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UPDATE OF APPROACHES TO THE RADIATION AND ENVIRONMENTAL MONITORING SYSTEM OF ATMOSPHERIC AIR

The article is devoted to highlighting the serious environmental problem of Ukrainian cities in terms of air pollution and organization of the system of environmental monitoring of atmospheric air in accordance with European approaches. As part of the implementation of the provisions of Directive 2008/50/EC into the national legislation of Ukraine, the author proposes to introduce environmental monitoring of atmospheric air quality based on the expansion of fixed measurements by means of indicative measurements of air quality indicators, taking into account regional problems of the territories. The war in Ukraine in 2022-23 has further actualized these issues. Therefore, studies on the consistency of indicative and fixed measurements of air quality indicators are relevant for Ukrainian cities.

The article presents an analysis of our own research on the experience of organizing an effective system of radiation monitoring of atmospheric air in the Mykolaiv region, as well as other materials of our own observations on possible radiation threats and research materials on the organization of radiation monitoring using sensors for indicative measurements of atmospheric air quality indicators. It is shown that the system of radiation monitoring of atmospheric air can be based on indicative measurements of exposure or equivalent dose rate (depending on the calibration), but with mandatory calibration of station sensors by radioiodine. It is also shown that it is necessary to introduce environmental monitoring of atmospheric air using indicative measurements of both chemical and radionuclide pollutants. At the same time, observations of the exposure dose rate are insufficient in the current radiation monitoring of atmospheric air, as they do not allow to quickly identify radionuclides in the air that are pure beta emitters.

Key words: *indicative measurements, atmospheric air, monitoring, radionuclides*

Introduction

Clean and safe atmospheric air is a public value and the last free natural resource that the majority of the population has no alternative to consumption. As part of the implementation of the provisions of Directive 2008/50/EC in the national legislation of Ukraine, it is proposed to introduce environmental monitoring of atmospheric air quality based on the expansion of fixed measurements by means of indicative measurements of air quality indicators, taking into account regional problems of the territories [4]. The war in Ukraine in 2022-23 has made these issues even more urgent.

In particular, the functioning of radiation monitoring of the atmospheric air. We witnessed that during the Russian aggression, military missiles were recorded over the units of the South Ukraine NPP in March and over the units of the Zaporizhzhya NPP in April. The consequences of what the Russians have done in the Chornobyl exclusion zone need to be studied and researched for a long time - today.

For many Ukrainian cities, high concentrations of formaldehyde and dust in the air, especially in cities with heavy traffic, are a serious problem [1-3, 5, 7]. Therefore, studies on the consistency of indicative and fixed measurements of atmospheric air quality indicators remain relevant for Ukrainian cities.

Materials.

The analysis presented in this article was based on:

1) the results of the functioning of the automated radiation monitoring system in the Mykolaiv region;

2) the results of own studies of the formation of effective radiation dose from the accidental intake of ruthenium-106 in Ukraine and European countries at 2018 year;

3) the results of own research on the implementation of a system of indicative measurements of atmospheric air quality indicators in Mykolaiv city at 2021-22 years.

Results and Discussion

1. Both in the EU and in Ukraine, automated external radiation monitoring systems (AERMS) in the 30-km zone around NPPs operate on the principle of indicative measurements of exposure dose rate (gamma background). In the Mykolaiv region, in the post-Chornobyl period, an automated radiation monitoring system (ARMS) was in operation for a long time (1986-2000) [9]), which the authors of this article were involved in organizing. This system allowed to have information on exposure dose rates in 17 settlements of the Mykolaiv region on a continuous basis. The system provided an opportunity to quickly assess the quality of atmospheric air in the settlements of the Mykolaiv region, to monitor the dynamics of exposure dose rate in these settlements in an automated mode. The deployment of this system in Mykolaiv region was dictated by the goal to provide open access to information on exposure dose levels in the region, where radionuclides from the NPPs operating around the region may enter the airspace.

The main goal pursued by the developers when organizing the system of radiation monitoring of atmospheric air is to optimize management decisions regarding the need for iodine prophylaxis for the population. From the experience of the Chornobyl and Fukushima accidents in Japan, it is known that radioactive iodine is one of the first releases into the air, which can enter the human body through the respiratory tract, skin and milk and is almost entirely concentrated in the thyroid gland.

Therefore, to reduce the risk of thyroid damage from radioactive iodine, a mechanism is needed that would allow for the rapid administration of a radioprotector, which in this case is stable iodine. The introduction of even a small amount of stable iodine into the human body prevents its accumulation by the thyroid gland. When radioactive iodine enters the body (through the lungs, skin), its accumulation in the thyroid gland reaches a maximum in 1-2 days, with 50-70% of this dose being formed in 2-6 hours. The absorption of radioactive iodine by the gland stops 5 minutes after taking stable iodine. If this is done within the first two hours, the radiation dose is reduced by 9-10 times. The most effective is the prophylactic use of stable iodine before the appearance of radioactive iodine in the air, drinking water, and food (milk, vegetables).

For the timely identification of radioiodine isotopes in the air, detectors were installed with a threshold of 250 μR/h. This threshold was determined based on the results of a correlation and regression relationship between the level of exposure dose rate and the level of 131I activity in the air: the maximum permissible level of 131I activity in the air of 5.55 Bq/m^3 corresponded to the level of 250 μR/h (Fig. 1). A programme was developed to alert the public to the need to block the thyroid gland with stable iodine when the detector is triggered when the limit level is exceeded. Thus, it can be assumed that indicative measurements of the exposure dose rate allowed for effective iodine prophylaxis of the population in case of exceeding the level of ^{131}I in the air.

This system of indicative measurements for assessing the radiation state of the atmospheric air was metrologically certified at one time. The system was based on SRP-88N radiometers. The system existed for a long time (1987-2001). Even now, residents of Mykolaiv recall it as a tool to reduce public concern about the lack of information on the state of the radiation background in the region where NPPs are located.

The experience of operating the automated radiation monitoring system in the Mykolaiv region, which was based on indicative measurements of exposure dose rate, showed a significant advantage in such measurements:

– the population of the region had current information on the level of exposure dose rate in all district centres of the region,

– the regional authorities had a tool for prompt decision-making in case of changes in the radiation situation. This information allowed to speed up the search for the necessary solution in case of changes in the radiation situation.

2. In 2017, both Ukraine and European countries detected ruthenium-106 in the air, which was transported from Russia [2]. The presence of ruthenium-106 in the air was detected in the Czech Republic, Switzerland, Poland, Italy, Germany, Austria, Slovakia, and others. The highest level of ruthenium-106 in France was recorded in Nice on 2-9 October, and in some areas of Romania, the concentrations of ruthenium-106 in the air were 1.5-2 times higher than in Russia, up to 10 mBq/m3. Ruthenium is an element of the eighth group of the fifth period of the periodic table of chemical elements. It is one of the platinum elements found in living organisms. It accumulates mainly in muscles. Its chemical properties are similar to the platinum metals (iridium, osmium, palladium, rhodium). It is used in small nuclear generators/radioisotope batteries of satellites,

Ruthenium-106 is beta radioactive. Ruthenium-106, like any radioactive isotope, poses a serious danger to humans, as its toxicity is on a par with cesium-137. When it enters the atmosphere and water bodies, it enters the human body by inhalation and ingestion, where it accumulates in the lungs and gastrointestinal tract. This, in turn, contributes to the deterioration of the nervous, cardiovascular and digestive systems, as well as to an increased risk of cancer. At the same time, the effects of its harmful effects do not appear immediately, but after several months. Unlike other radionuclides, the distribution of ruthenium in the body is determined by the physiological state of the organism and the physicochemical properties of ruthenium-106 compounds, which makes it difficult to assess the toxic hazard of ruthenium.

We have analysed the results of studies of the content of ruthenium-106 in the air of certain settlements of the Mykolaiv region, analysed the radioecological situation in the southern region of Ukraine due to the passage of the radioactive cloud in September-October 2017 [2]. The dynamics of the content of ruthenium-106 in the atmospheric air in each of the settlements during a two-week period (from 22.09.2017 to 05-06.10.2017) was analysed. Based on the results of this analysis, histograms were constructed and trends in the content of ruthenium-106 in each settlement were determined $C_{106_{Ru}}^{air} = C_{106_{Ru}}^{air}(t)3$). Total human intake of ruthenium-106 during this period $P_{106_{Ru}}^{air}$ (Bk) in each settlement, we determined: $P_{106_{Ru}}^{air} = \int (C_{106_{Ru}}^{air}(t) \times V^{air})\, dt$, V^{air}– is the reference daily volume of air inhalation by an adult, l/day (22.22 l/day is accepted).

Effective equivalent dose from inhalation of ruthenium-106 to humans $H_{106_{Ru}}^{air}$ (Зв) can be defined: $H_{106_{Ru}}^{air} = P_{106_{Ru}}^{air} * ДЦ_{106_{Ru}}^{inhal}$, $ДЦ_{106_{Ru}}^{inhal}$ – dose price of ruthenium-106 for inhalation (assumed $1{,}2 * 10^{-7}$Zv/Bk).

As a result, it was found that the average individual effective dose to the population from ruthenium-106 inhalation was 0.57±0.12 μSv. It is clear that today the radiation background from ruthenium-106 in this area has not changed significantly. However, due to the threat of secondary rise of the latter in the event of wind storms, it is worth monitoring the content of this radionuclide in the soil and in the air over the areas that were exposed to the ruthenium-106 cloud in September-October 2017.

These results showed that it is impossible to completely distance oneself from radioactive and radioecological hazards. We need to be prepared and able to quickly assess the radiation situation. In particular, in our opinion, it is necessary to introduce environmental monitoring of atmospheric air based on indicative measurements not only for chemical pollutants but also for radioactive ones. At the same time, observation of the exposure dose rate is insufficient in the current radiation monitoring of atmospheric air, as it does not allow for the prompt identification of radionuclides in the air that are pure beta emitters.

3. Under the Association Agreement, Ukraine has committed to approximating its legislation to a number of directives that set standards for limiting the content of certain types of pollutants in the air. As part of the implementation of the provisions of Directive 2008/50/EC into the national legislation of Ukraine, it is proposed to introduce environmental monitoring of atmospheric air quality based on the expansion of fixed measurements by means of indicative measurements of air quality indicators, taking into account regional problems of the territories. In accordance with paragraph 26 of Article 2 of Directive 2008/50/EC of 21 May 2008 on atmospheric air quality and cleaner air for Europe [1], "indicative measurements are measurements that meet data quality requirements that are less stringent than those for fixed measurements".

Today, Ukraine has created a market for stations for indicative measurements of air quality parameters. At the indicative level, stations use electrochemical gas analysers and optical dust meters.

We have systematised the stations for indicative measurements of atmospheric air quality indicators on the Ukrainian market and presented stations for indicative measurements to address certain environmental problems of atmospheric air pollution:

1) stations for indicative measurements of atmospheric air quality indicators only in accordance with the requirements of Directive 2008/50/EC: CO, NO_2, PM10 and PM2.5, temperature, relative humidity;

2) stations for indicative measurements of air quality indicators in accordance with the requirements of Directive 2008/50/EC and the regional problem related to atmospheric emissions from motor vehicles: CO, NO_2, PM10 and PM2.5, temperature, relative humidity, CH_20.

Since 2020, Petro Mohyla National University has been operating the Oxygen Air Fresh Max "EcoRozum" station, the results of which can be seen in the current mode on the online map https://eco-city.org.ua/, and we have presented the analysis of these measurements in our publications [3-7]. Since the autumn of 2022, we have also organised monitoring of the radiation background using a corresponding radiometer station. In the current mode, this data can be viewed on the online map https://www.saveecobot.com/maps.

To assess the effectiveness of the use of indicative measurement stations in the atmospheric air monitoring system, we conducted a comparative analysis of the values of atmospheric air quality indicators in Mykolaiv in the period July 2021 - January 2022. The study materials were the results of measuring the content of formaldehyde in the city's atmospheric air at 7 indicative measurement stations in Mykolaiv, which is currently displayed on the online map https://eco-city.org.ua/ To compare the obtained results of indicative measurements, we analysed the results of determining the formaldehyde (CH_2O) content at 4 stationary reference stations for monitoring the atmospheric air of Mykolaiv in the period January-December 2021. The bar chart (Fig. 2) shows the results (average values) of fixed measurements and the results of indicative measurements of formaldehyde content in the atmospheric air of Mykolaiv.

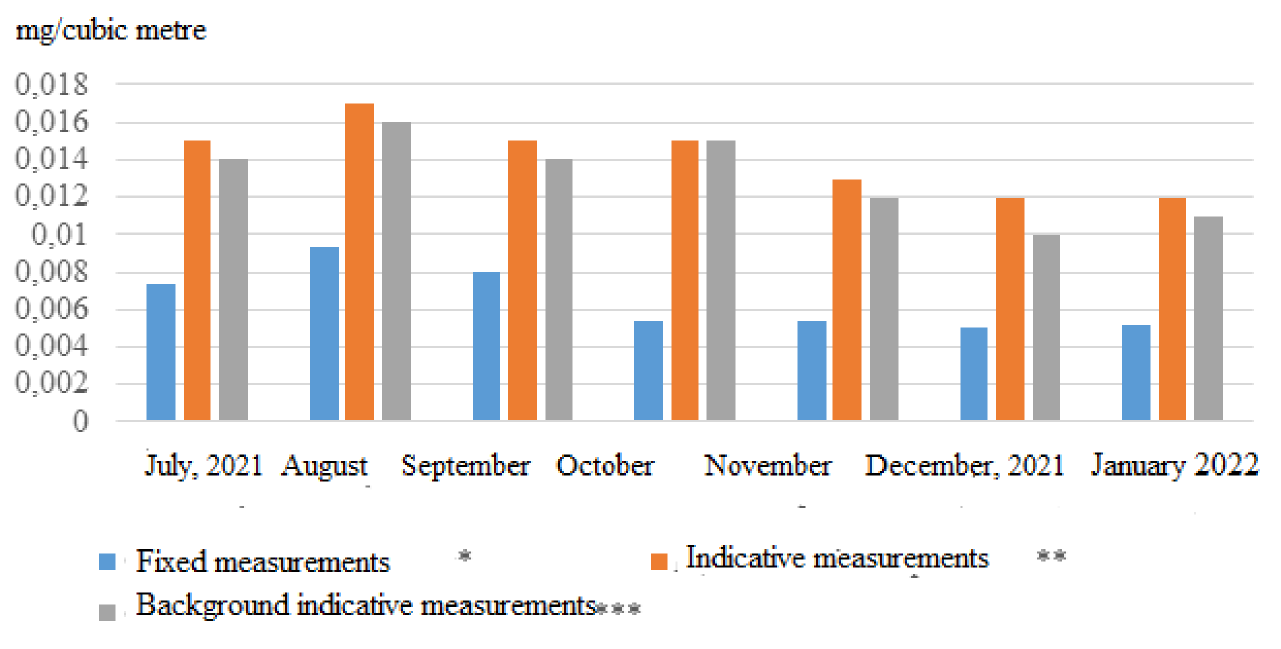

Fig. 2 Average monthly values of formaldehyde content in the atmospheric air of Mykolaiv for July 2021 - January 2022 based on the results of fixed measurements and indicative measurements

As can be seen, the average values of formaldehyde in the atmospheric air of Mykolaiv based on the results of indicative measurements exceed the corresponding values of fixed measurements by 1.5-1.6 times, and vice versa: the maximum values of formaldehyde in the atmospheric air of Mykolaiv based on fixed measurements exceed the maximum values recorded during indicative measurements by 1.6-1.8 times. This fact once again confirms that at the reference level of pollution (e.g., formaldehyde), environmental monitoring of atmospheric air should be organised not only by means of fixed measurements, but also supplemented by indicative measurements using complex compact stations designed to carry out indicative measurements of air quality indicators. The obtained close results of atmospheric air quality indicators at all 7 indicative measurement stations indicate that when choosing the location of such a station in a city with large traffic flows for background measurements of atmospheric air quality indicators, such a station should be located at a great distance from the road.

Conclusions

1. In case of nuclear accidents at NPPs, one of the first atmospheric radionuclide pollutants is radioactive iodine (^{131}I), which can enter the human body through the respiratory tract, skin and milk and is almost entirely concentrated in the thyroid gland. The atmospheric air radiation monitoring system uses sensors to measure the exposure dose rate or effective dose. To improve the existing system of radiation monitoring of atmospheric air, it is desirable to calibrate the sensors for measuring the exposure dose rate by gamma radiation of radioiodine (^{131}I). This will optimize the decision-making process for the introduction of iodine prophylaxis.
2. The current system of radiation monitoring of atmospheric air does not allow timely and prompt identification of beta-emitting radionuclides in the air. Elevated levels of ruthenium-106 in the air due to its man-made transfer from the territory of Russia in the fall of 2018 were not recorded by this system. The results of dosimetry in the Mykolaiv region in the fall of 2018 from man-made ruthenium-106 showed that the average individual effective dose from beta radiation of ruthenium-106 during inhalation was 0.57 ± 0.12 μSv. It is necessary to improve the system of environmental monitoring of atmospheric air through systematic radiometry of atmospheric air samples and atmospheric deposition.
3. The average values of formaldehyde content in the atmospheric air of Mykolaiv based on the results of indicative measurements exceed the corresponding values of fixed measurements by 1.5-1.6 times, and vice versa: the maximum values of formaldehyde content in the atmospheric air of Mykolaiv based on fixed measurements exceed the maximum values recorded during indicative measurements by 1.6-1.8 times. It is necessary to implement environmental monitoring of atmospheric air using indicative measurements for both chemical and radionuclide pollutants. At the same time, observations of exposure dose rate are insufficient in the current radiation monitoring of atmospheric air, as they do not allow prompt identification of radionuclides in the air that are pure beta emitters.

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