Development of the automated data management system for radiation monitoring of forests

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Abstract. Since the system of radiation control in forestry was formed even before the mass introduction of information technologies, data processing in radiation monitoring retains the approaches conditioned by the traditional, paper-based document management. The aim of this project is to develop a unified automated system for collection, control and analysis of data from radiation monitoring of forests in the Russian Federation. The system is based on the use of the unified software ‘SpectraLineBG’ for spectrometric devices, on the creation of a cloud data storage server, and the development of a software environment for storing and processing of the obtained material. The system allows to check the accuracy of all the obtained results of measurements and to make their subsequent correction. The described method of data collection is universal for spectrometric studies and can be used not only in forestry, but also in any organization involved in radiation control of the environment. Using the accumulated material, the system allows to analyze the distribution and the dynamics of radionuclides in space and time, to calculate the coefficients of the transition of radionuclides from soil to vegetation for one or more species in different areas.

1. Introduction
Large areas of the forests of the Russian Federation are contaminated with radionuclides. This pollution is caused by nuclear weapons tests, accidents and incidents at nuclear power plants and other nuclear fuel cycle facilities. The largest of them are the accident at weapons-grade plutonium production plant Mayak in 1957 and the accident at the Chernobyl nuclear power plant in 1986 [1].

The implementation of economic activities in areas of radioactive contamination involves conducting radiation surveys (RS) and radiation monitoring of forests (RMF) [2].

The system of radiation control in forestry was formed before the mass introduction of information technologies, so the processing of RS and RMF data retains the features of traditional, paper-based document management. This approach creates risks of loss of archival data, complicates their processing and involvement in scientific analysis.

The study of the regularities of the dynamics of the radiation situation requires ensuring the comparability of data obtained five, ten, twenty years ago. To do this, it is necessary to know how sampling was carried out in each case, the preparation of counting samples, what instruments and methods of spectrometry were used. It is almost impossible to get such information after years. To date, the main spectrometric equipment used in radiation control laboratories is the scintillation spectrometric complexes ‘Multirad’/’Progress’ (Russia) and ‘Atomtech’ (Belarus), whose software does not make it possible to save complete information about the conducted research. Therefore, an urgent problem is
the creation of an information system that could store all the necessary material, from field data to laboratory results, including all the necessary parameters of spectrometric measurements [3].

The aim of this work is to develop an information system that will allow combining long-term results of radiation monitoring of forests and other radiation surveys of forests of the Russian Federation in a single software environment [4].

2. Methods
In 2014, two gamma-spectrometric complexes based on ultrapure germanium semiconductor detectors (Gamma-1P, JSC SPC ASPECT, Russia) were put into operation in the radiation control laboratory of our Institute (ARRISMF). The resolution of the semiconductor sensor is much higher than the resolution of the scintillation sensor, that’s why the rate of measurements of radionuclides in soil and forest vegetation samples at high densities (from 10 Ki/km² and higher) over time approached one hundred samples per day. Therefore, the question arose: ‘How to record, check and analyze the obtained results?’

For these purposes, the laboratory staff has been working for several years on the development of a software method for collecting and analyzing the measurement results of spectrometric devices, based on the studied materials on the management of information systems for radiation monitoring [5-9]. This software solution is based on the use of a unified software for spectrometric devices LSRM ‘SpectraLine’; creation of a cloud server for storing all the necessary data and development of our own software for collecting and analyzing the obtained measurement results. It should be noted that a spectrometric method for measuring gamma radiation is used today for the measurement of Cs-137, the main dose-forming radionuclide in the territory of the Russian Federation since the accident at the Chernobyl nuclear power plant. The described method of data collection and analysis is also used to study alpha- and beta-emitting radionuclides based on the same software (figure 1).

![Spectra of Ionizing radiation: gamma (a), beta (b) and alpha radiation (c).](image)

**Figure 1.** Spectra of Ionizing radiation: gamma (a), beta (b) and alpha radiation (c).

Spectrometric software SpectraLine, unlike the Progress, Atomtex or Canberra, is a universal program in terms of performing spectrometric measurements. It allows not only automatic, but also manual processing of the received spectra; and also to calibrate and adjust the program for almost all existing spectrometers of radiation ray today. An important feature of this software environment is the ability to use third-party configuration storage directories for a specific device, including the storage of calibrations, sample measurement spectra, and reports with measurement results. As part of the work of our institute, a secure cloud server was created for storage and remote access to all the necessary electronic materials. Using a cloud server allows the system administrator to work in any location convenient for him, if he has Internet access.

Thanks to the ability to save the spectrometer configurations on a cloud server, we can include any spectrometer of any laboratory with Internet access in our data storage system. The spectrometer configuration stores all current information about the spectrometer: all calibrations, including geometry calibrations and energy calibrations, as well as radionuclide libraries, etc. The cloud server, unlike direct access servers, makes it possible to make an automatic copy of the data, and work in the absence of an Internet connection. With the ability to access the software configuration of the device, the system
administrator can connect it to their SpectraLine platform and check the correctness of the existing settings of the device and, if necessary, make all edits and adjustments to obtain more accurate radionuclide measurement results. This is mainly about ‘calibrating spectrometer by energy’. It is also possible to remotely open the spectrum of each measurement and process it manually. The connection is made via the synchronized data of the cloud server, so the spectrometer operator continues to work in its normal mode.

Initially, the SpectraLine family software did not have automated measurement algorithms. By default, the energy calibration of the spectrometer and the processing of spectra for calculating the concentration of radionuclides in samples are performed manually by the operator. However, our goal was to create a software environment in which it would be no more difficult for users to use the software interface than for Progress or Atomtex. A simplified software interface for measurements is an important condition for the implementation of this software product in a radiation-monitoring laboratory. Therefore, at our request, the software developer created an add-on, with the help of which the processes of calibration and processing of spectra are performed automatically. After each measurement, the program automatically saves a spectrum of measurements and a text report with the results of measuring the content of radionuclides in the sample. Both files have a unique name consisting of the measurement time and the digital index of the device. This approach excludes the possibility of repeating spectra with the same file name in the database. They contain all the necessary information about the sample under study and the measurement properties: sample code, sample description, sample collection date, sample collection location, geometry used for measurement, mass of the sample to be counted, measurement time, detector code / device name, and radionuclide content in the counting samples. When re-processing the spectrum, the original version of the files will be overwritten. Despite the presence of a software add-on for automatic calibration and calculation of radionuclides in a sample, the operator also has the ability to perform all measurement processes manually.

From an information security point of view, it is important to note that access to data stored on the server, including measurement results and instrument configurations, is limited to three-stage administrative access rights. Unauthorized access to system data is excluded.

After saving the measurement results on the server, they can be entered into the database. To work with the measurement database, a software environment was developed for collecting and analyzing data based on MYSQL technologies and web services. The program specifies the data storage directory, after which the program searches for text files with the measurement results (files of the ‘.fp3’ type) in the specified directory and subdirectories, scans their contents and writes the necessary data line by line to the database. Every time it is scanned and filled, the program checks the spectrum name coincidence and excludes the repeated filling of the data. The database administrator can load any required data array from the program in the form of an Excel table, convenient for further statistical processing (figure 2).

A separate database with its own individual structure has been created for each type of spectrometric measurement. It is impossible to combine different types of measurements for one selected sample into one structural table, since each type of spectrometric study has its own set of characteristic information about the preparation of the sample and the spectrum of its measurement.

In addition to the databases of spectrometric measurements, a database of information about sampling sites was created [10]. Its main task is to save a complete description of the sampling sites identified by the ‘Sampling Site Code’. It contains all the necessary geographical, taxation and radiation information of the sampling points: coordinates, region, forest area, quarter, description of forest tiers, soil type, equivalent dose rate, as well as the values of the average densities of radiation pollution for the main dose-forming radionuclides. This data array is filled in manually and automatically saved to the server to minimize the possibility of losing the original data. At its core, the sampling site database is the basis for the GIS information system for forest radiation pollution.
In addition, a necessary condition for the operation of the information system, within the framework of conducting radiation monitoring, is the creation of a database of the primary list of samples taken in the forest (the so-called ‘electronic sampling log’). Each sample is assigned its own digital code with a description. All data is entered into a digital database at the time of selection, or on the same day after returning from the forest. The digital sample code is printed on the sample passport form and allows you to identify the sample even if the description information is lost.

3. Discussion

Over the past five years of using the information system of data collection and analysis described by us, it has proved to be as effective as possible. This allowed us to save all the accumulated material in recent years. Also, thanks to the mutual assistance of colleagues from organizations involved in radiation monitoring of forests, every year the databases of measurements and forest sites are updated with restored archival materials in the format of the current database. An important achievement of the system is that the materials of any of the samples taken over the past five years have not been lost. All the necessary studies have been carried out, and the results have been saved.

Now, our information system includes five officially registered databases:

- Comprehensive description of sampling sites for radioecology research in the forests of the Russian Federation;
- The content of gamma-emitting radionuclides in the components of forest ecosystems;
- Content of beta-emitting radionuclides in forest ecosystem components;
- Content of alpha-emitting radionuclides in forest ecosystem components;
- Total alpha- and beta- radiation activity in forest ecosystem components.

Now, the database of measurements of gamma-emitting radionuclides (Cs-137, K-40, Ra-226, Th-232) includes more than 20 thousand records, which include not only the results of radiation monitoring, but also data from the research activities of our department. The database of beta-emitting radionuclides includes more than 500 measurements of Sr-90, alpha-radionuclides such as Am-241-about 200. The database of sampling sites describes more than 1000 forest plots from more than 20 regions of our country, where there is contamination with radionuclides of both fabricated and natural origin. All data is structured in one standardized sample description format, which makes it possible to sort the data and make samples for any type of research.

Owing to the accumulated material, we can analyze the distribution of radionuclides in space and time, and calculate the coefficients of the transition of radionuclides from soil to vegetation for one or more species in different forest areas. From the point of view of conducting radiation monitoring, the potential of this system is much greater than it may seem at first glance.
Now, our information system includes four gamma-ray spectrometers, one alpha-spectrometer and one beta-spectrometer located in the radiation control laboratory. The system was repeatedly tested in the laboratories of the Bryansk and Kaluga regions, owing to which all the information capabilities of conducting radiation monitoring were clearly demonstrated. The system can be connected to any spectrometric device of leading Russian and Western manufacturers, such as Progress, Atomtech, Aspect, Canberra, Ortec, BSI, etc. (figure 3).

![Spectrometric devices](image)

Figure 3. Spectrometric devices operating in the system of data collection and analysis: semiconductor gamma-ray spectrometer (a); scintillation gamma-ray spectrometer (b); scintillation beta spectrometer (c); semiconductor alpha spectrometer (d).

The described method of data collection and analysis can be used by organizations involved in radiation control separately from each other, since the developed software environment is universal and its use is not associated with the developer. Today, there are several problems for the mass adoption of this system. The first one is the conservative attitude of the heads of organizations involved in radiation research to the data security issues. The second one is the conservative attitude to new software solutions, since most laboratories have been working with spectrometric programs introduced many years ago, and it does not make sense to change the existing methods of work, from their point of view. The third one is the financial costs necessary to purchase new software. The main solution to these problems is popularization and massive demonstration of all possible described information systems in organizations engaged in radiation control. Only the personal experience of use makes clear the convenience of the methods embedded in the system.

4. Conclusion
More than 60 years after the accident at weapons-grade plutonium production plant Mayak and 35 years after the accident at the Chernobyl nuclear power plant, the information system for radiation monitoring of Russian forests remains at the level of local surveys and the preparation of text reports on paper. The absence of a global information system makes it impossible to assess all aspects of the consequences of radiation disasters. In this article, we propose a draft software solution for collecting, storing and analyzing the results of spectrometric measurements of the content of radionuclides in forest components in a single information system. The system is based on the use of a unified software for spectrometric devices, the creation of a cloud data storage server, and the development of a software environment for storing and processing the obtained material. The system allows not only to save all the accumulated material about spectrometric measurements, but also to remotely check their quality. Storing the configurations of spectrometric instruments on the server makes it possible to remotely check the accuracy of measuring instruments and, if necessary, to make corrections. The system can work with any spectrometric device of leading Russian and Western manufacturers, such as Progress, Atomtech, Aspect, Canberra, Ortec, BSI, etc. The system has been repeatedly tested in the laboratories of the Bryansk, Kaluga and Moscow regions and received positive ratings of its use. The system is constantly being optimized and new algorithms are being introduced to automate the processes of analyzing data on radiation pollution of forests.
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