a forecast of radioactive contamination of the environment.

The issue of forming a network of posts for SARCS was considered in detail in works [3, 4] from the point of view of increasing the accuracy of the assessment of the levels of radiation pollution of the natural environment of the territory of Ukraine and dose loads on the country's population.

However, after the publication of this monograph (2015), little has changed in the field of implementation of approaches to the formation of a network of automated radiation control (monitoring) posts, both around the RHO and on the territory of Ukraine. Thus, there are still no requirements for the optimal placement of posts for the purpose of determining the radiation state of the environment and early warning of radiation accidents, both on the territory of the country and on the territory of the countries bordering Ukraine.

In the article, the author, based on his own work, their adaptation to national and international requirements and accumulated experience in various countries, including Ukraine, offers a conceptual approach to building a network of **observation posts for the State Automated Radiation Monitoring System (SARMS) on territory of Ukraine**, the purpose of which is to detect in real time the danger of radiation contamination of the country's territory in the event of an emergency situation in the RHO of Ukraine or neighboring countries, to obtain reliable information about the state of the radiation situation, facts, nature and scope of its possible change (forecast).

The organizational and functional structure of SARCS (SARMS) consists of several levels, which are presented in Fig. 1.

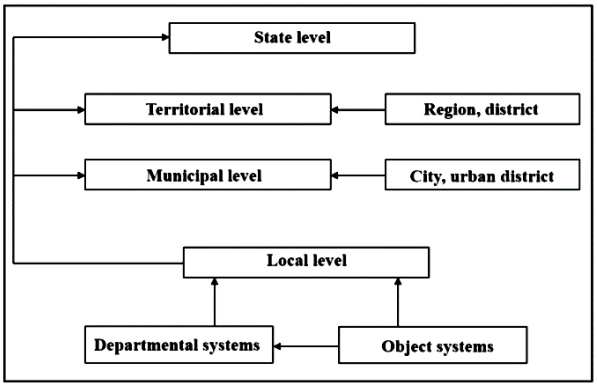

Fig. 1. Organizational and functional structure of ARCS and ARMS of the state level

Currently, such a multi-level state system does not exist in Ukraine. There are only elements of the local level, such as object automated systems (ARCS NPP, ARNS in the Chernobyl Exclusion Zone (CHEZ), ARCS of the State Specialized Enterprize "Association "Radon"), which are subordinate to various departments, which makes it difficult to obtain generalized and reliable information about the state of the radiation situation in the territory of the entire country.

Ukrainian industry standard UIS 95.1.01.03.024-97 was taken into account when forming the network of ARCS NPP posts "Automated radiation monitoring systems for nuclear power plants" was taken into account. Basic provisions", which recommends taking into account weather conditions and placing control posts near or within the population centers located in the control zone. It is worth noting that the main functions of ARCS in this Standard are more in line with the functions of ARMS than ARCS. However, later in the article we will call the automated systems that are at the NPPs of Ukraine ARCS systems, as it is currently customary.

The number of ARCS posts **in the 30-km observation zones of Ukrainian NPPs** is: 11 – at the Khmelnytskyi NPP, 13 – at the Rivne NPP, 18 – at the Zaporizhzhia NPP (now in the occupied territory) and 14 – at the South Ukrainian NPP.

In automatic mode, the following are measured: exposure dose power (ED) gamma radiation; volumetric activity (VA) of α-emitters in air; VA of β-emitters in the air; VA of iodine in the air; VA of liquid discharges.

In the Chornobyl exclusion zone, there are currently the following facility automated systems: ARCS of the Chernobyl Nuclear Power Plant, ARMS of the "Vektor" production complex and radioactive waste storage facility (RWSF) "Buryakivka", ARCS of the Central Spent Nuclear Fuel Storage Facility and the Integrated radiation monitoring early warning system (IRM&EWS), to which all automated systems located on the territory of the CHEZ are connected.

According to the project, the IRM&EWS for 2020 included: 69 automated gamma radiation ED control posts (39 are currently in working order); 3 automated ground and one high-altitude weather stations; post of automatic control of radioactivity of aerosols; 3 automated water control posts of the Pripyat River.

The State Specialized Enterprise (SSE) "Association "Radon" has 5 sites with RWSF, which belong to the Dnipro, Lviv, Odesa, and Kharkiv branches, and the Central production site. They have 5 ARCS posts each, which measure the ED of gamma radiation.

At the moment, the ARCS of the SSE "Association "Radon" does not provide data exchange with any existing radiation control systems in Ukraine and abroad. All other ARCS transmit data either to the Information and Crisis Center of the State Nuclear Regulation Inspection of Ukraine, or to other systems inside (UkrHMC) and outside of Ukraine (IAEA).

The author does not know what methodological recommendations or normative documents were used in the formation of the network of posts in the Chernobyl exclusion zone and at the sites of the SSE "Association "Radon".

Other RHOs of Ukraine (State enterprise eastern ore dressing complex (SE Vostgok), SE "Baryer", Institute for Nuclear Research of the National Academy of Sciences, National Science Center Kharkov Institute of Physics and Technology and State Enterprise "USIE Izotop") **do not have ARCS or ARMS.**

Based on the information about existing automated systems in Ukraine, which is currently publicly available, it can be concluded that there is no uniform methodological support for all monitoring subjects, which justifies the approach to determining the number of monitoring (control) points and their optimal placement.

Thus, in total, all the object ARCS and ARMS (hereinafter simply AS) of Ukraine today have about 120 posts (provided the equipment is operational), which are located in the radiation control zone of enterprises, and **unevenly distributed across the country.**

120 posts are enough to quickly and reliably assess the radiation situation near enterprises, but not enough to assess the situation in the entire territory of the country. Thus, object-based automated systems of radiation control (monitoring) of the environment cover less than 3% of the territory of Ukraine. As for Ukraine's borders, automated monitoring systems cover only the territory adjacent to the CHEZ, which is about 2% of Ukraine's border with neighboring states.

The above means that it is impossible to reliably assess the radiation situation in the entire country based only on the readings of the post sensors of the facility AS, which belong to various departments, and it is also impossible to reliably control the cases of transboundary transfer of radioactive substances.

In addition, works [3, 5] show that the network of posts of ARCS NPP will be "transparent" for radionuclides ejected from the station in the event of adverse weather conditions at the time of the accident, which cause the emission flare to spread in a narrow sector (15…20°). That is, the network of ARCS posts at any of the Ukrainian NPPs under these conditions will not provide reliable information about the radiation situation in the monitoring zone. The same can probably be said about other Ukrainian object AS, but this statement requires verification.

As it was said above, the existing object ASs belong to different departments and solve tasks specific to these departments, work in different modes and conditions, that is, they are not combined into a single system. Therefore, the question arises: will the ARCS or SRMS facilities existing in Ukraine be able to register the spread of the emission flare in the event of an emergency situation at one of the RHOs within the country?

In the event that an accident occurs on the territory of the country at one of the RHO, which has an AS, but it ceases to function as a result of an accident or malicious activity, and at the same time the rest of all object AS, including ARCS NPP, will be in working condition (the most favorable case), then the time of receiving information about an emergency situation at this RHO will be determined by the distance from this object to the automated observation post of another RHO, weather conditions (wind direction and speed) and the actions of persons who make decisions on the implementation of anti-radiation measures.

There can be many options. However, under all options, for the realities of Ukraine, the time to respond to an accident and coordinate actions between various departments can be many hours, which is an unacceptably long time to start carrying out the necessary operational measures to take measures to protect the population.

The same picture will be observed in the event of an accident on the RHO outside the borders of the country, which is complicated by the uncertainty of the development of the situation on the territory of another state.

It follows from the above that the existing system of object AS in Ukraine is not able to quickly reflect changes in the radiation situation in the event of an emergency both inside the country and outside of it.

Therefore, such a network of automated state-level observation posts should be formed, which would take into account all the risks and uncertainties listed above and would allow to detect signs of changes in the radiation situation as early as possible, its causes and the degree of danger to people, regardless of the place and sources of radiation risks.

It is possible to solve this task in Ukraine if, taking as a basis the network of posts of object AS that already exists in the country, and adding to it a relatively uniform network consisting of 179 non-automated observation posts of the Ukrainian Hydrometeorological Center (UkrHMC), at which ED is measured gamma-radiation (of which 32 posts are located in the temporarily occupied territory) [6] belonging to the State emergency service of Ukraine (Fig. 2), as well as the network of ground weather stations of the UkrHMC (now there are about 190 of them, taking into account the occupied territories), which located near the same

places as the monitoring posts [7], as a result of forming an **integrated network of observation posts.**

Optimizing the number of observation posts of the UkrHMC, related to the economic side of creating a network of posts, can be carried out using one of the known methods, for example, the multi-criteria optimization method, the minimax method or the method of permissible error of observation results.

Then you can start work on automating the system. This is a complex process that requires a separate discussion.

As a result, such **integration of the network of automated observation posts will allow for continuous automated monitoring of radiation parameters on the territory of the country and perform prognostic assessments, and the AS itself becomes an integrated automated radiation monitoring system (IARMS) in the full sense of this concept.**

Fig. 3 shows a hypothetical diagram of the location of automated observation posts after the integration of networks.

Fig. 2. Atmospheric air radiation control posts (ED) on the territory of Ukraine:
– active observation posts of UkrHMC, – temporarily inactive observation posts of UkrHMC [6]

Fig. 3. The scheme of the location of observation posts of the IARMS, covering the entire territory of Ukraine

A separate issue is how **to place IARMS posts** to obtain representative and accurate results of current measurements and forecast calculations of the radiation situation both on the territory of the country and near the borders of Ukraine with other countries on whose territory RHOs are located.

It is proposed to base the methodology of forming such a network of IARMS posts on the ecological-hygienic principle, which takes into account both sanitary-hygienic and ecological approaches to radiation control. This means that at the stage of creating a system of automated control (monitoring) of the radiation situation, such a network of control posts should be formed that would take into account not only the most unfavorable weather conditions, but also the relief of the area, types of landscapes, the predicted density of contamination of the underlying surface from fallout from the radioactive cloud, the number population and other quantifiable characteristics of the area and emission sources, as well as economic and physical and technical characteristics of the system. **This approach can be methodically implemented using the results of meteorological data monitoring, landscape and demographic zoning of the studied territory, as well as prognostic calculations, for example, using the RODOS system [3].** (The RODOS system includes mathematical models and databases for modeling and assessing the development and consequences of possible radiation accidents, as well as planning immediate and long-term countermeasures, and is aimed at increasing the ability to respond to national and cross-border emergencies in Europe).

According to the author of the article, **the most modern approach to the organization of permanent radiation monitoring could be a national system of remote land zoning** using space and air (unmanned aerial vehicles) means.

The development of such monitoring tools provides a fundamentally new opportunity to solve the extremely complex problem of forecasting and prevention of spontaneous natural phenomena and man-made accidents and catastrophes. Modern space and aerial means of observation in combination with ground means can ultimately ensure the detection of man-made sources of danger. as well as prompt transmission of monitoring data to almost any point on the globe.

CONCLUSIONS

The existing network of object systems of automated radiation control (monitoring) in Ukraine is not able to quickly reflect changes in the radiation situation in the event of an emergency both inside the country and outside its borders.

The task of creating a network of observation control posts for the Automated Radiation Monitoring System of Ukraine can be solved by taking as a basis the network of posts of departmental object automated systems and the network of non-automated posts of radiation monitoring of atmospheric air of the UkrHMC, which belongs to the State Emergency Service of Ukraine, as well as the network of weather stations UkrHMC, followed by optimization and automation of UkrHMC posts, and then integration with departmental automated posts into one system.

To provide a representative and accurate assessment of measurements of radiation parameters during automated radiation control (monitoring), such as around nuclear power plants and other radiation-dangerous objects, as well as on the territory of the country and on the border, the network of observation posts should be formed taking into account the ecological and hygienic principle on the basis of monitoring of meteorological data, landscape and demographic zoning of the studied territory, as well as prognostic calculations using special computer programs, for example, using the RODOS program system.

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ПІДХОДИ ДО ПОБУДОВИ МЕРЕЖІ ПОСТІВ АВТОМАТИЗОВАНОГО РАДІАЦІЙНОГО МОНІТОРИНГУ НА ТЕРИТОРІЇ УКРАЇНИ

С.В. Барбашев

Наводиться опис концептуального підходу до побудови мережі автоматизованих постів спостереження Інтегрованої автоматизованої системи радіаційного моніторингу навколишнього середовища на території України. Для вирішення цього завдання пропонується взяти за основу мережу постів існуючих об'єктових автоматизованих систем і мережу неавтоматизованих постів радіаційного моніторингу атмосферного повітря Українського гідрометеорологічного центру, з подальшим проведенням робіт з оптимізації кількості постів Українського гідрометеорологічного центру та їх автоматизації, а потім інтеграції всіх постів в одну систему. Інтегровану мережу постів спостереження пропонується формувати з урахуванням еколого-гігієнічного принципу.