Public Control of Radiation Hazardous Facilities: Experience and Results

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Research Article

Keywords: public control, awareness, radionuclides, activity, dose rate, environment, spectrometry

Posted Date: January 4th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1210421/v1

Abstract

Independent public control of nuclear facilities is aimed at raising awareness of the general public about the effectiveness of measures to protect the environment from the radiation effects. The experience and the result of interaction between specialists of the Academy of Sciences and a higher school in organizing and conducting public control by instrumental methods of the territories for the location of radiation-hazardous facilities: uranium mining sites by underground leaching, the area of the Belarusian nuclear power plant in the pre-operational period, the area of the floating nuclear power plant "Akademik Lomonosov" and the publicly accessible territory of control area of the Mayak Production Association. Such a pooling of efforts allows for the formation of new ways of obtaining reliable information for any interested public. The results of special studies characterizing the radioecological situation in the surveyed territories are presented.

1. Introduction

The implementation of a number of national projects is largely due to the successful application of technologies based on radioactive substances and nuclear materials [1]. Their unique capabilities and widespread use have made them an integral part of modern world. However, the understanding of this thesis in society has not yet been established. The environmental, political, social, and economic consequences of the use of nuclear energy are of great concern and controversy among the population. Modern organizational, engineering and technical measures to control the impact make it possible to ensure acceptable risks for humans and environmental components during normal operation of radiation hazardous facilities [2]. Further development and expansion of the use of atomic energy should not threaten the needs of future generations to preserve a favorable environment [3–5].

Among the key issues of sustainable development of the use of atomic energy is the problem of public acceptability of current and planned activities [6]. The population often overestimates the likelihood and severity of the consequences of possible accidents and underestimates the efforts of regulatory bodies and operating organizations to prevent or reduce radiation risks [7]. Members of the public may have subjective views on radiation risks formed under the influence of various factors. Statements from government oversight officials are often insufficient to increase public confidence in radiation risk assessments or measures to control such risks. The public perceives information about the development and improvement of technologies in the nuclear industry ambiguously. A number of studies have shown psychological and psychometric factors that can influence risk perception, as well as differences between expert or technical assessment of risks versus public perception [8–11]. Inaccurate, incomplete information, objective data presented in a complex form, inaccessible to the wide public, increase mistrust in the activities of nuclear facilities and form the basis for panic, stress and protest movement. The negative public perception of the activities of nuclear facilities is reinforced by sources of information with conflicting assessments of radiation risks. In such cases, the population with great confidence refers to the overestimation of the existing hazard.

To raise awareness of the population about the effects of radiation on health and the environment, complete, timely information based on facts and presented in a simple and understandable form is necessary [12, 13]. Mass media, public associations and influential persons play a significant role in shaping public opinion.

Educational institutions are of great importance in raising public awareness of nuclear safety and radiation protection [10]. Representatives of higher educational institutions a priori have the competence of collecting, analyzing and transmitting information in an understandable form. The participation of higher education institutions, as independent experts, in the dialogue between the public and operating organizations contributes to raising awareness and adequate perception of risks by the public concerned. One of the ways of positioning higher educational institutions as an independent party is the organization by the teaching staff and the implementation by the forces of senior students, young scientists of independent public control of the activities of radiation hazardous facilities. The operating organizations are interested in the participation of a competent, independent participant who enjoys the confidence of both the enterprise and the public.

This article presents examples of public control of three radiation hazardous facilities: the Belarusian NPP in the pre-operational period, Dalur JSC - an enterprise for the extraction of uranium by the method of underground leaching and the floating NPP Akademik Lomonosov and the territory of the publicly accessible territory of control area of the Mayak Production Association.

2. Instruments And Methods

The methods used in the public control differ from those used by the operating organizations. Those radiation factors that are of interest to the public may not be considered by operating organizations due to negligible exposure or due to lack of reliable information. The basis for the choice of measuring instruments and procedures for instrumental control are methods of detection – in situ measurements or sampling for a more detailed examination in the laboratory.

The volume and quality of the results is significantly influenced by the thoroughness of the initial data analysis and research planning, within which it is necessary to consider [14]:

- characteristics of existing or planned sources of releases, discharges, and radioactive waste, including the composition of radionuclides, their physical and chemical form;
- mechanisms of the transfer of radionuclides in natural environments, environmental features affecting the transfer, as well as their seasonal changes.

Thus, within the framework of the implemented public control programs, a methodology has been developed for conducting a pre-operational radioecological assessment of the state of the environment in the area of the NPP location, which allows: to correctly assess the impact on the environment; determine the radiation doses to the population and personnel during the operation of the NPP; determine areas and methods for monitoring the radioecological situation in the area of the NPP location; prevent erroneous

interpretation of radiation monitoring data. The algorithm for conducting a pre-operational radioecological assessment of the state of the environment is shown in Fig. 1. An example of public control of a Belarusian NPP site using this algorithm is presented in [15, 16].

The MKS-AT6101DR spectrometer (Fig. 2a) with NaI(Tl) scintillation detector was chosen as the hardware for the presented approach. The MKS-AT6101DR included a data display unit, which allows visualizing the gamma radiation spectrum at the measured point of the terrain (Fig. 2b).

An automotive gamma survey using a spectrometer for radiation scanning MKS-AT6101S (Fig. 3a) or MKS AT6103 (Fig. 3b) allows to expand the survey area.

3. Results And Discussions

3.1 Investigations of the radioecological situation in the area of the Belarusian NPP in the pre-operational period

Instrumental studies in the area of the Belarusian NPP were carried out in August 2019. During the expedition, automotive (Fig. 4) and pedestrian gamma surveys were carried out and the activity concentrations of natural radionuclides were determined, both by a non-destructive method (using the MKS-AT6101DR) and by sampling followed by measurement on a gamma spectrometer with a HPGe detector. The contribution of detected radionuclides to the dose rate on surveyed areas is presented in Fig. 5. The detailed results of the monitoring are presented in [15, 16].

3.2 Investigations of the radioecological situation in the area of the floating nuclear thermal power plant "Akademik Lomonosov"

An example of assessing the radioecological situation was demonstrated during an expedition in October 2021 to the area of the floating thermal power plant (FNPP) “Akademik Lomonosov”, Pevek, Chukotka Autonomous Okrug. A distinctive feature of this expedition was the joint participation of representatives of public organizations, academic and university science. Public organizations can point out the main relevant issues to the objects of atomic energy use, and the scientific community provides a choice of instruments and methods for an objective answer to the needs of society.

On the territory of the floating nuclear power plant, on the territory of Pevek and surrounding area field spectrometric measurements on the surface of soils and coatings were carried out. The use of field spectrometry made it possible to quickly answer the question of what radionuclides caused the external exposure of a person in the surveyed area. The identification of radionuclides was carried out directly at the measurement site, without sampling. At least 20 spectrometric measurements with MKS-AT6101DR were carried out on the territory of the floating nuclear power plant, urban areas, and areas remote from the city.

The performed survey did not reveal the presence of artificial radionuclides in the surveyed areas. The dose rates on surveyed areas are presented in Table 1. The data from Chukothydromet on the dose rate in

Pevek since 2013 were analyzed to confirm the correctness of the obtained results. The radiation background in Pevek, on FNPP and the surrounding grounds is completely formed by natural sources: natural radionuclides: ^{40}K, ^{226}Ra, ^{232}Th (Fig. 6) and cosmic radiation.

Table 1
– Dose rate values for FNPP and Pevek

Dose rate	FNPP site	Pevek	Surrounding grounds	Chukothydromet data for Pevek
Average, μSv/h	0.07	0.12	0.18	0.13
Min, μSv/h	0.05	0.09	0.04	0.08
Max, μSv/h	0.1	0.18	0.26	0.18

The results of the expedition indicate that for two years of operation the floating nuclear power plant did not affect to the radioecological situation in the area of its location. The results of the expedition were presented at a press conference for the mass media and demonstrated for residents of Pevek at a meeting in the city administration.

3.3 Investigation of the radioecological situation in the area of uranium mining by the underground leaching method

Public radioecological control of JSC Dalur on uranium mining by in-situ leaching was carried out in September 2020. Reviewing of 42 wells was carried out in two areas differing in life cycle. The expert analysis of the pipeline system did not reveal areas with traces of technological solution leaks on the pipe surfaces or damage to vegetation in surrounding area. The instrumental control methods used in the current project included radiometric studies of production sites and surrounding areas to determine the range of dose rates characteristic of the "background" areas. MKS-AT6101DR and MKS-AT6101S were used as instruments for measuring. Radiometric studies were carried out by the method of pedestrian and automotive gamma survey. The route of the pedestrian gamma survey was chosen to obtain the dose rate values both in the production area and in the surrounding (background) area. Moving along the selected route, the operator performed a gamma scan at the mining site, a field adjacent to the site and the nearest forest area. Field and woodland are taken as background areas. The location of the plots is shown in Fig. 7.

As a result of pedestrian gamma survey, the following data was obtained:

- 61 values of the dose rate in the background section "Forest";
- 125 values of the dose rate in the background section "Field";
- 625 dose rate values at the production site.

Samples of the obtained values of the dose rate in the indicated areas are characterized by specific values of the central tendencies and range (Table 2).

Table 2
Results of dose rate measurement by the method of pedestrian gamma survey

Dose rate	Background		Mining
	Field	Forest	Production area
Average, μSv/h	0.051	0.058	0.115
Median, μSv/h	0.052	0.057	0.075
Standard deviation, μSv/h	0.0022	0.0046	0.0057

Despite the close values of the results of measuring the dose rate in the background areas "Forest" and "Field", their central tendencies are statistically significantly different, which confirms the result of comparing the samples by the t-test ($p << 0.05$). The values of the dose rate of gamma radiation in the area where uranium mining sites are located are specific for various landscape conditions. The abnormal values of the dose rate for the forest landscape exceed 0.053 μSv/h. Abnormal values of the dose rate for the agricultural landscape exceed 0.078 μSv/h.

To determine the reason for the significant difference between clean areas with different landscape conditions, a representative spectrometric study is required. For the comparing the dose rate values at the uranium mining sites, it is necessary to select the measurement results on clean landscapes with similar environmental conditions as background.

3.4 Radiological monitoring of the publicly accessible territory of control area of the Mayak Production Association

As a result of the Kyshtym accident in 1957, more than 20,000 km^2 of the territory, later called the East Ural radioactive trace (EURT), was contaminated. The accident resulted to the release into the atmosphere of a large amount of radionuclides, including ^{137}Cs with the longest half-life (30.17 y). Part of the territory of EURT is included in the control zone of the Mayak Production Association. In November 2021 radiological monitoring of the publicly accessible territory of control area was conducted. The aim of the study was to determine the dose rate and the activity concentration of natural radionuclides (^{40}K, ^{226}Ra, ^{232}Th) and ^{137}Cs at different sites. MKS-AT6101DR was used as instrument for measurements.

The results of measurements demonstrated the presence of ^{137}Cs in the soil in 10 surveyed areas out of 16 (Fig. 8). The highest activity concentration of ^{137}Cs (about 100 Bq/kg) is observed on a forest site that was not subjected to mechanical stress, therefore, ^{137}Cs remained in the upper layers of the soil after releases due to accident.

The dose rate values are in the range from 0.046 to 0.121 μSv/h. The activity concentrations of natural radionuclides are: ^{40}K – from 27.6 to 593.0 Bq/kg, ^{226}Ra – from 0 to 23.7 Bq/kg, ^{232}Th – from 0 to 39.6 Bq/kg. Fig. 9 demonstrates the contribution of individual radionuclides to the dose rate.

Conclusion

The implemented pilot projects of public control using instrumental methods by students and young scientists are an effective way to raise public awareness of the state of the environment in the areas where nuclear facilities are located.

Public control by instrumental methods at the stage of construction of the Belarusian NPP made it possible to determine the "background" content of gamma-emitting radionuclides in individual components of the environment. The given results can serve as a basis for a radiation monitoring program, substantiation of requirements for instruments and monitoring methods, as well as for assessing risks during normal operation of the Belarusian NPP.

The results of the radioecological expedition to the area of the FNPP "Akademik Lomonosov" made it possible to present an independent assessment of the formation of radiation exposure in the city of Pevek and the adjacent territory. Objective data made it possible to answer the most important question for the residents of Chukotka about the impact of the two-year period of operation of the floating nuclear power plant on the ecology situation of the territory. The results are especially important for the indigenous population, whose diet and nutritional quality are largely determined by the conditions for the life of the local flora and fauna. Over the two years of operation, the FNPP has made it possible to significantly reduce environmental pollution from discharges, emissions, waste products of the operating coal fired Chaunskaya TPP, and at the same time did not affect the change in the radioecological situation in the area of its location.

The implementation of public control by instrumental methods of uranium mining sites using the underground leaching method showed that the values of the gamma radiation dose rate in the area of uranium mining sites are specific for various landscape conditions. Abnormal values of the dose rate, indicating signs of technogenic pollution of soil or ground, exceed 0.078 μSv/h. Dose rate values in the surveyed mining areas that do not exceed 0.078 μSv/h can reasonably refer to unchanged background values.

The Radioecological monitoring of the publicly accessible territory of control area of the Mayak Production Association has demonstrated the presence of ^{137}Cs in 10 surveyed areas of 16, the activity concentration ranges from 3.2 to 107.0 Bq/kg. The obtained experimental data are in good agreement with the previously published values in the EURT atlas, where the activity concentrations of ^{137}Cs are up to 0.2-0.5 Ci/km^2 (~ 43.5-108.0 Bq/kg) [17]. The values of ^{137}Cs activity concentration are lower than the minimum significant activity concentration [18], therefore, they create a dose rate less than 10 μSv/year. The maximum values of activity concentration of natural radionuclides are: 593.0 Bq/kg for ^{40}K, 23.7 Bq/kg for ^{226}Ra, 27.3 Bq/kg for ^{232}Th.

The proposed format of interaction between higher education. the Academy of Sciences and nuclear facilities significantly expands the categories of participants in public control over the activities of

radiation hazardous facilities. Such a pooling of efforts allows for the formation of new ways of obtaining objective information for any interested parties, including the public.

By attracting representatives of higher education and academic institutions to participate in instrumental methods of public control, operating organizations get the opportunity to use unique means and methods for measuring physical and chemical factors of environmental impact that are not included in the industrial monitoring program but are of public interest. The participation of senior students in instrumental control methods contributes to their acquisition of skills (competencies) in planning, organizing, performing goal-oriented tasks, acquaints with the specifics of production processes of the surveyed enterprises, and expands the possibilities for a reasonable choice of place of work.

References

1. Gorin, N.V., Ekidin, A.A. & Golovikhina, O.S. Nuclear power engineering as an important element of Russia's national priority projects. Current issues in nuclear energy, № 1, 5–15 (2021). (In Russian)
2. Ekidin, A.A., Vasilyev, A.V. & Vasyanovich, M.E. Modern technologies of environmental impact management as a tool for compliance with the ALARA principle. Biosfernaja sovmestimost': chelovek, region, tehnologii, № 2 (18), 67–74 (2017). (In Russian)
3. Guidance for the application of an assessment methodology for innovative nuclear energy systems, INPRO. Manual. Vol. 1- 9, IAEA-TECDOC-1575/Rev.1, IAEA, Vienna (2008).
4. INPRO Methodology for sustainability assessment of nuclear energy systems: Environmental impact of stressors, IAEA Nuclear Energy Series No. NG-T-3.15, IAEA, Vienna (2016).
5. Recommendations of the International Commission on Radiological Protection, ICRP Publication 60, 1990.
6. UNITED NATIONS. Our Common Future (Report to the General Assembly). World Commission on Environment and Development. UN, New York (1987).
7. INTERNATIONAL NUCLEAR SAFETY GROUP, Stakeholder Involvement in Nuclear Issues, INSAG Series, 2006
8. Communication and stakeholder involvement in environmental remediation projects. IAEA Nuclear Energy Series No. NW-T-3.5. IAEA, Vienna (2014).
9. Patrakov, E.V., Stepanova, A.Yu. & Ekidin, A.A. The needs of the population for improving the quality life in terms of radiation risks. Azimut nauchnyh issledovanij: jekonomika i upravlenie, Vol. 7, № 4 (25), 230-232 (2018). (In Russian)
10. Stepanova, A.Yu. & Ekidin, A.A. Dentification of information needs and competencies of young students to ensure radiation safety. Azimut nauchnyh issledovanij: pedagogika i psihologija. Vol. 7, № 3 (24), 233-236 (2018). (In Russian)
11. Gorin, N.V., Ekidin, A.A., Nechaeva, S.V. & Golovikhina, O.S. Information Interests of Society and Nuclear Facilities: Lessons from Conflicts. Gosudarstvennoe upravlenie. Jelektronnyj vestnik, 83, 47–61 (2020). (In Russian)

12. Gorin, N.V. et al. On the formation of radiation literacy of the population. Zdravoohranenie, obrazovanie i bezopasnost', 4 (16), 137–145 (2018). (In Russian)
13. Gorin, N.V., Ekidin, A.A., Nechaeva, S.V. & Golovikhina, O.S. Harmonization of information interaction between the public and enterprises of the nuclear industry in *The dynamics of relations between the state, society and big business in modern Russia: the practice of dialogue and conflict resolution on the example of the regions of presence of nuclear enterprises* (ed. A.Ju. Shutov, A.L. Demchuk, I.I. Kuznecov) 58-67 (Moscow, 2020). (In Russian)
14. INTERNATIONAL ATOMIC ENERGY AGENCY, Environmental and Source Monitoring for Purposes of Radiation Protection, General Safety Guides, 2005
15. Ekidin, A.A et al. Field Methods for Studying the Radiation Situation in the Area of the Belarusian NPP in the Pre-Operational Period. ANRI 2(101), 31–44, 2020. (In Russian)
16. Nazarov, E.I. et al. Radiological assessment of the Belarusian nuclear power plant site in the pre-operational period, RAD Conf. Proc. 4 142–148; 10.21175/RadProc.2020.30 (2020)
17. Atlas of the East Ural and Karachaevsky radioactive traces, including the forecast until 2047, Ed. Yu.A. Israel, 2013, 140 p. (In Russian)
18. Standards of radiation safety NRB-99/2009. Sanitary rules and regulations SanPiN 2.6.1.2523-09 (In Russian)

Figures

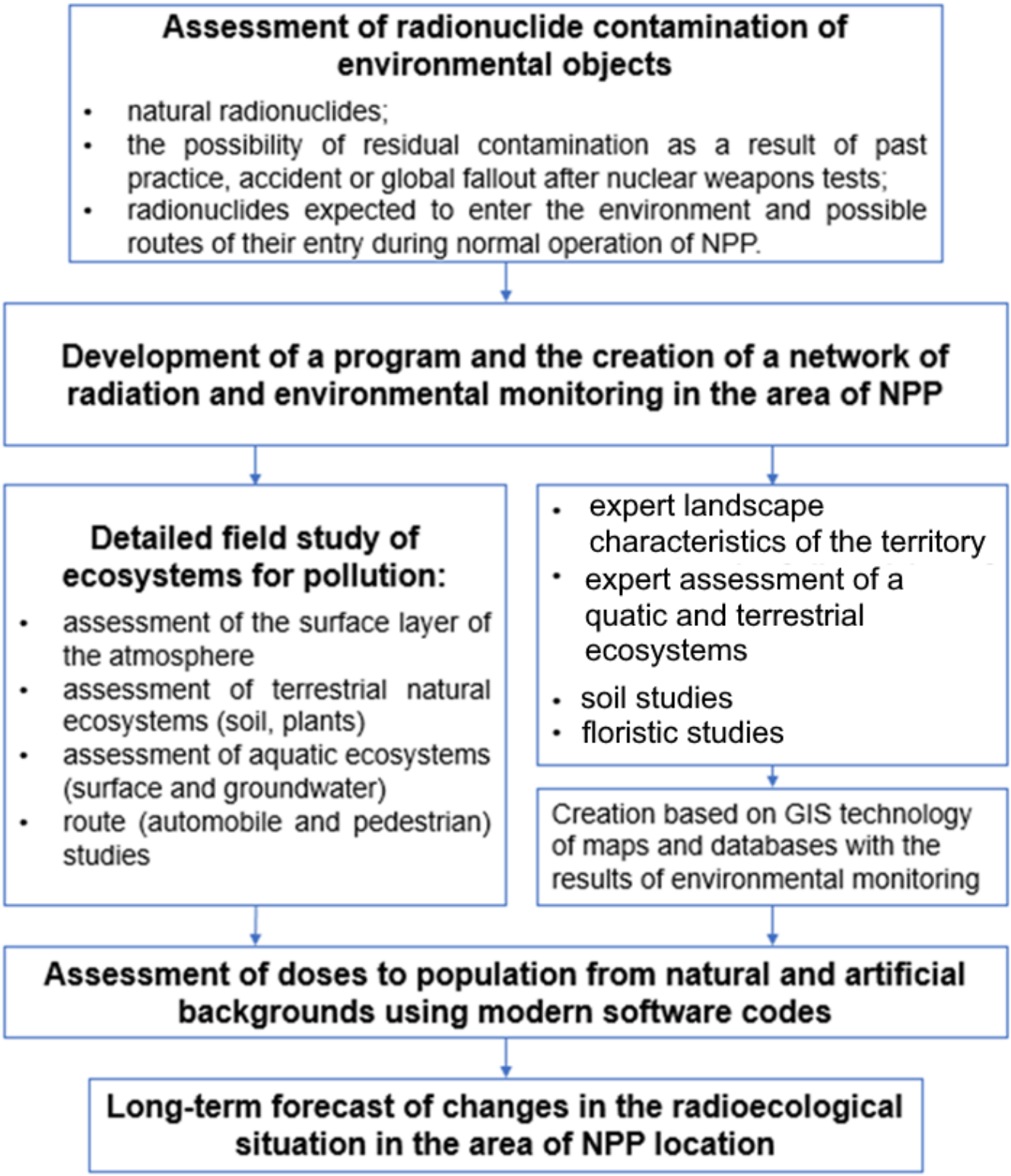

Figure 1

Algorithm for pre-operational radioecological environmental assessment

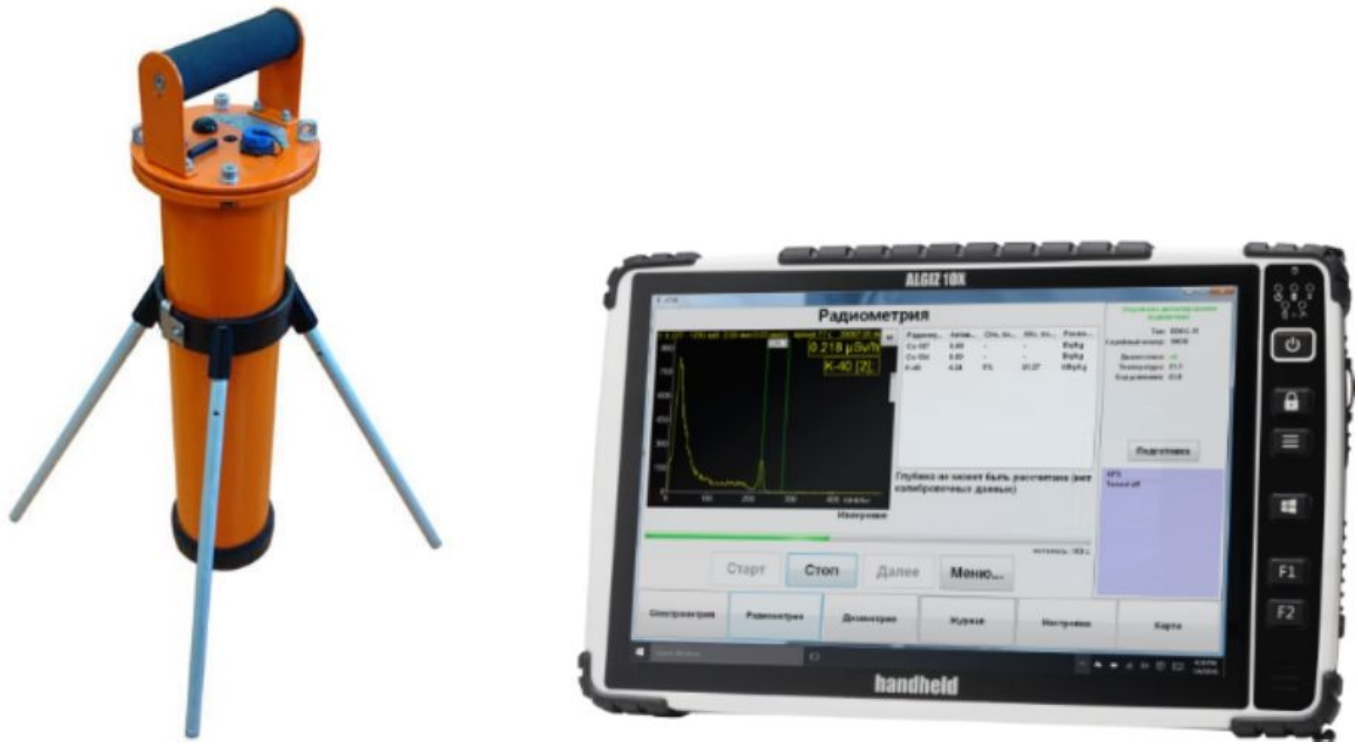

Figure 2

a - MKS-AT6101DR, b – Data display unit

a *b*

Figure 3

a – MKS-AT6101S, b – MKS-AT6103

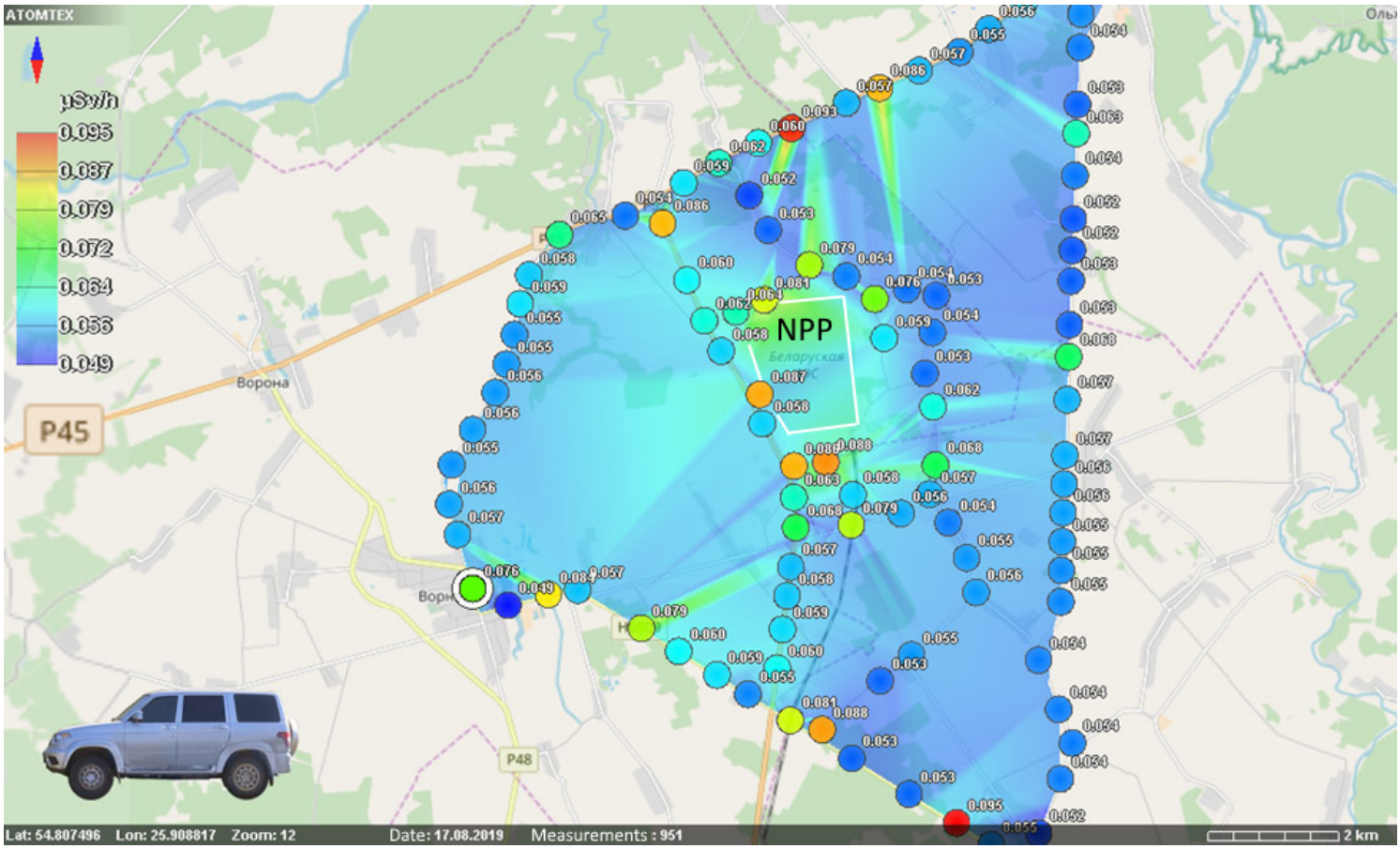

Figure 4

Automotive gamma survey results

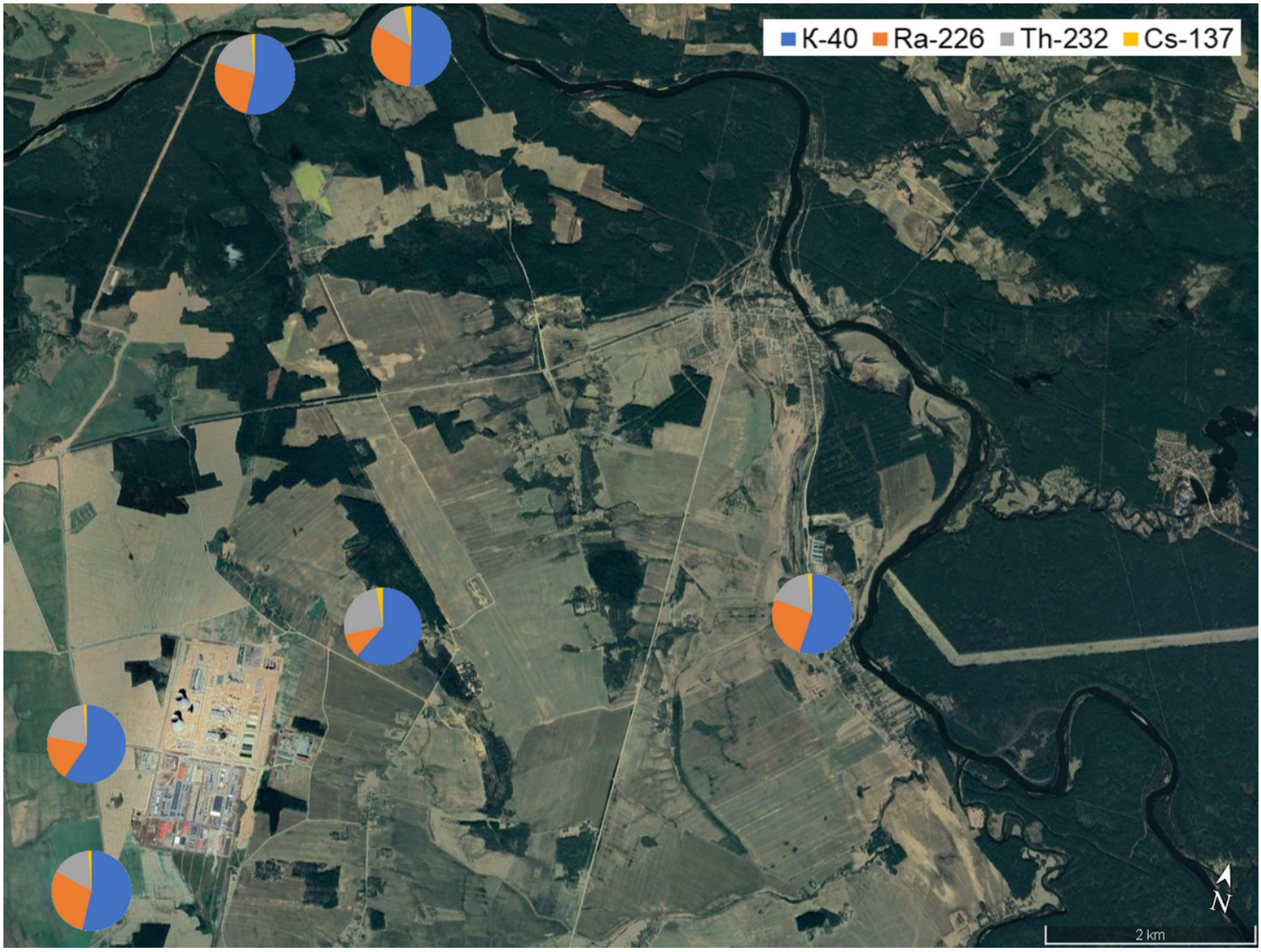

Figure 5

Contribution of radionuclides to the dose rate in the area of Belarusian NPP

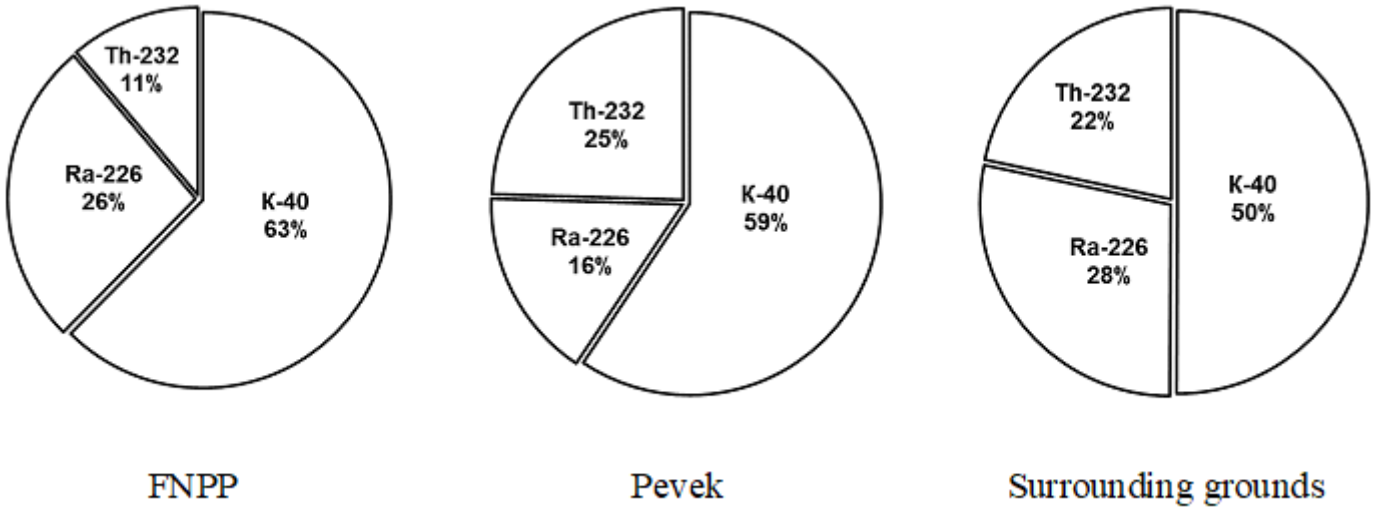

Figure 6

Contribution of natural radionuclides to the dose rate

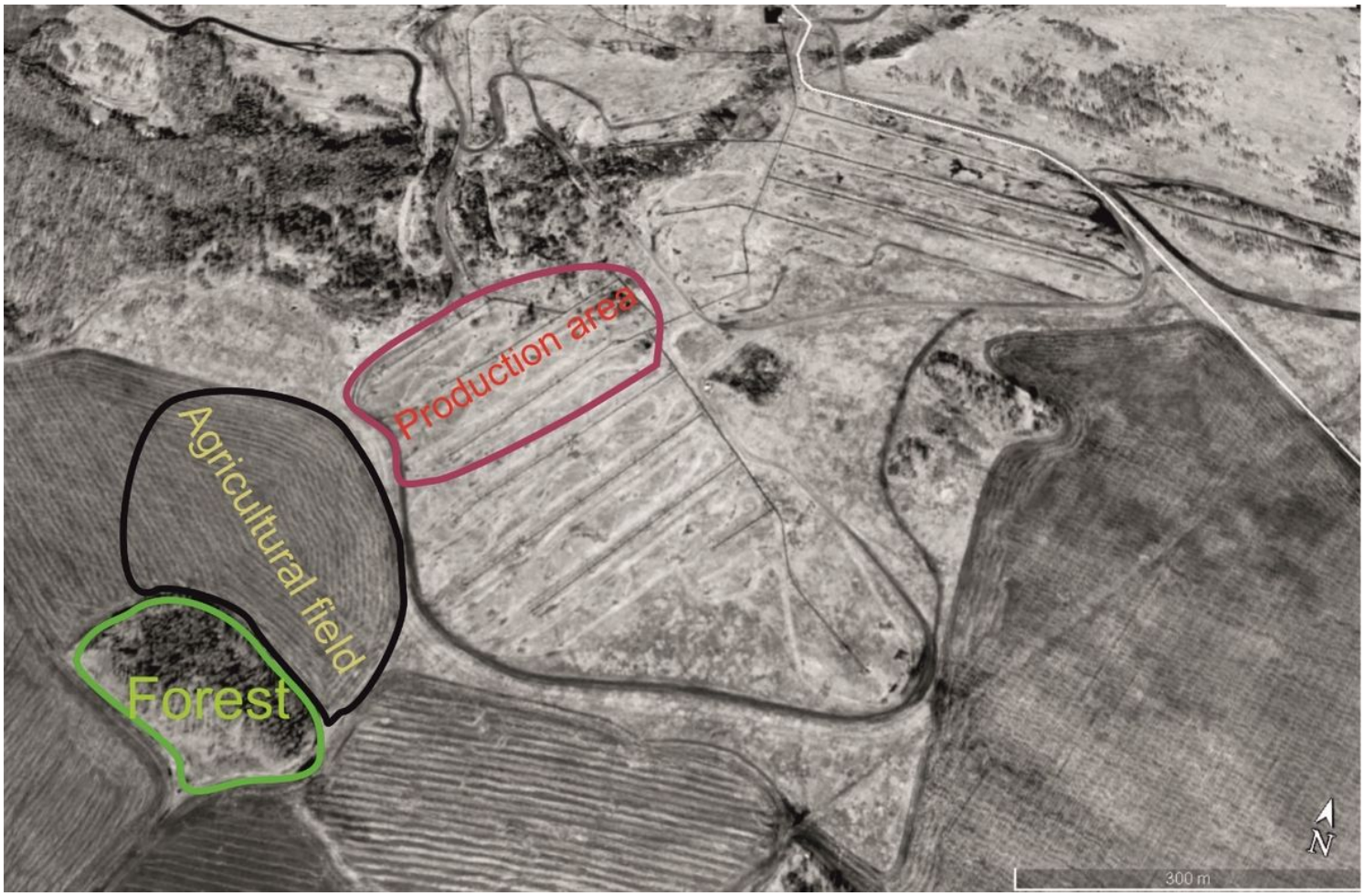

Figure 7

Location of the surveyed areas: mining, field, forest

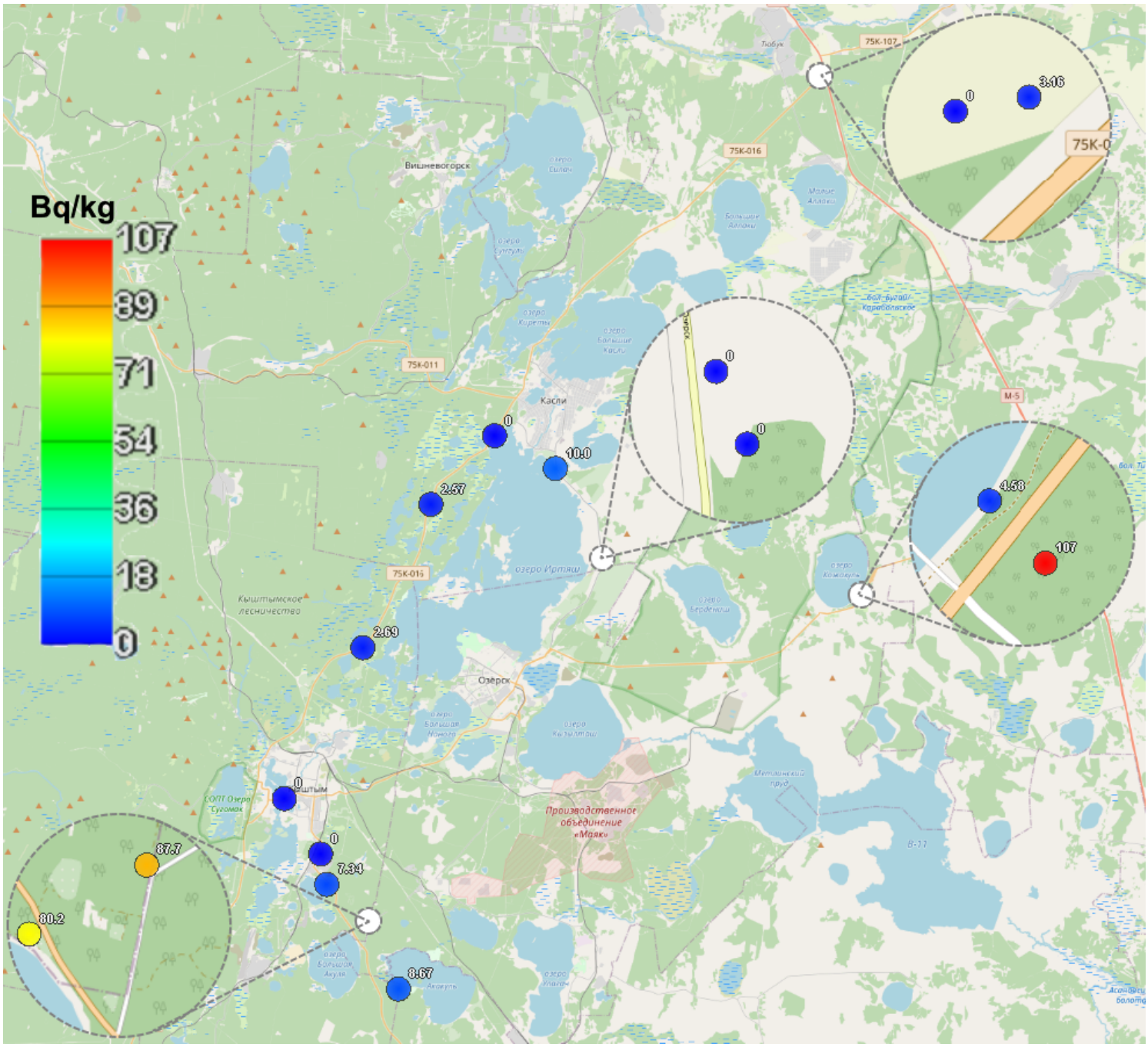

Figure 8

Activity concentration of ^{137}Cs in the upper layers of the soil on the surveyed areas

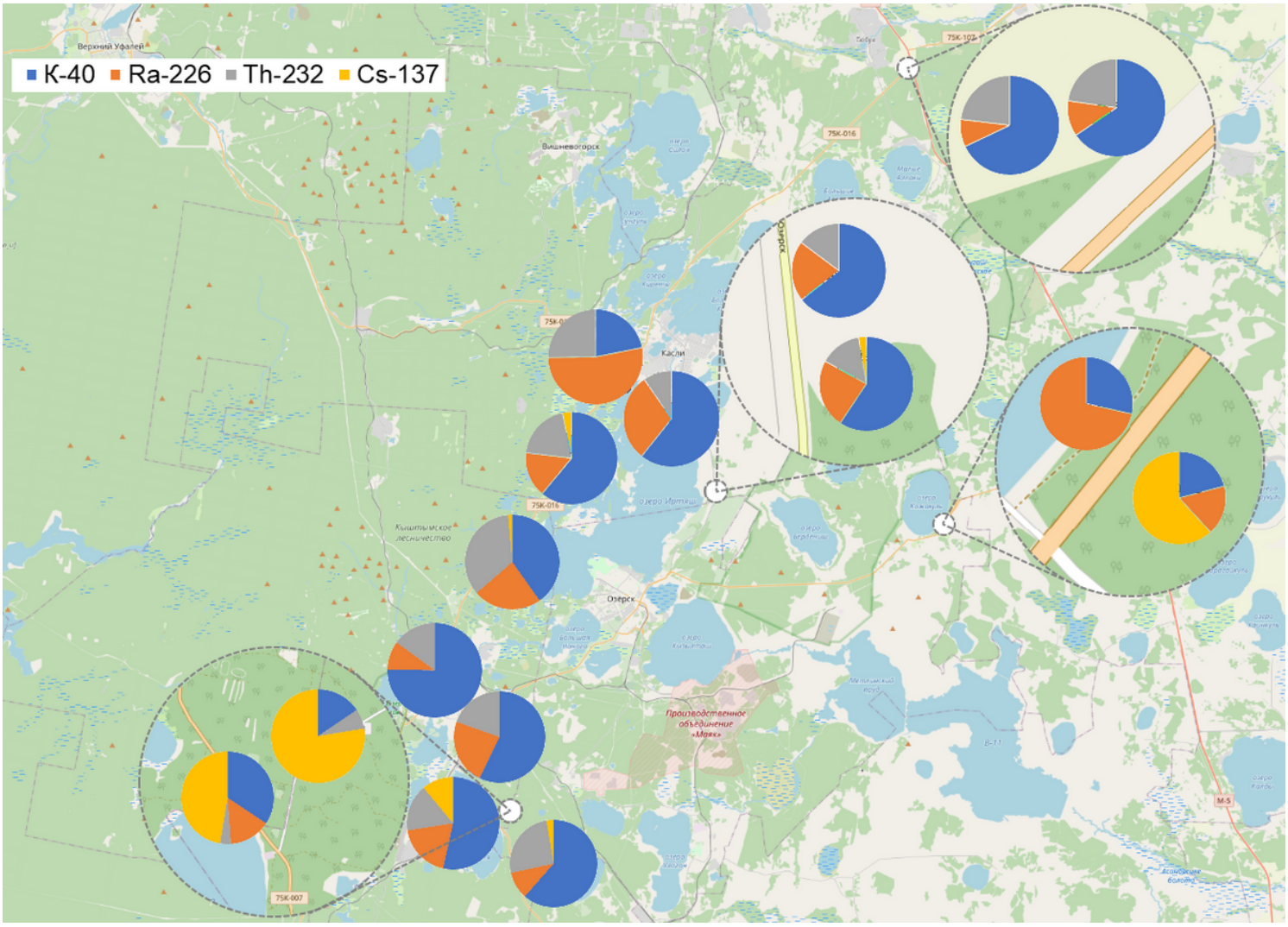

Figure 9

Contribution of radionuclides to the dose rate on surveyed areas