RADIOECOLOGICAL MAPPING OF THE TERRITORY OF BELARUS ON THE BASE INFORMATION OF RADIATION MONITORING

M.G. GUERMENTCHUK, O.M. ZHUKOVA, E.D. SHAGALOVA, I.I. MATVEENKO
State Committee for Hydrometeorology, Minsk, Belarus

Abstract

The accident at the Chernobyl nuclear power plant (NPP) is the largest technogenic accident of our time. The global consequences of this accident for the whole mankind will be of a larger significance with the course of time. An important problem which arose during the period following the accident was the evaluation of radioactive contamination of the territory of Belarus and the creation a specific monitoring system. Although the radioactive contamination caused by the Chernobyl accident affected the whole world, Belarus was subjected to the most intensive radioactive contamination. Around 23% (46 450 km$^2$) of the territory of Belarus was subjected to more than 37 kBq/m$^2$ contamination by caesium-137. There are 27 cities and more than 3600 populated districts with a total population of 2.2 millions which were contaminated. The preparation of maps of the distribution of iodine-131 according to the situation on 10 May 1986, and ruthenium-106 and cerium-144 for 30 May 1986 has been carried out. Every three years, based on the results of the complex examination, maps of caesium-137, strontium-90 and plutonium isotopes in the soil are issued. Because of the non-uniformity of the radioactive contamination, 350 thousands of personal plots of land are examined, and radiation passports issued to their owners. This measure was taken for reasons of protection as well as an effort to reduce the dose loads, thus increasing the safety of the residents of the contaminated territories.

1. THE RADIATION MONITORING SYSTEM APPLIED IN BELARUS

In Belarus, radiation monitoring includes measurements in: atmospheric air, soil and surface water. At present, for the entire territory of Belarus, a broad network of the regular observation points are in operation. These are: 55 stations for power measurement of exposition gamma-emanation dose; 25 control points of radioactive pollution from the atmosphere; 6 control points of radio-dopi's content in the air; 181 reference sites for the study of radiation situation dynamics; 18 landscapes and geochemical grounds for the study of radionuclides migration in the soil; 5 control sites in the big rivers of Belarus for the radionuclides content of the surface waters.

All environment radioactive contamination data were stored in an automated database and processed using the geo-information system RECASS. It is used to estimate and forecast the situation and deduce the living conditions of a given area. The most complicated situation was observed during the first period after the Chernobyl nuclear power plant (NPP) accident, due to the great quantity of the deposited short-lived radionuclides and the radionuclides with half-lives of up to 1 year. It was suggested that the methodical approaches in evaluating the contamination of the territory of the Republic with these radionuclides should be done through the preparation of the reconstruction maps. The work on remediation of irradiation doses received by the population during the first few days after the accident needs to be continued for the planning and realization of preventive and medical measures.

2. THE RECONSTRUCTION AND MAPPING OF I-131, CE-144 AND RU-106 CONTAMINATION IN APRIL–MAY 1986

As a result of air movements to the north-western, northern and north-eastern directions during the initial period after the accident, a significant increase of the exposition dose rate was registered practically in the whole territory of Belarus. The levels of radioactive contamination by
short-lived iodine-131 in many regions of the Republic were so high, that the resulting irradiation of millions of people was considered as period of "iodine impact" (Fig. 1).

In April–May 1986, the highest levels of iodine-131 fall-out were registered in the nearest 10–30 km zone in the Bragin, Khoiniki, Narovlya areas of the Gomel region, where the content of iodine-131 in the soil reached 37 000 kBq/m² and in some cases even more. The exposition dose rates of the gamma-radiation were 25–100 mR/h. In the Chechersk, Kormyany, Buda-Koshelev, Dobrush areas, the levels of contamination reached 18 500 kBq/m². In the south-western regions, that is in the areas of Elsk, Lelchitsy, Zhitkovichi, Petricov of the Gomel region, and Pinsk, Luninets, Stolin areas of the Brest region, were significantly contaminated. High levels of contamination were also registered in the north of the Gomel and the Mogilev areas. For example, in a number of places of the Vetka area of the Gomel region, the content of iodine-131 in the soil was more than 20 000 kBq/m². In the Mogilev region, the highest contamination by iodine-131 was registered in the populated areas of the Cherikov and Krasnoaolye areas, where the level reached 5550–11 100 kBq/m².

The high level of contamination by iodine-131 has resulted in large doses of irradiation, first of all, on thyroid gland, that gave rise in the future to a significant increase of its pathology. As of January 1995, the number of thyroid cancer cases in adolescents was 379. For comparison, only 4 cases were registered in January 1986. However, as noted earlier, the contamination registered in the initial period after the accident was not only by iodine-131 but also by such short-lived radionuclides as molybdenum, technetium, lanthanum, barium, radioactive noble gases (xenon, krypton). This has caused high doses of irradiation in the population, which should be taken into account in evaluating values of received doses by the population, living in contaminated territories, those evacuated from the evacuation zone and personnel who participated in the elimination of the consequences of the accident.

The reconstruction of the distribution of iodine-131 according to the situation on 10 May 1986, ruthenium-106 and cerium-144 on 30 May 1986 has been carried out. At the initial stage of the accident, the main contribution to the contamination of the natural environment and the formation of dose loads on the population were the long-lived radionuclides caesium-137 (30 years), strontium-90 (29 years), plutonium-238 (88 years) plutonium-239 (24000 years), plutonium-240 (6537 years), plutonium-241 (14,4 year), caesium-134 (2 years), and the short-lived iodine-131 (8 days), lanthanum-140 (40 hours), neptunium-239 (2 days), barium-140 (13 days), molybdenum-99 (66 hours). Strontium-89 (50 days) including the number of radionuclides with the periods of half-lives up to 1 year (cerium-144: 284 days, ruthenium-106: 368 days).

The work on remediation of irradiation doses, received by the population in the first days after the accident needs to be continued for planning and realization preventive and medical measures. Radioactive releases outside the area of Unit-4 have resulted in significant contamination of distant districts, populated areas and water bodies. Increase of radioactivity as a result of the Chernobyl NPP accident has been registered at a distance of ten thousands of kilometers from the place of the accident.

3. PRESENT ESTIMATION OF CS-137, SR-90 AND PU-238, -239, -240 CONTAMINATION IN THE TERRITORY OF BELARUS AND CS-137 FORECAST

Data on environment Cs-137, Sr-90 and Pu-238, -239, -240 contamination are stored in an automated database and are processed using the geo-information system RECASS. This information is used to estimate and make forecasts of the situation and the expected living conditions (Figs. 2–5). In Belarus 46 450 km² of the territory were contaminated with Cs-137, where the content in the soil was equal to more than 37 kBq/m². Twenty seven cities and more than 3600 populated areas with a total population of 2.2 millions, which is more than 1/5 of the population of Belarus, were affected. As a result of the Chernobyl NPP accident, the Gomel, Mogilev and Brest regions appeared to be the most contaminated.
Распределение йода-131 в почве на территории Республики Беларусь
по состоянию на 10 мая 1986 года (реконструкция)

FIG. 1. Radioactivity contamination of I-131 in the soil of Belarus (10 May, 1988).
FIG. 2. Radioactivity contamination of Cs-137 in the soil of Belarus (1 January, 1995).
Fig. 3. Radioactivity contamination of Sr-90 in the soil of the Gomel and Mogilev Regions of Belarus (1 January, 1995).

There are cases, within the same populated area, where clean (uncontaminated) sites are found in the neighbourhood of highly contaminated places. The populated area Kolyban of the Bragin area of the Gomel region can be taken as an example, where the value of contamination by caesium-137 is in the range of 170 to 2400 kBq/m². The maximum level of caesium-137 in the soil of the populated areas of the nearest zone to the Bragin area was 2600 kBq/m², and in the distant zone, of some 250 km away, for instance, in the populated area Chudyany of the Chericov area in the Mogilev
region, levels of $5\text{1000 kBq/m}^2$ were registered. In the Brest region, in the south-eastern part, in 6 regions the content of caesium-137 in the soil range from 37 to 185 kBq/m$^2$, and the maximum levels reach 400 kBq/m$^2$. In the Minsk, Grodno areas and 4 populated areas of the Vitebsk region, the content of caesium-137 in the soil amounts to 37 kBq/m$^2$. In the other territories of Belarus, the levels of contamination of the soil by caesium-137 are higher in comparison to the values registered before the accident. Only in the north-western regions of the Vitebsk region they are comparable to the global fall-out levels.

**FIG. 4.** Radioactivity contamination of Pu-238, 239, 240 in the soil of Belarus (1 January, 1995).
FIG. 5. Map of radiation projection of the area of the Republic of Belarus for 2016. Concentration of Cs-137 detected in the territory (kBq/m²).
The contamination of the territory of the Republic with Sr-90 has a more local character. The levels of contamination of the soil with Sr-90 of more than 6.5 kBq/m² are found over an area of 21 100 km², i.e. 10% of the total area of the Republic. The maximum levels of Sr-90 in the soil in the populated areas of the nearest zone are found within the 30-km zones of the Chernobyl NPP, in the Khojnik area of the Gomel region, with 1800 kBq/m². The highest contents of Sr-90 in the soil of a distant zone (250 km away), were registered in the Cherikov area of the Mogilev region, were they amounted to 29 kBq/m². In the northern part of the Gomel region, Vetka area, amounts of 137 kBq/m² were registered.

The contamination of the soil by the plutonium isotopes amounting to more than 0.37 kBq/m² covers an area of nearly 4000 km², about 2% of the area of the Republic. These territories are predominantly located in the Gomel region and the Chechersk area of the Mogilev region. Contamination of the soil by plutonium isotopes of 0.37 up to 3.7 kBq/m² reached the highest levels in the Bragin, Narovlya, Khoiniki, Rechitsy and Dobrush, Loev areas of the Gomel region. The contents of plutonium in the soil of 3.7 kBq/m² is characteristic for 30-km zones of the Chernobyl NPP. The highest levels of plutonium isotopes in the soil were registered in the Massany populated area of Khoiniki area with values of more than 111 kBq/m².

4. ATLAS ON CAESIUM CONTAMINATION OF EUROPE AFTER THE CHERNOBYL NUCLEAR POWER PLANT ACCIDENT

The European Commission and Belarus, Ukraine and the Russian Federation took part in the preparation of the Atlas on caesium contamination of Europe after the Chernobyl NPP accident. The main purpose of the Atlas is:

- to present information on the spatial distribution of deposited Cs-137;
- to indicate how the levels of Cs-137 contamination after the Chernobyl NPP accident have increased compared to global deposition;
- to identify relatively "clean" territories the contamination of which is mainly related to global fallout;
- to present information on radioactivity contamination in Europe to scientist in different fields;
- to allow the estimation impact of accident.

A geographic information system (GIS), ARC/INFO, has been used for the preparation of the Atlas on caesium contamination in Europe. The analysis of Cs-137 data was the main problem. Our position related to the analysis of Cs-137 data, using ARC/INFO, should include the re-evaluation of:

- maximum values, quantity,
- initial range of isolines,
- number of points with absolute values of less than min-isolines.

The analysis of the absolute values should be carried allowing for the data on the global contamination around the points, which are dubious. The map of distribution of the contamination should be constructed, using various methods in case of different parameters. On the basis of the expert evaluation, the best method of interpolation of mapping should then be chosen. A GIS system will allow the evaluation of the distribution of the radioactive contamination in the territory of Europe and construct the isolines of the contamination by various methods. The following methods of interpolation are used:

- IDW (methods of inverse radii),
- TIN (methods of Delane triangulation),
- Kriging (methods of Kriging).
5. CONCLUSION

In connection with the presentation noted above it is necessary to emphasize the increased role of radiation control and monitoring of the contaminated territories, the result of which will permit the observation of changes to reveal additional sources of contamination, as well as to predict further development of the radiation-ecological situation. This forecast should be used as the basis for formulating the policy of protective measures.

BIBLIOGRAPHY


GERMENCHUK, M., ZHUKOVA, O., SHAGALOVA, Eh., MATVEENKO, I., Distribution of Radioactive Iodine-131 (reconstruction) in the Territory of the Republic of Belarus, evaluation of Radiological Situation During the First Days after the Accident at ChNPP, Republican Conference "Hygienic and Psychological-Social Aspects of Accident at ChNPP", Gomel (1993).


