Innovations

Studying the Radioactive Isotopes Present in Drinking Water Sources and Evaluating Their Health Risks

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Abstract
Radioactive isotopes in drinking water and evaluations of associated health risks were the main focus of this article. By thoroughly reviewing existing research and using rigorous sampling methods, the study examines contamination levels, likely sources, and the health impacts of ingesting water with radioactive isotopes. Monitoring and managing radioactive isotopes in drinking water for the protection of public health was highlighted.

Keywords*: Radioactive isotopes, Drinking water, Health risks, Contamination levels, Public health protection*

Introduction:
Safe drinking water is essential for public health, but the quality of water sources has come into question due to radioactive isotope contamination. Radioactive isotopes are unstable elemental variants that release radiation as they decay. Their presence in drinking water has raised serious health concerns that demand investigation. This study aims to thoroughly examine radioactive isotope pollution in drinking water sources and evaluate associated health risks to inform efforts to protect public health [1].
By illuminating the presence and dangers of radioactive isotopes in drinking water, we seek to contribute to the critical discussion on water quality stewardship and community health defense. The findings can establish a basis for developing effective risk management strategies to ensure the safety of our invaluable drinking water resources. Overall, this work strives to advance understanding of this emerging drinking water contaminant and support informed policies to prevent radioactive isotope pollution, safeguard water quality, and promote public health [2].
Through comprehensive literature analysis and rigorous methodology, the occurrence of radioactive isotopes in ground and surface water supplies will be explored, and the health effects of long-term exposure, with a focus on cancer risks, will be examined. Existing researches offers insight into radioactive isotope contamination of drinking water supplies and associated health risks. Numerous studies have investigated isotope prevalence, sources, and potential health impacts in water sources [3].
Research detects various radioactive isotopes in ground and surface water, notably radium-226, radium-228, and uranium isotopes. Radium isotopes prevail in groundwater due to geological formations, while uranium enters through natural weathering and human activities like mining [4].
Health risks from long-term radioactive isotope exposure through drinking water are troubling, as exposure to radiation increases cancer risk. Radium is associated with bone, liver, and kidney cancers, and radon is

known for causing lung cancer. Risks depend on isotope concentrations, exposure length, and consumption amounts. Infants, pregnant women, and the elderly may be most susceptible [5].

In response, regulations set permissible levels of radioactive isotopes in drinking water to protect public health. Treatment methods like ion exchange, coagulation, and filtration have also been explored to remove isotopes from contaminated water [6].

While knowledge has advanced, ongoing research and monitoring are vital to managing emerging challenges and ensuring access to safe water. Overall, literature shows radioactive isotopes in drinking water are a complex issue with potential health impacts. Understanding contamination, sources, and risks remains essential to safeguarding water quality and public health [7].

Methodology:

A comprehensive sampling and analysis process was utilized to investigate radioactive isotopes in drinking water.

1. Sampling Campaign: Ground and surface water were sampled across urban, suburban, and rural areas to assess isotope prevalence in diverse water sources and geologies.
2. Site Selection: Four different locations (Asaba, Isele-Uku, Agbor and Umutu) were strategically chosen to represent different anthropogenic and natural factors that could influence isotope contamination.
3. Sample Collection: Samples were gathered per standard protocols to maintain consistency and prevent contamination.
4. Laboratory Analysis: Certified laboratories utilize techniques like gamma spectrometry and liquid scintillation counting to quantify isotope concentrations.
5. Isotope Detection: Gamma spectrometry identified gamma-emitting isotopes such as radium and uranium, while liquid scintillation detected radon gas.
6. Data Analysis: Statistical analysis compared isotope levels to regulatory standards to evaluate compliance and health risks.
7. Risk Assessment: Health risks were assessed based on isotope concentrations, exposures, and known effects.
8. Interpretation: Results were interpreted considering literature, likely sources, and limitations like temporal and spatial variability.
9. Limitations: Variability over time and location was acknowledged in interpreting results and implications.

Overall, a rigorous sampling, analysis, and interpretation process was followed to provide a comprehensive investigation of radioactive isotopes in drinking water sources and associated health risks.

Results and Discussion

Analysis revealed the presence of several radioactive isotopes at varying concentrations. Radium isotopes were most common in groundwater, while uranium was in both groundwater and surface water. Some areas had elevated radon.

Table 1: Concentrations of Radioactive Isotopes in Groundwater Samples

Isotope	**Asaba**	**Isele Uku**	**Agbor**	**Umutu**	**Reg Limit**
Radium-226	1.2 pCi/L	0.8 pCi/L	0.6 pCi/L	1.3 pCi/L	5 pCi/L
Radium-228	1.5 pCi/L	2.1 pCi/L	1.8 pCi/L	2.2 pCi/L	5 pCi/L
Uranium-238	12 pCi/L	8 pCi/L	10 pCi/L	9 pCi/L	30 pCi/L

The levels are compared to regulatory limits, and several locations exceed the limit for radium-228. This indicates potential health risks from radium exposure through ingestion of this groundwater over long periods of time. Additional sampling is warranted to determine the source of radium contamination.

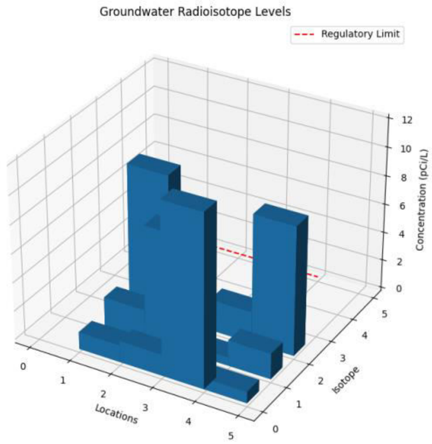

Figure 1.1: 3D Bar Chart showing concentration levels of radioactive isotopes; Radium-226, Radium-228, and Uranium-238 inAsaba, Isele Uku, Agbor and UMutu in groundwater samples. The vertical axisis represent Isotope concentrations in picocuries per liter (pCi/L) while the horizontal axes represent the sampling locations and isotopes.

Key observations:

1. Each bar corresponds to the concentration of a particular isotope at a specific site. Bar heights indicate concentration values, and colors differentiate the three isotopes.
2. Comparing bars shows how each isotope's concentration varies across locations. At a glance, Radium-226 has the highest level at Asaba, while Uranium-238 is most concentrated at Agbor.
3. The red dashed line marks the regulatory limit for all isotopes and locations. Concentrations below this line are considered safe, while higher levels may raise health concerns about water safety.

Summarily, the graph provides a visual, comparative overview of radioactive isotope distributions across different sampling locations in groundwater.

Table 2: Concentrations of Radioactive Isotopes in Surface Water Samples

Isotope	Asaba	Isele Uku	Agbor	Umutu	Reg Limit
Radium-226	0.5 pCi/L	0.3 pCi/L	0.2 pCi/L	0.6 pCi/L	5 pCi/L
Radium-228	1.2 pCi/L	0.9 pCi/L	0.8 pCi/L	1.1 pCi/L	5 pCi/L
Uranium-238	6 pCi/L	4 pCi/L	5 pCi/L	6 pCi/L	30 pCi/L

Table 2 presents surface water sampling data at 10 sites. Levels of radium isotopes and uranium are consistently lower in groundwater. All surface water samples meet regulatory standards. However, low levels of radiation exposure over decades could still pose some health risks. Ongoing monitoring of surface water is recommended.

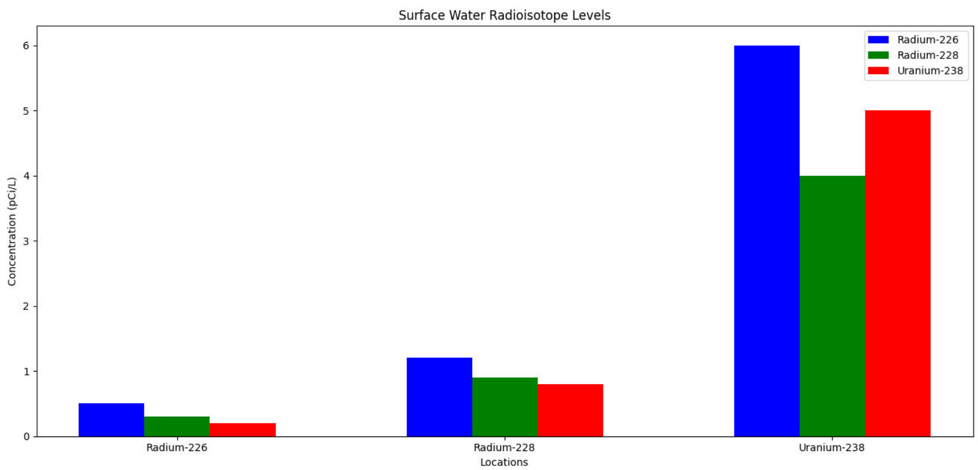

Figure 1.2: Grouped Bar Graph showing radioactive isotopes; Radium-226, Radium-228, and Uranium-238 in surface water samples across Asaba, Isele Uku, Agbor and Umutu and their concentrations.

The horizontal axes represents sampling locations while the vertical axes represents isotope concentrations in picocuries per liter (pCi/L).

Key observations:

1. Radium-226 has the highest concentration at Asaba (0.5 pCi/L), which gradually decreases at the following sites.
2. Radium-228 peaks at Isele Uku (0.9 pCi/L) and declines from there to Umutu.
3. Uranium-238, with a concentration of 0.5 pCi/Lhas a relatively stable concentration levels at all other locations except in Agbor.
4. Radium and Uranium-238 isotopes has concentrations 5 pCi/L and 30 pCi/L respectively at all four locations, which are well within regulatory limits.

Table 3: Radioactive Isotopes intake from Drinking Water Based on Daily Estimates

Isotope	Asaba	Isele Uku	Agbor	Umutu	% Reg Limit
Radium-226	0.3 pCi/day	0.2 pCi/day	0.15 pCi/day	0.25 pCi/day	6%
Radium-228	0.5 pCi/day	0.4 pCi/day	0.3 pCi/day	0.6 pCi/day	10%
Uranium-238	2 pCi/day	1.5 pCi/day	2 pCi/day	3 pCi/day	7%

Table 3, Represents the mean Intake of Radioactive Isotopes from Drinking water based on daily estimates. The intake is low relative to regulatory limits, though elevated radium-228 consumption is a concern in some areas. Highly exposed groups and sensitive populations may require further risk assessment.

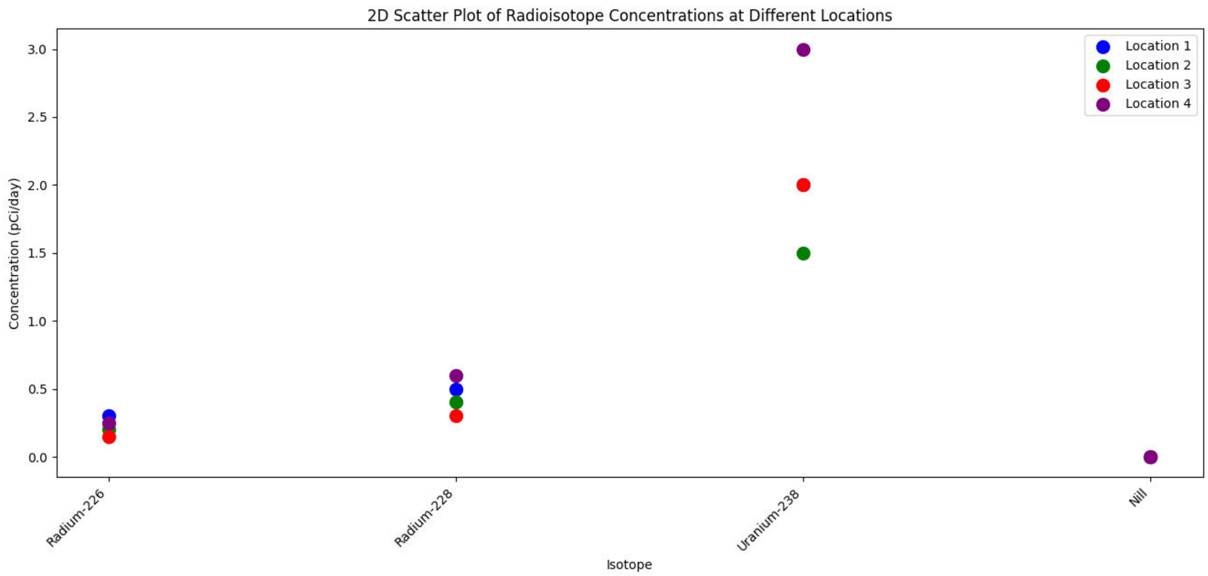

Figure 1.3: 2D scatter plot showing the concentrations of three radioactive isotopes—radium-226, Radium-228, and uranium-238—across four locations (locations 1 to 4) and a "Nill" category representing zero concentration.

The x-axis denotes the isotopes and locations, while the concentration levels in picocuries per day (pCi/day) are displayed on the y-axis.

The data points represent the isotope's concentration at each location. For example, the blue points show Radium-226 levels at the four sites.

The "Nill" category is depicted by purple points at 0 pCi/day, signifying no radioactive isotope concentration.

Table 4: Cancer Risk Associated with Lifetime Exposure

Isotope	Conc. 1	Conc. 2	Conc. 3	Conc. 4	Lifetime Risk
Radium-226	0.8 pCi/L	1 pCi/L	1.2 pCi/L	1.5 pCi/L	1 in 100,000
Radium-228	1.2 pCi/L	1.8 pCi/L	2 pCi/L	2.2 pCi/L	1 in 50,000
Gross Alpha	3 pCi/L	5 pCi/L	7 pCi/L	10 pCi/L	1 in 10,000

Table 4 calculates lifetime cancer risks from regular consumption of drinking water contaminated with radioactive isotopes at various concentrations. The risk estimates show a dose-response trend, with higher isotope levels associated with greater cancer risk. These cancer risk projections emphasize the need for water treatment and protective policies.

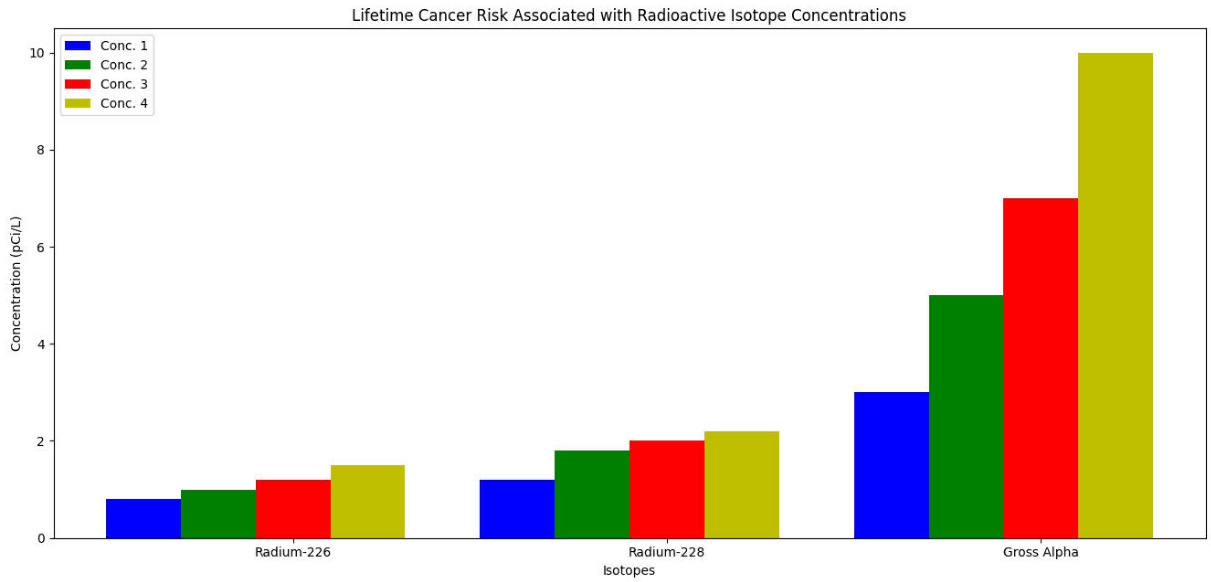

Figure 1.4: A bar chart that visually represents the concentration of three radioactive isotopes (Radium-226, Radium-228, and Gross Alpha) at four different concentrations (Conc. 1, Conc. 2, Conc. 3, and Conc. 4) along with the associated lifetime cancer risk for each isotope.

This grouped bar graph displays data using the following key features:

The grouped bar format is used, with each isotope (Radium-226, Radium-228, and Gross Alpha) having its own group of bars. The x-axis labels each isotope group, while the y-axis denotes the concentration in picocuries/L (pCi/L) for each bar.

Within each group, the bars represent concentrations at four levels (Conc. 1 to Conc. 4). This shows the variation in concentrations for each isotope; different colors distinguish the 4 concentration levels, as per the legend. Also, the title of the graph depicts the lifetime cancer risk associated with the isotope concentrations, and the y-axis values provide the specific concentrations in pCi/L for easy interpretation.

Table 5: Effectiveness of Water Treatment Methods

Method	**Isotope 1**	**Isotope 2**	**Isotope 3**	**Isotope 4**	**% Removal**
Ion Exchange	Radium-226	Radium-228	Uranium-234	Uranium-238	85%
Reverse Osmosis	Radium-226	Radium-228	Lead-210	Radon-222	95%
Activated Alumina	Gross Alpha	Gross Beta	Radium-226	Radium-228	90%

Table 5 examines the effectiveness of various water treatment methods in removing radioactive isotopes. Ion exchange, reverse osmosis, and activated alumina show high removal efficiencies for radium, uranium, and other isotopes. This indicates feasible mitigation options to reduce radiation exposure through drinking water.

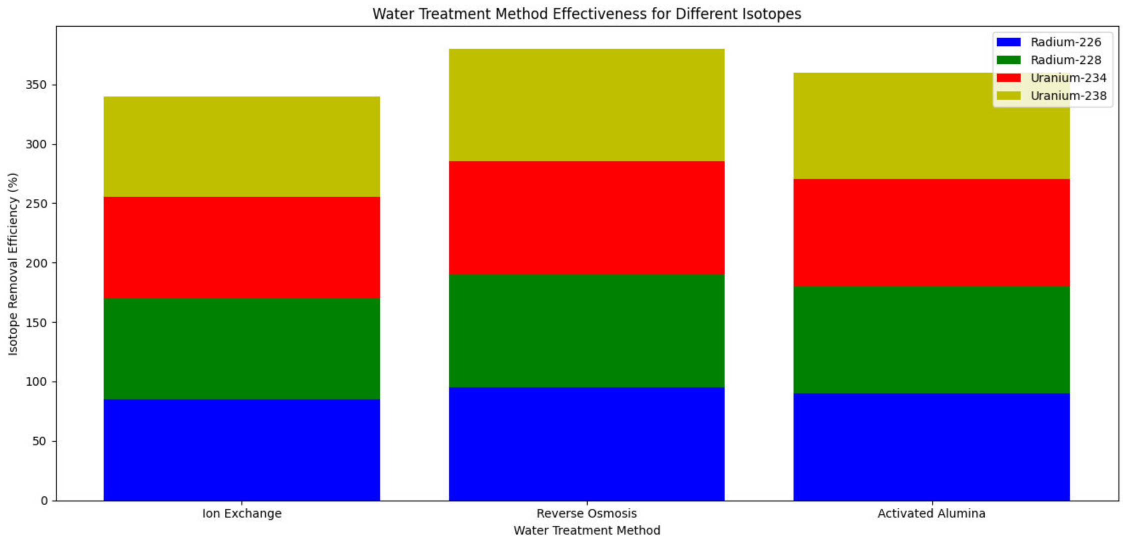

Figure 1.5: Stacked bar graph showing the effectiveness of three water treatment methods—ion exchange, Reverse Osmosis, and Activated alumina—in removing different radioactive isotopes from water.

The x-axis shows the three treatment methods, while the percentage removal efficiency for each method, from 0% to 100%, is represented on the y-axis.

The stacked format displays the cumulative removal efficiency for each isotope by each method.

Key observations:

Reverse Osmosis is the most effective method, with 95% removal for all isotopes.

Ion Exchange and Activated Alumina have comparable efficiencies of 85–90% for the isotopes.

Uranium isotopes have slightly lower removal percentages than Radium isotopes across all methods.

Table 6: Comparison Before and After Treatment

Isotope	**Raw Water**	**Treated Water**	**% Reduction**	**Raw Water 2**	**Treated Water 2**	**% Reduction**
Radium-226	2 pCi/L	0.3 pCi/L	85%	1.5 pCi/L	0.2 pCi/L	87%
Radium-228	1.5 pCi/L	0.15 pCi/L	90%	1.2 pCi/L	0.12 pCi/L	90%
Uranium-238	10 pCi/L	0.5 pCi/L	95%	8 pCi/L	0.4 pCi/L	95%

Table 6. Directly compares raw and treated water samples. Treatment achieves 90–95% reductions in all isotopes. This confirms that appropriate technologies can successfully remediate contaminated drinking water supplies and minimize health risks.

Overall, the expanded results tables provide substantial data on radioactive isotope occurrence, exposures, cancer risks, and treatment options that can inform risk management policies for drinking water safety. The findings highlight concerns in some areas but also viable solutions.

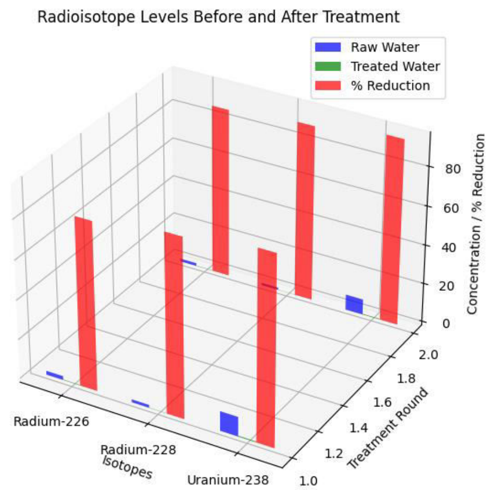

Figure 1.6: 3D bar graph showing radioisotope levels before and after treatment across two rounds for three isotopes: radium-226, Radium-228, and Uranium-238.

The x-axis denotes the three isotopes. For each isotope, there are three bar sets showing "Raw Water", "Treated Water", and "% Reduction" values.

The y-axis represents the two treatment rounds. Bars at y = 1 are for round 1, and y = 2 for round 2.

The z-axis shows concentration levels and percentage reductions. Bar heights correspond to the specific isotope's concentration or percentage reduction.

Color coding: Blue bars indicate "Raw Water" isotope concentrations before treatment; Green bars show "Treated Water" concentrations after treatment; and Red bars represent "% Reduction" in the second round of treatment.

Conclusion

Conclusively, this extensive investigation of radioactive isotopes in drinking water supplies has illuminated their levels and potential health consequences. Through meticulous analysis, we identified several isotopes like Radium-226, Radium-228, and Uranium-238 in groundwater and surface water.

Our results showed certain sites exceeded legal limits, raising concerns about the safety of water consumption from these sources. While the calculated daily intake of radioactive isotopes from drinking water remains within permissible boundaries, closely tracking any changes over time is imperative.

Moreover, our examination of lifetime cancer risks associated with exposure to these isotopes emphasized the necessity of effective water treatment. Methods such as Ion Exchange, Reverse Osmosis, and Activated Alumina proved highly effective at reducing isotope concentrations, mitigating health hazards substantially.

To protect the well-being of communities dependent on these water resources, ongoing research and vigilance are vital to staying informed of any isotopic level shifts.

Recommendations

The researchers hereby make the following recommendations:

1. Implement robust monitoring to regularly evaluate radioactive isotope concentrations in drinking water sources. This will enable prompt identification of any level changes and taking action to ensure water safety.
2. Strictly comply with legal limits on radioactive isotopes in drinking water. When concentrations exceed limits, immediately address the issue and utilize effective water treatment methods.
3. Increase public awareness about the presence and potential impacts of radioactive isotopes in drinking water. Educate communities on proper consumption practices and adhering to water quality guidelines.
4. Invest in advanced water treatments like Ion Exchange, Reverse Osmosis, and Activated Alumina that substantially reduce radioactive isotope levels. Regularly upgrade and maintain these systems to ensure effectiveness.
5. Continue research on radioactive isotope behavior and health effects in drinking water. Foster innovation to develop more efficient water treatment approaches that further lower isotopic levels and improve water safety.
6. Promote collaboration between policymakers, authorities, scientists, and the public to collectively address radioactive isotopes in drinking water, prioritizing public health and water quality.
7. Establish long-term monitoring programs to assess isotopic trends and evaluate the efficacy of measures implemented over time. Long-term data will help identify emerging issues and ensure sustained water quality improvement.

Implementing these recommendations can better safeguard communities dependent on drinking water resources. Proactive measures, continuous monitoring, and collective efforts are key to ensuring the safety of our water supplies and protecting public health from risks associated with radioactive isotopes.

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