Radiation monitoring of the environment: innovative technologies and informatization

To cite this article: S A Maskevich and M G Germenchuk 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **487** 012001

IOP Conf. Series: Materials Science and Engineering **487** (2019) 012001 doi:10.1088/1757-899X/487/1/012001

Radiation monitoring of the environment: innovative technologies and informatization

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Abstract. Now the Republic of Belarus has a modern system of radiation monitoring of the environment, which is based on innovative technologies, including information technologies. The Republic of Belarus has good practices in organizing radiation monitoring of the environment after the accident at the Chernobyl NPP. Between 1986 and 2017, over 630,000 soil samples were measured for radionuclide contamination, including cesium-137. With the use of GIS technologies maps of radioactive contamination of the territory of Belarus with cesium-137, strontium-90, isotopes of plutonium and americium-241 have been created. New methodical approaches to the formation of a radiation monitoring system were developed in case of new threats to radiation safety, for example, the construction of nuclear power plants. Based on the experience of studying the behavior of radionuclides, an integrated biospheric approach to the organization of radiation monitoring of the environment is developed.

1. Introduction

Radioactive contamination is one of the most dangerous types of environmental contamination, both in terms of the negative impact on public health, and in terms of the subsequent inclusion of artificial radionuclides in biogeochemical natural cycles and their subsequent long-term effects on the elements of the biosphere.

Now in the Republic of Belarus there is a complicated radioecological situation, which is caused by global radioactive contamination due to nuclear tests of the environment and the consequences of the Chernobyl disaster. Currently, Belarus is building a Belarusian nuclear power plant, which could become a new potential source of nuclear and radiation hazards.

2. Sample data extraction

The development of a scientific justification for measures to ensure the radiation protection of irradiated individuals required the introduction of a new approach to the problem, and should now be based on the study of the types of exposure situations. According to the International Commission on Radiation Protection (ICRP) Publication 103, three types of situations are considered: planned exposure, existing exposure and emergency exposure [1]. For the Republic of Belarus, such an approach allows solving the tasks of ensuring radiation safety, including using innovative technologies and informatization in the conduct of radiation monitoring of the environment.

The main goals and objectives of studying and assessing the radiation situation using radiation monitoring can be viewed from two perspectives. The most common "pragmatic" approach is to assess the radiation situation for studying pathways of forming radiation doses, by including radionuclides in the trophic chains at different stages of their migration in the environment, i.e. to solve the pragmatic task of radiation monitoring [2].

Another global but less applicable approach is the study of the behavior of radionuclides as participants in the geochemical transfer of elements in the biosphere. This view of the problem allows solving the problems of ensuring radiation safety and protection not only of the population, but also of vulnerable environmental objects, i.e. provides a comprehensive biosphere approach.

The choice of the goal of studying and assessing the radiation situation: the solution of the pragmatic task of ensuring the radiation safety of the population or the implementation of an integrated biosphere approach is fundamental in terms of defining a strategy for organizing and managing a radiation monitoring system.

Currently, the use of an integrated biosphere approach in the Republic of Belarus is becoming a priority, because the state system for preventing and eliminating emergencies is designed to ensure effective protection of the population and territories from natural and man-made emergency situations, which should be adequately reflected in programs for radiation monitoring of the environment.

In addition, this approach is consistent with ICRP Publication 103, where, in addition to "practice and intervention" in the field of radiation protection, it is proposed to establish principles for proving sufficient environmental protection, which generally corresponds to the principles of an integrated biosphere approach [1].

Scientific studies of the consequences of nuclear weapons tests on the environment have created a new level of scientific understanding of the behavior of radioactive elements of artificial origin in the biosphere, in comparison with classical geochemistry, and radioactive contamination as a result of the Chernobyl disaster required their further development.

In the works of Yu A Izrael, F I Pavlotskay, K P Makhanko, C I Bobovnikova, S M Vakulovsky, V A Vetrov, V M Prokhorov, E D Shagalova, A N Marey, R M Alexakhin and others performed before 1986, the main attention was paid, first of all, to the study of radioactive fallouts from the atmosphere and their spatial distribution throughout the territory of the Soviet Union as a whole and the Republic of Belarus in particular, the so-called. global bomb contamination.

In rhe results of their research have been created a scientific basis for solving the "pragmatic" task of estimating radiation doses. On the other hand, based on classical geochemistry, they obtained results that allowed creating a scientific basis for describing the behavior of such radionuclides as cesium-137 and strontium-90 in the environment.

The results of studies on the migration of cesium-137 and strontium-90 global origin due to nuclear weapons tests in soils were successfully applied in the study and minimization of radioecological consequences of the Chernobyl catastrophe.

In the Republic of Belarus, studies of global bomb contamination conducted prior to the Chernobyl accident, including the work of E D Shagalova, made it possible to assess the radiation situation on the territory of Belarus for this period. The following parameters were studied: the exposure dose of gamma radiation, soil contamination with cesium-137 and strontium-90, the characteristics of their vertical migration in the soil.

It should be noted that this approach corresponds to the established world practice of ensuring radiation safety and is reflected in the IAEA Glossary under the definition of "natural analogue". According to [2], "the situation arising in natural (natural) conditions, which is used as a model for processes affecting technogenic systems, and allows you to draw the conclusions necessary to draw conclusions about the safety of an existing or planned nuclear installation. In particular, these can be mineral deposits containing radionuclides whose migration history, covering very long periods of time, can be analyzed, as well as the results used in modeling the potential behavior of these or similar radionuclides in the geosphere for an extended period of time.

After the Chernobyl catastrophe, a wide circle of specialists from the most affected countries, the Republic of Belarus, Ukraine, the Russian Federation, has been and continues to be engaged in studying and assessing the radiation situation, analyzing regional features of radionuclide behavior in the environment and investigating the mechanisms of their migration in the biosphere.

E P Petryaev, I M Bogdevich, V I Ternov, S K Firsakova, E D Shagalova, M G Germenchuk, O M Zhukova, V Yu Ageyets, G A Sokolik, A M Dvornik, Yu. M Zhuchenko et al created the foundation modern system of radiation monitoring of the environment in the Republic of Belarus.

Initially, studies of Chernobyl contamination were based on previously formed scientific views and approaches to solving the "pragmatic" task of assessing radiation doses, mainly from strontium-90 and cesium-137, but the scale of pollution and the severity of radioecological consequences required a new approach to assessing the radiation situation.

Consider the need to improve methodological approaches to assessing the radiation situation after the Chernobyl disaster, taking into account environmental pollution by iodine-131 [3].

It should be noted that during the period of nuclear weapons tests in the atmosphere, the study of the behavior of radioactive iodine-131 in the environment was not a top priority, due to a short half-life, it almost completely disintegrated in the troposphere and stratosphere, and its insignificant quantities that reached the surface, due to the global nature of the process, were almost completely absorbed by the world's oceans. Therefore, the task was not to assess the dose loads from radioactive iodine, including iodine-131, especially taking into account regional geochemical features of individual territories.

At the same time, research carried out in the 70s of the 20th century, L I Lozovsky on the study of regional features of the distribution of stable iodine in the soils of Belarus made it possible to estimate the content of iodine in one of the most important reservoirs of the biosphere-soil, to reveal the spatial variability of its concentrations, to identify the zones of so-called iodine deficiency, and, accordingly, the "iodine" deficiency in food and drinking water.

From the point of view of the theory of risk, these geochemical features of soils increased the vulnerability of the population of Belarus in the event of accidental pollution of the environment by radioactive iodine.

These geochemical and, accordingly, radiological assessments of risks could be used as a basis for the iodine prophylaxis of the population in the first period of the Chernobyl catastrophe during the so-called "iodine strike" and thereby significantly increase its effectiveness.

As is known, WHO recognized cases of thyroid cancer induced by radioactive isotopes of iodine due to the Chernobyl accident, the most serious consequences of the disaster for public health. In Belarus, after the Chernobyl disaster, over 1,500 cases of thyroid cancer in children and adolescents have been reported. Specialists note that the deficit of stable iodine in the environment and, accordingly, in foodstuffs creates the prerequisites for aggravation of the effects of radioactive isotopes of iodine on the thyroid gland, which means the presence of potential radiological risks.

The non- homogenous distribution of radioactive iodine throughout the territory of Belarus and, correspondingly, the incidence of thyroid cancer in children and adolescents, as well as the difficulties in calculating dose loads on the thyroid gland, required the use of a comprehensive biospheric approach, including the regional background of stable iodine. In addition, at the subsequent stages of assessing the radioecological consequences of the disaster, the lack of actual data on the pollution of environmental objects with radioactive iodine isotopes throughout the country required the use of calculation methods for the reconstruction of depositions and dose loads.

As already noted, radionuclides of artificial origin, entering the environment, are included in biogeochemical natural cycles, are involved in the geochemical transfer of elements between reservoirs of the biosphere and at the same time disrupt the structure of their natural elemental composition and balance.

The transfer of radioactive elements of iodine, primarily iodine-131 and iodine-129, which occurred as a result of radioactive contamination of the environment as a result of the Chernobyl disaster, is such a breach of balance.

In April-May 1986, the so-called "fresh" fission products of uranium, including iodine radionuclides, appeared in the atmosphere. These radionuclides, due to advection and atmospheric dispersion processes, moved in the atmosphere and then fell onto the underlying surface, including soil, vegetation, surface water, and entered artificial objects.

Thus, the natural balance of iodine content in individual reservoirs of the biosphere (surface layer of the atmosphere, surface water, biota, etc.) was disturbed, since its quantity increased due to radioactive, including short-lived isotopes.

In the general case, according to V I Vernadsky, each atom, having passed four forms of finding chemical elements (rocks, magma, biotic objects and scattered form), eventually returns to the beginning of the cycle. Moreover, the existence of such cyclic processes obeys the theory of "equilibrium of inhomogeneous media", proposed in the 19th century by V Gibbson, which relates the mechanism of transfer of elements to physical and chemical processes.

From a methodological point of view, it is important to understand that the life cycle of individual atoms can be infinite or finite. And it is the radioactive isotopes of chemical elements that have finite cycles, which is determined by their fundamental property of spontaneous radioactive decay and, accordingly, the half-life of each of the radionuclides.

That is why the amount of radioactive iodine in individual biosphere reservoirs depends on the radiation-chemical transformation of radionuclides in the reservoir, from the time, as well as the rate of their migration in the reservoirs and between them. The contribution of radioactive iodine to the planetary balance depends on the half-life of individual iodine radionuclides.

From this, one can make the conclusion that the time of radioactive isotopes stay in the biosphere and its individual reservoirs is extremely important for planning programs and evaluating the results of radiation monitoring. And the time of their stay in individual reservoirs of the biosphere and biotic objects, however, as well as in the biosphere as a whole, depends on their physico-chemical and radiation properties. The problems associated with the monitoring of short-lived radioactive isotopes of iodine in 1986, and, accordingly, the problems of estimating the doses of thyroid irradiation, are a vivid confirmation of this.

It should be noted that according to V I Vernadsky, a human is a "geochemical force" not only due to the passage of matter through his organism, but also due to the influence of anthropogenic activity in general on the flow and change of natural geochemical processes.

A vivid illustration of such influence on the environment can be the impact of agriculture, energy and transport, mining of minerals, primarily hydrocarbon energy. For the Republic of Belarus, potash mining, the chemical industry and related environmental problems, as well as an accident at the Chernobyl nuclear power plant, whose consequences for the country are assessed as an "ecological" catastrophe, are also very significant.

One of the significant sources of additional involvement of radionuclides in biogeochemical cycles is the widespread use of organic and mineral fertilizers and various chemical meliorants with an increased content of natural radionuclides, for example, the use of potassium fertilizers containing in their composition up to 0.01% radioactive potassium-40 in a mixture of stable isotopes potassium-39 and 41.

As it was mentioned above, the system of radiation monitoring of the environment should provide a solution to two tasks: to estimate the doses of population exposure and to assess the state and radioactive contamination of the biosphere.

The key to a common solution to these two problems is the use of an integrated biosphere approach. Its essence lies in the fact that the mechanism of radioactive contamination of the environment is described from the point of view of natural and anthropogenic processes occurring in the biosphere, which makes it possible to evaluate and predict the pollution of both the biosphere as a whole and its individual objects, including man.

Thus, the concept of radioactive contamination of the environment can be defined as "the involvement of radioactive, including artificially obtained, isotopes in the cyclic transfer of elements in the biosphere through natural geochemical and anthropogenic processes".

According to the IAEA Glossary, radioactive contamination is defined as "radioactive substances present on surfaces or inside solid materials, liquids or gases (including the human body) where their presence is not expected or desirable, or the process leading to their presence in such places" [2].

This definition allows us to study the mechanisms of radionuclide behavior in the environment and their geochemical transfer. As examples of such involvement in the geochemical transfer and creation of new sources of radioactive contamination, one can consider the accumulation of radioactive cesium-137 in the so-called geochemical barriers in the soil or accumulation of radionuclides in bottom sediments of surface water bodies. In either case, the specific activity of radionuclides increases in a separate biosphere reservoir in comparison with adjacent reservoirs, which creates the prerequisites for the emergence of a new potential or active source of pollution. It is on these premises that the description of the mechanisms of radioactive contamination of groundwater and groundwater after the Chernobyl catastrophe is based.

Another example of the emergence of new sources of radioactive contamination in the biosphere after the Chernobyl disaster is the process of the appearance and accumulation of americium-241 in separate biosphere reservoirs, which is the product of the decay of plutonium-241 and was initially absent from the accidental release. However, now its specific activity in environmental objects is increasing, including in those "places" where, according to [2], its presence was not expected or undesirable, thereby creating a new source of additional irradiation.

In the Republic of Belarus, a radiation monitoring system has been established and is functioning, which is part of the national environmental monitoring system of the Republic of Belarus (NSME). The NSME includes a wide network of observation points and accredited laboratories. The main objects of radiation monitoring are atmospheric air (ground layer), soils, including agricultural and forest, surface and groundwater, animal and plant objects.

3. Results

In the first years after the catastrophe at the Chernobyl NPP, a survey of almost the entire territory of the Republic of Belarus was carried out. Radiation monitoring was carried out in all settlements of the Republic of Belarus (more than 20 thousand), on all agricultural and forest lands. Soil samples were taken out and analyzed to assess the contamination of cesium-137 (figure 1) and strontium-90. In the southern part of the country, in the 100-km zone of the Chernobyl NPP, the radioactivity of plutonium isotopes was measured, and subsequently, radioactivity of americium-241. When creating maps of radioactive contamination and predicting its changes, modern information technologies are used, for example, various GIS, geo-oriented databases, etc. [4].

For the period 1986 - 2016 years more than 635,4 thousand soil samples were taken, more than 1 million 519 thousand measurements of the dose rate of gamma radiation at the sampling sites and determinations of the specific activity of individual isotopes were carried out.

Based on the survey of the territory of the country in the first period after the disaster in 1986 - several times, then - annually, subsequently - once in five years, maps of radioactive contamination of the territory of Belarus with cesium-137, strontium-90 and isotopes of plutonium, as well as prognosis maps of cesium-137 contamination.

Based on these data, a list of settlements "Forecast of changes in the radiation situation in populated areas located in radioactive contamination zones" has been prepared, where a forecast of radioactive contamination of soils in individual settlements by cesium-137, strontium-90 and plutonium isotopes is given.

Today one of the most important tasks of ensuring radiation safety in the Republic of Belarus is the introduction of innovative technologies in conducting observations of the radiation situation at the Chernobyl and Belorussian nuclear power plants. For this purpose, an automated system of radiation monitoring has been created and successfully functioning in Belarus, which includes measurements of dose rate of gamma radiation in air, radioactive iodine-131 in the near-surface atmosphere on-line, monitoring of radionuclide content in environmental objects: atmospheric air , surface water, soil, as well as observations of chemical pollution of atmospheric air, surface water and hydrometeorological parameters [5].

A mandatory requirement is the provision of quality control in measuring laboratories in accordance with ISO / IEC 17025-2001.

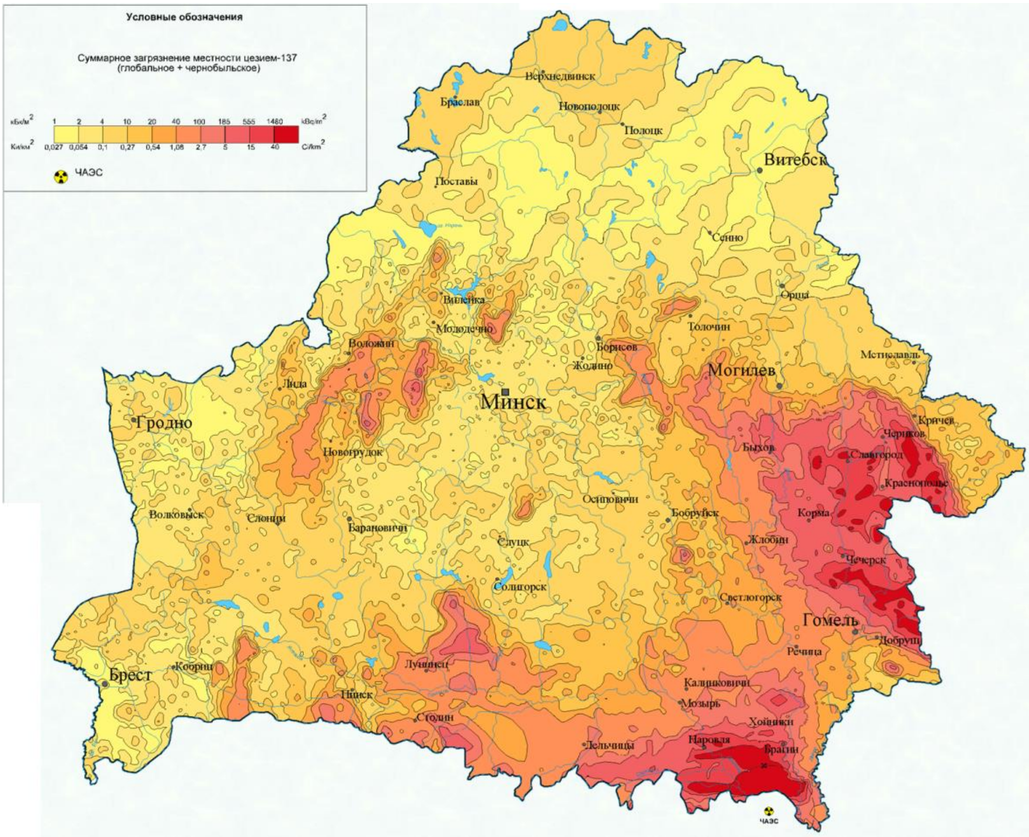

Figure 1. Radioactive contamination of soil by cesium-137 in the Republic of Belarus (May 1986).

This approach makes it possible to assess the radiation situation in on-line mode, as well as to carry out the forecast of radioactive contamination of atmospheric air, surface waters and soils taking into account real currently hydrometeorological conditions. For such calculations, certified computer codes are used.

4. Conclusion

Currently, the Republic of Belarus has a modern system of radiation monitoring of the environment, which is based on innovative technologies, including information technologies. After the accident at the Chernobyl NPP, the Republic of Belarus has the good practices in organizing radiation monitoring of the environment. With the use of GIS technologies maps of radioactive contamination of the territory of Belarus with cesium-137, strontium-90, isotopes of plutonium and americium-241 have been created.

New methodical approaches to the formation of a radiation monitoring system were developed in the event of new threats to radiation safety, for example, the construction of nuclear power plants. Based on the experience of studying the behavior of radionuclides, integrated biospheric approach to the organization of radiation monitoring of the environment is proposed.

Today we can say that the Republic of Belarus has a modern radiation monitoring system that is based on modern innovative technologies and allows ensuring the radiation safety of the population and the environment at a socially acceptable level.

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