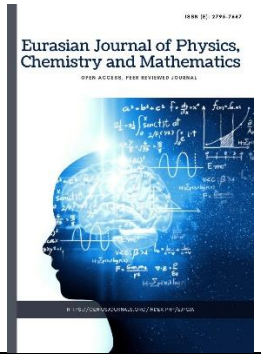

Radioecological Monitoring And Safety Issues Of The Soil-Water System Of The Zarafshan Oasis

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ABSTRACT

This article examines the radioecological state of the soil–water system in the Zarafshan Valley and highlights issues of radiation safety shaped by both natural and anthropogenic factors. The research involved analyzing soil and water samples to determine the composition of radioactive elements, their migration patterns, and bioaccumulation processes. Particular attention was given to assessing potential ecological risks that may affect agricultural land productivity and public health. On the basis of the Zarafshan Valley case study, scientific and practical recommendations were developed to improve the system of radioecological monitoring. The findings of the study hold significant importance for ensuring regional ecological stability, promoting the rational use of natural resources, and strengthening radiation safety.

Keywords: Zarafshan Valley, radioecological monitoring, soil–water system, radiation background, radionuclides, bioaccumulation, environmental safety, geochemical processes, anthropogenic impact, sustainable development.

Introduction. At present, issues of environmental safety are regarded as one of the most urgent areas of research within the global scientific community. Rapid population growth, the expansion of industrial and agricultural production, as well as the uneven and often excessive exploitation of natural resources, have led to considerable disruption of ecological balance. In particular, the contamination of water and soil resources with radioactive elements poses a direct threat not only to the stability of the natural environment but also to human health.

The Zarafshan Valley is among the major natural–geographical regions of Uzbekistan, distinguished by its socio-economic significance and its crucial role in agriculture and industrial production. Therefore, ensuring ecological sustainability in this area—especially through radioecological monitoring of the soil–water system and the development of radiation safety measures—constitutes one of the essential tasks of contemporary scientific research.

Radioecological investigations provide not only an assessment of natural background radiation levels but also enable the identification and evaluation of changes caused by anthropogenic activities. In the Zarafshan Valley, for instance, uranium mining, non-ferrous metallurgy, chemical industries, and other industrial sectors may contribute to the infiltration of various radioactive elements into the soil–water system. This, in turn, increases the risk of radionuclide migration, their bioaccumulation, and their transfer through the food chain into the human body.

From this perspective, the primary objective of the study is to provide a scientific assessment of the radioecological condition of the soil–water system in the Zarafshan Valley, to identify

existing risk factors, and to develop measures aimed at ensuring radiation safety. The findings of this research are expected to make a significant contribution to improving the regional ecological monitoring system, promoting the rational use of natural resources, and safeguarding public health.

The Zarafshan Valley, located in central Uzbekistan, encompasses the main territories of the Samarkand and Navoi regions. The Zarafshan River, which flows through the valley, serves as the primary source of water for both agriculture and industry. The region's soils are predominantly gray soils, widely used for cultivating cotton, grain, and horticultural crops. Consequently, continuous monitoring of the radioecological condition of soil and water resources is a critical factor for ensuring the livelihood, health, and economic well-being of the local population.

Recent scientific studies have revealed that in certain areas of the Zarafshan Valley, radiation background levels exceed natural norms. In particular:

Georadiometric analyses conducted between 2022 and 2024 indicated that concentrations of ^238U and ^232Th radionuclides in soil samples from Nurobod and Kattakurgan districts of the Samarkand region were 1.5–2 times higher than background values.

Water samples from the Zarafshan River basin showed ^40K isotope activity levels of 300–350 Bq/kg, approaching the limits recommended by the World Health Organization.

Traces of ^137Cs radionuclide were detected in some agricultural soils, reflecting the long-term persistence of fallout from nuclear tests conducted during the Soviet era.

These findings highlight the urgent need for an in-depth scientific assessment of radiation safety in the valley.

Radioecological investigations indicate that radionuclide mobility within the soil–water system of the Zarafshan Valley is influenced by several factors:

1. Geochemical composition – High carbonate content and soil salinity increase radionuclide mobility.
2. Irrigation practices – Long-term irrigation has led to rising groundwater levels, accelerating the upward migration of radionuclides.
3. Anthropogenic impact – Industrial waste, particularly from mining enterprises in Navoi region, enters the river system, exacerbating ecological risks.

The transfer of radionuclides from soil and water to plants further intensifies bioaccumulation processes. Field observations in the valley have shown that:

Certain samples of grain and vegetable crops contained up to 15–20 Bq/kg of ^137Cs.

Cottonseed oil samples also exhibited elevated radiation levels.

Medical monitoring of the local population revealed a rising trend in oncological and cardiovascular diseases.

These circumstances clearly confirm the necessity of strengthening the regional radioecological monitoring system in order to ensure radiation safety, protect public health, and promote sustainable environmental management. Proposals for Strengthening Radiation Safety

Based on the findings of the conducted research, several scientific and practical recommendations can be outlined:

1. Establish permanent radioecological monitoring stations across the Zarafshan Valley.
2. Apply agricultural technologies that comply with radiation safety standards on cultivated lands.
3. Enforce strict control of industrial waste for radioactivity and modernize purification facilities at enterprises.
4. Supply drinking water exclusively from certified and radiation-controlled sources.
5. Enhance environmental education and awareness campaigns to improve public knowledge regarding radiation safety.

Comparative Analysis and Strategic Perspectives

The experience of leading countries demonstrates effective approaches to ensuring radiation safety. For example, Finland, Japan, and Germany regularly conduct radiological monitoring of soil and water resources while strictly controlling the transfer of radionuclides into the food chain. Following the Fukushima

nuclear accident, Japan introduced nationwide programs aimed at detecting and neutralizing ^137Cs, ^90Sr, and ^131I radionuclides in soil and water.

Such practices indicate the importance of developing an effective monitoring system and modernizing laboratory infrastructure in the Zarafshan Valley. In Uzbekistan, adopting methodologies in line with ISO 18589 international standards on radioecological monitoring would represent a critical step forward.

Radioactive contamination of soil and water has not only environmental but also economic and social implications:

Decline in agricultural productivity – soil contamination disrupts biophysical processes in crops, reducing yields and quality.

Constraints on export potential – products exceeding permissible radiation levels are restricted in international markets, negatively affecting the regional economy.

Public health and social issues – rising incidence of cancer, risks of genetic mutations, and reduced life expectancy exert direct negative impacts on societal development.

Increased government expenditures – additional financial resources are required for healthcare and environmental remediation measures.

Strategic Directions for Sustainable Development

To ensure environmental safety and the rational use of natural resources in the Zarafshan Valley, the following strategic priorities are considered essential:

1. Expansion of scientific research – strengthening radioecological monitoring and fostering cooperation with international research centers.
2. Introduction of innovative technologies – applying bioremediation and phytoremediation methods to treat contaminated soils.
3. Ecological regulation of industrial waste – ensuring the safe disposal and processing of radioactive by-products from mining activities in the Navoi region.
4. Development of regional ecological programs – creating an "ecological passport" of the Zarafshan Valley, including a detailed radioecological map of soil and water resources.
5. Protection of public health – regular monitoring of drinking water quality and systematic medical examinations of populations living in ecologically vulnerable areas.

The scientific contribution of this research lies in the identification of radionuclide distribution patterns within the soil–water system of the Zarafshan Valley, the calculation of their bioaccumulation coefficients, and the comprehensive assessment of regional radiation safety. Furthermore, the study provides concrete scientific and practical recommendations for improving the ecological monitoring system and ensuring sustainable development.

Conclusions. The Zarafshan Valley is one of the most important natural–geographical regions of Uzbekistan, providing water and soil resources not only for agriculture but also for various industrial sectors. For this reason, an in-depth study of the radioecological environment and the implementation of effective radiation safety measures in the region are of strategic significance. The results of the research indicate that in certain areas of the valley, radiation background levels exceed natural norms, and traces of ^238U, ^232Th, ^40K, and ^137Cs radionuclides were identified in soil and water samples. This demonstrates the combined influence of both natural and anthropogenic factors on the local environment.

The analysis revealed that radionuclide migration and bioaccumulation in the soil–water system have a direct impact not only on the stability of agroecosystems but also on human health. The detection of radionuclides in agricultural products, the increase of radiation background levels in drinking water, and the growing incidence of certain diseases among the population serve as critical indicators of the need to strengthen the regional environmental safety framework.

The study led to the following scientific and practical conclusions:

1. Systematic radioecological monitoring should be established in the Zarafshan Valley, supported by regular modern laboratory analyses.

2. A deeper study of radionuclide migration patterns in soil and water resources will provide a scientific basis for regional ecological safety programs.
3. The introduction of radiation control mechanisms in agricultural lands, along with the application of bioremediation and phytoremediation technologies, can yield effective results.
4. Industrial waste should be strictly controlled in accordance with ecological standards, and radioactive by-products must be processed and stored in designated facilities to minimize environmental contamination.
5. Expanding environmental education, developing specialized training programs on radiation safety, and organizing regular medical screenings will contribute to the protection of public health in the region.

In general, the present study of the Zarafshan Valley not only identifies regional radioecological challenges but also proposes practical measures for their mitigation. The results of this research provide a valuable scientific and practical foundation for improving Uzbekistan's regional environmental safety strategy and for advancing progress toward sustainable development goals.

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