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Exploring Radionuclide Behavior: A Study in the 'Karpov' Institute Vicinity

L. Scalise[1] and G. Lavrentyeva[2]

[1] *levyscalise@usp.br, Nuclear Energy and Energy Research Institute, Sao Paulo, Brazil and Obninsk Institute for Nuclear Power Engineering, Obninsk, Russia.*
[2] *lavrentyeva_l@list.ru; Obninsk Institute for Nuclear Power Engineering, Obninsk, Russia and Bauman Moscow State Technical University, Kaluga, Russia*

1. Introduction

Contamination of water, land, and air by diverse chemicals and wastes poses significant environmental and health threats, primarily emanating from industrial and commercial sources [1]. Protecting our environments and communities necessitates a collective responsibility, with monitoring teams playing a crucial role in maintaining a healthy and safe environment [2]. In 2022, a comprehensive soil sampling initiative was undertaken at 12 locations surrounding the "Karpov" Research Institute of Physical Chemistry in Obninsk, Russia (NIFHI) [3]. Renowned for its research reactors utilizing enriched uranium as fuel, the institute raises concerns about potential threats to the nearby areas. Laboratory analysis of the soil samples uncovered the presence of gamma-emitting radionuclides (137Cs, 232Th, 226Ra, and 40K) and chemical elements (K, Na, and Cl). This investigation delves into the environmental contamination in the proximity of the "Karpov" Research Institute, emphasizing radionuclide dynamics and their implications for both human and environmental health. The subsequent sections provide an exploration of the soil sampling results, focusing on specific findings and their significance for effective monitoring and management, ultimately ensuring community well-being and a safe environment.

2. Methodology

To achieve the research objectives, a comprehensive approach integrating field studies, laboratory experiments, and rigorous data analysis was employed. The study area was meticulously chosen for its relevance to radionuclide contamination, given the presence of a nuclear facility and nearby residences that interact with the surrounding vegetation

enclosing the Karpov Institute. Sampling locations were strategically selected to encompass

variations in soil properties, land use patterns, and potential sources of radionuclides (see Fig. 1). The fundamental characterization of soil and plant samples played a pivotal role in

the research methodology. Soil samples from diverse locations were analyzed to assess the geographical distribution of radionuclides and understand their interactions with soil components. Parameters such as pH, organic matter content, cation exchange capacity, and texture were determined to elucidate the influence of soil properties on radionuclide mobility. Plant samples collected from areas encircling the Karpov Institute were analyzed for radionuclide concentrations to unravel uptake and translocation mechanisms.

The determination of radionuclide presence and concentration involved the utilization of advanced measurement techniques and analytical procedures, with gamma spectroscopy being the chosen method. Validated through quality control measures such as blank samples and duplicate analyses, this technique ensured the accuracy and precision of the results. Subsequent data analysis encompassed statistical treatments, employing descriptive statistics, regression analysis, and hypothesis testing to identify trends, correlations, and significant differences. The creation and application of models for radionuclide migration in the soil-plant system provided a quantitative understanding of underlying processes, facilitating scenario prediction. In summary, the research technique combined field observations, laboratory tests, and data-driven analysis, enabling a comprehensive investigation into radionuclide migration in the soil-plant system. This holistic strategy, supported by rigorous methods and analytical techniques, aimed to deliver reliable and valuable insights for environmental risk assessment and management in the context of radionuclide contamination.

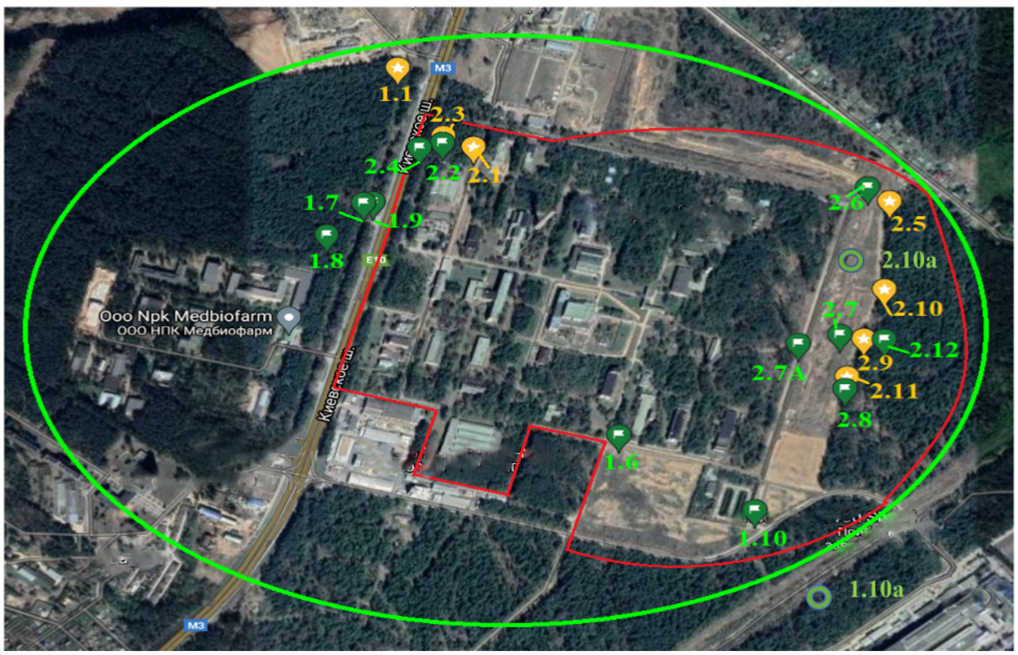

Figure 1: Layout of sampling points on the territory near NIFHI. Source: the Authors.

3. Results and Discussion

The study yielded several significant outcomes, shedding light on the physico-chemical parameters of soils within the influence zone of the Karpov Institute in 2022. The characterization of soils revealed predominant light, loamy, and sandy compositions, with variations in total moisture capacity, pH levels within the optimal range for plant growth, and notable correlations between electrical conductivity, soil composition, and pH. The concentrations of potassium, sodium, and chlorides were also analyzed, highlighting distinct patterns, especially elevated sodium levels in areas affected by deforestation for automobile circulation within the Karpov Institute area. Furthermore, the assessment of radionuclide specific activities, both in 2022 and previous years, elucidated trends in natural radionuclides (K-40, Ra-226, Th-232) and technogenic radionuclide Cs-137. Notably, the specific activity of Cs-137 in 2022 remained well below the established standard. The study established a direct link between radionuclide activity and soil properties, with specific activity variations observed at distinct points based on the presence of carbonate, moisture capacity, and electrical conductivity. Points with the highest specific activities lacked carbonate presence, exhibited over

50% moisture capacity, and demonstrated lower electrical conductivity, while points with the lowest activities contained carbonate, had moisture capacity below 50%, and exhibited higher electrical conductivity. These findings contribute crucial insights for understanding the complex interplay between soil characteristics and radionuclide dynamics, facilitating informed environmental risk assessment and management strategies.

4. Conclusions

In summary, this research offers a thorough exploration of the environmental dynamics around the "Karpov" Research Institute in Obninsk, Russia. By combining field studies, laboratory experiments, and data analysis, the study unveils critical insights into soil characteristics, radionuclide activities, and their interdependencies. Noteworthy findings include controlled levels of technogenic radionuclide Cs-137, well below safety standards, and nuanced fluctuations in natural radionuclides. The correlation between radionuclide activity and specific soil properties enhances our understanding of environmental risks. This research contributes valuable knowledge for effective environmental risk management near nuclear research facilities, emphasizing community well-being and a secure environment.

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