Vital Surveillances

National Monitoring for Radioactivity in Drinking Water — China, 2012–2024

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ABSTRACT

Introduction: To establish baseline radioactivity levels and ensure the safety of drinking water quality in China, gross alpha and gross beta radioactivity levels in drinking water were surveyed from 2012 to 2024.

Methods: The surveillance was conducted through the national monitoring system for radioactivity in drinking water, organized by The National Institute for Radiological Protection (NIRP) during the period 2012–2024. Drinking water samples were collected and pretreated in accordance with a unified protocol, and radioactivity was determined using alpha/beta counting systems by local laboratories.

Results: From 2012 to 2024, over 11,000 drinking water samples were collected and analyzed across 29 provinces, including areas surrounding nuclear power plants. The mean concentration ranges of gross alpha and gross beta radioactivity levels in all regions and various water bodies were 0.01–0.17 Bq/L and 0.05–0.38 Bq/L, respectively, all of which are below the guidance values specified in the national standard GB 5749 (0.5 Bq/L for gross alpha and 1 Bq/L for gross beta). However, the gross alpha and gross beta activity levels in well water were higher than those in other water bodies. The results indicate that radioactivity in drinking water primarily originates from natural radionuclides.

Conclusions: Drinking water in China maintains normal background levels of radioactivity. Nuclear power plant operations do not seem to have an impact on surrounding water sources.

Drinking water safety is a critical health and development concern at the national, regional, and local levels. Although drinking water typically contributes minimally to overall radionuclide exposure under normal circumstances, radioactivity in drinking water remains an important consideration (*1*). Radionuclides in drinking water can originate from both natural and human-made sources. Particularly significant for human radiation exposure from drinking water are naturally occurring radionuclides from the thorium and uranium decay series — such as radium-226, radium-228, polonium-210, lead-210, and radon — which are dissolved from rocks and soil. These radionuclides, typically present as dissolved ionic species, can infiltrate water sources through natural geological processes or anthropogenic activities, such as uranium mining and other extractive industries involving naturally occurring radioactive materials (*2*).

Natural radionuclide activity concentrations vary across regions, depending on local geology in drinking water. Global data on the levels of naturally occurring radionuclides in drinking water have been reviewed by UNSCEAR (*2*). In most cases, the activity concentrations are very low, making detailed analysis of specific radionuclides unnecessary for routine monitoring. Consequently, the most commonly used screening method is gross alpha and gross beta activity measurements (*3*–*4*). Regulatory frameworks for monitoring radioactivity in drinking water, along with corresponding guideline levels for gross alpha and gross beta activity, have been established in the European Union, the United States, Canada, and other countries (*5*–*7*). In China, gross alpha and gross beta are among the 43 regular indices listed in the Standards for Drinking Water Quality, with guidance values of 0.5 Bq/L for gross alpha and 1 Bq/L for gross beta (*8*), in line with WHO recommendations (*1*).

China's national radioactive monitoring data for drinking water largely predates 2000, with a gap in systematic monitoring during 2000–2011. To ensure drinking water safety under new circumstances of rapid nuclear energy development, monitoring was reinitiated in 2012. The National Institute for Radiological Protection (NIRP), under the China CDC, was tasked with organizing nationwide radioactive monitoring of drinking water. From 2012 to 2024, in collaboration with provincial laboratories, over 11,000 drinking water samples were collected and analyzed for gross alpha and gross beta activity. This effort underscores the commitment to safeguarding public health by maintaining drinking water quality within safe and acceptable limits. The data obtained contribute to establishing the baseline levels of natural radioactivity in China's drinking water supplies.

METHODS

In accordance with the sampling and distribution requirements outlined in the technical manuals for drinking water radiation monitoring issued by NIRP, provincial monitoring institutes conducted annual collection and analysis of drinking water samples. The investigation covered 29 provinces, including areas within 30 km of nuclear power plants. Sampling was conducted in both dry (spring/winter) and wet (summer/autumn) seasons. Samples were categorized by water source: finished water, tap water, well water, and reservoir water. This systematic approach ensured comprehensive monitoring and assessment across diverse sources and conditions.

Sample collection and preservation strictly followed national standards (*9*). To ensure sample representativeness and prevent contamination, water was allowed to flow continuously for a short period before collection (*10*). Pretreatment steps, such as acidification and/or filtration, were performed to minimize potential interferences affecting radioactivity measurements. Samples were collected in pre-cleaned polyethylene containers and acidified with dilute nitric acid to a final concentration of 2% to maintain sample homogeneity and prevent the adsorption of radionuclides on container walls.

The analysis procedures followed national standards (*11*). For each sample, one liter of acidified water was taken in a beaker and heated to sub-boiling on an electric heating plate. When reduced to less than 50 mL, the samples were transferred to an evaporating dish. One milliliter of sulfuric acid was added, and the mixture was heated until a residue was produced. The residue was placed in a muffle furnace at 350 °C for 1 hour to prepare measurement sources.

Gross alpha and beta radioactivity were measured using alpha/beta counting systems. Low-background multi-detector alpha/beta counters with different models were used as counting instruments. The most widely used measurement techniques are proportional counting and solid-state scintillation counting, while some laboratories employ semiconductor silicon detectors and grid ionization chambers. For alpha counting efficiency calibration, the most commonly used radionuclide is ^{241}Am, though a few laboratories utilize natural uranium. For beta counting efficiency calibration, ^{40}K (as potassium chloride) is typically employed.

To ensure data quality, all instruments were verified by the national metrology department. All participating laboratories participated in annual inter-comparison exercises organized by NIRP (*3*). NIRP also drafted annual monitoring manuals, conducted training, and provided on-site guidance to ensure consistent, high-quality monitoring practices nationwide.

RESULTS

From 2012 to 2024, over 11,000 drinking water samples were collected and analyzed. Figure 1 shows the activity concentrations of gross alpha and gross beta

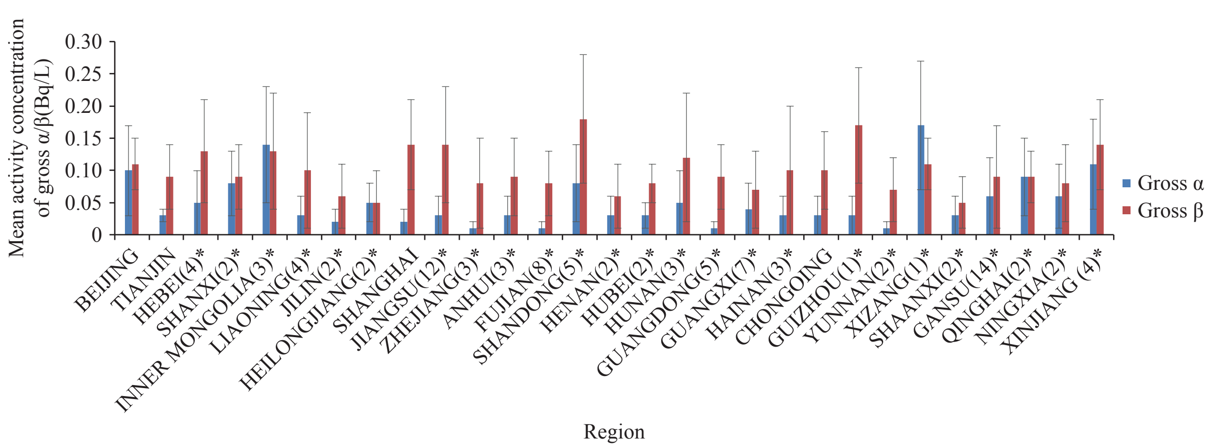

FIGURE 1. Concentrations of gross alpha and gross beta activity in finished water across different regions.
Note: * number of cities covered by the data.

in finished water bodies across different regions. The mean gross alpha activity concentration ranged from 0.01 Bq/L to 0.17 Bq/L, while the gross beta activity concentration ranged from 0.05 Bq/L to 0.18 Bq/L. Although some regional variation was observed, all values remained below the national guideline levels.

Figure 2 presents the gross alpha and gross beta radioactivity levels in four types of water bodies during the dry and wet seasons. The interquartile range (25%–75%) analysis revealed minimal seasonal variations in the gross alpha and gross beta activity concentrations of each water body type. Two independent sample *t*-tests revealed no statistically significant differences (α=0.05) in both gross alpha and gross beta activity concentrations between the dry and wet seasons for any water body, except for well water, which showed a statistically significant difference (α=0.05) in mean gross alpha radioactivity concentration between the dry and wet seasons. Additionally, the gross alpha and gross beta radioactivity levels were higher in well water, as natural radionuclides are more commonly found in drinking water derived from groundwater sources than surface water (*2*).

Figure 3 presents the mean gross alpha and gross beta radioactivity concentrations in various water bodies during 2018–2024. In finished water, the gross alpha range was 0.03–0.04 Bq/L, and the gross beta range was 0.09–0.10 Bq/L. In tap water, the gross alpha range was 0.03–0.04 Bq/L, and the gross beta range was 0.11–0.13 Bq/L. In reservoir water, the gross alpha range was 0.02–0.03 Bq/L, and the gross beta range was 0.08–0.12 Bq/L. In well water, the gross alpha range was 0.09–0.17 Bq/L, and the gross beta range was 0.21–0.38 Bq/L. The t-tests comparing well water with the other 3 water types (finished water, tap water, and reservoir water) showed that the radioactivity concentration in well water (mean=

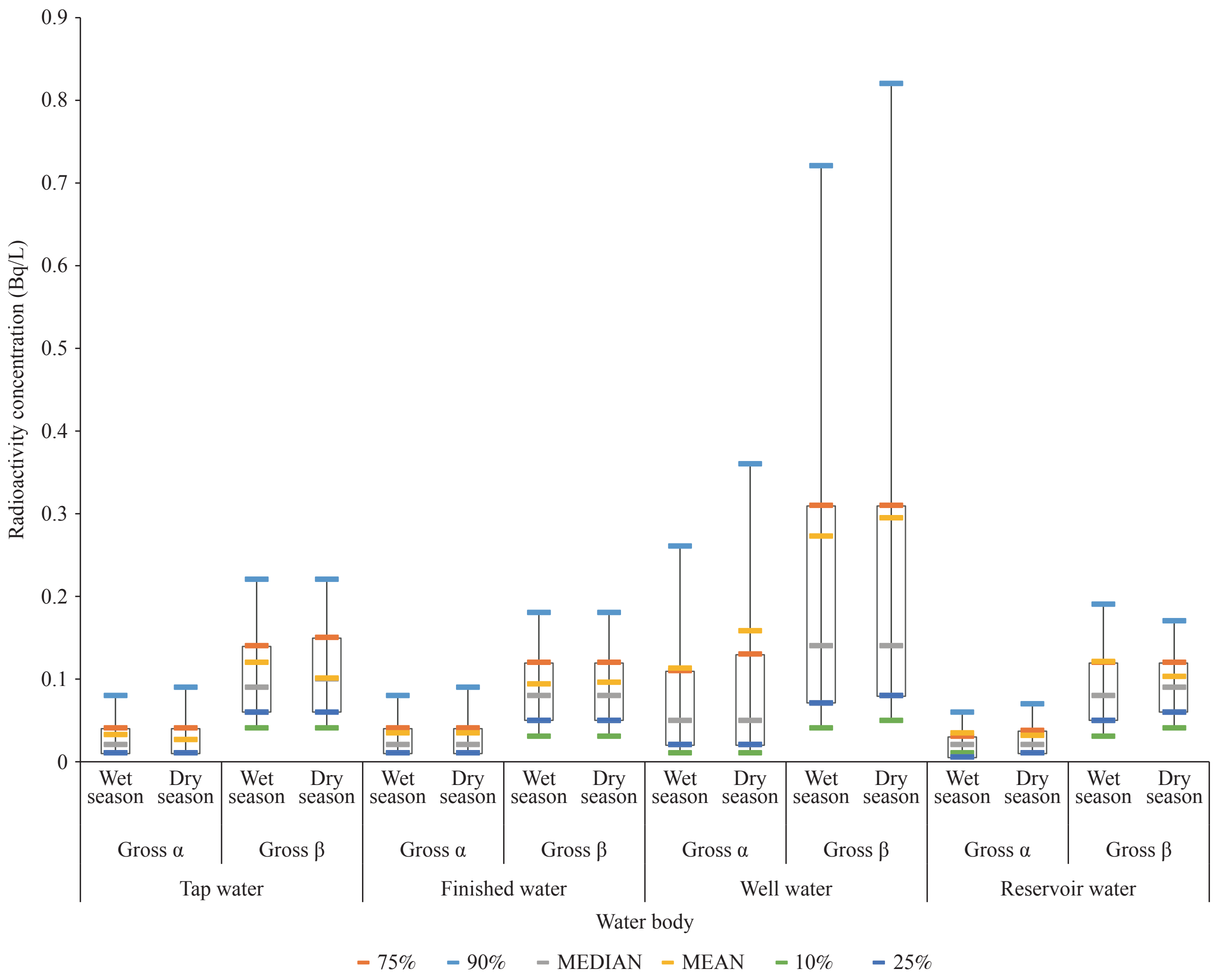

FIGURE 2. Gross alpha and gross beta activity concentrations in drinking water during the wet and dry seasons (2012–2024).

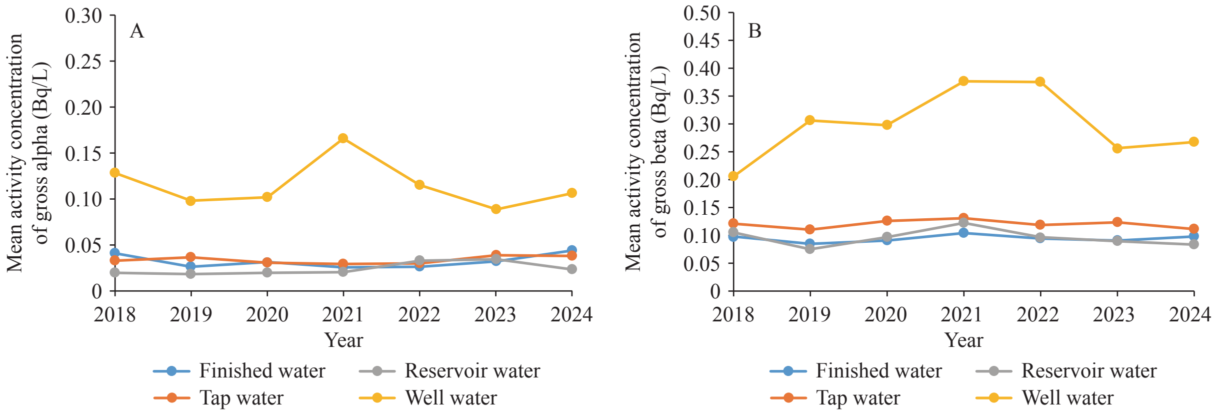

FIGURE 3. Gross alpha and gross beta activity concentrations in drinking water during 2018–2024. (A) Gross alpha; (B) Gross beta.

TABLE 1. Gross alpha and gross beta concentrations in drinking water across the nation and around nuclear power plants during 2012–2024.

Water body type	No. of samples	National regions (excluding areas near nuclear power plants)				No. of samples	Near nuclear power plants			
		Gross alpha		Gross beta			Gross alpha		Gross beta	
		Mean	Range (P_{10}, P_{90})*	Mean	Range (P_{10}, P_{90})*		Mean	Range (P_{10}, P_{90})*	Mean	Range (P_{10}, P_{90})*
Reservoir water	216	0.03	<0.01–0.07	0.11	0.03–0.23	360	0.02	<0.01–0.06	0.10	0.04–0.15
Finished water	3,733	0.04	<0.01–0.10	0.09	0.01–0.18	1,477	0.02	<0.01–0.05	0.10	0.04–0.18
Tap water	624	0.04	<0.01–0.11	0.11	0.04–0.22	2,549	0.03	<0.01–0.08	0.12	0.04–0.22
Well water	203	0.09	<0.01–0.19	0.17	0.04–0.35	812	0.14	<0.01–0.34	0.31	0.05–0.81

* This represents the data between the 10th and 90th percentiles.

0.12 Bq/L) was significantly higher than that in other water types (α =0.05).

Table 1 presents the gross alpha and gross beta radioactivity concentrations in drinking water nationwide and around nuclear power plants. The Shapiro-Wilk test showed a non-normal distribution of data (P<0.05). To evaluate the overall distribution level of the monitoring data, the data range between the 10th and 90th percentiles is provided. The gross alpha and gross beta concentrations in reservoir water, finished water, and tap water were consistent between the two regions. Although gross beta concentrations in finished water and tap water around nuclear power plants were slightly higher than the national levels, the differences were not statistically significant (α =0.05). A statistically significant difference (α =0.05) was observed in gross alpha and beta concentrations in well water between the 2 regions. However, the difference is not considered practically significant. Certain individual monitoring points, mainly those involving well water, exhibited relatively high levels of gross alpha (>0.5 Bq/L) or gross beta (>1 Bq/L) radioactivity. For samples with gross beta exceeding 1 Bq/L, the result included the contribution of ^{40}K. However, after subtracting the contribution of ^{40}K, the gross beta in these samples did not exceed 1 Bq/L.

DISCUSSION

The radioactivity levels in drinking water are an important factor for assessing drinking water safety and public health risks. Nationwide surveys of the radioactivity levels in drinking water have been conducted by the Health Department since the 1960s. According to previous reports (*12*), the highest levels of radioactivity in tap water were observed in the 1960s, attributed to atmospheric nuclear tests; levels subsequently declined and eventually stabilized. However, systematic monitoring was lacking between 2000 and 2011. Nationwide monitoring of drinking water radioactivity was reinitiated in 2012, providing valuable data on the natural background levels of radioactivity in China's drinking water. This study presents the national survey results from 2012 to 2024, including monitoring data from areas surrounding nuclear power plants.

In the initial phase of this survey, monitoring focused primarily on nuclear power plant provinces, expanding nationwide in 2018. The results indicate that radioactivity levels in drinking water consistently fluctuate within background ranges (*12*–*13*).

The results indicate no significant difference in radioactivity levels between drinking water samples collected near nuclear power plants and those from other regions, except for slightly higher levels in well water, which are not considered practically significant. This is because whenever well water samples exceed the standard, continuous sampling and monitoring are implemented at those points.

The radioactivity levels vary across provinces, as the activity concentrations of natural radionuclides – particularly in groundwater – can vary significantly due to geological processes (*1*).

Among the monitored samples, certain individual monitoring points, primarily those involving well water and other underground sources, exhibited relatively high levels of gross alpha radioactivity (>0.5 Bq/L). These points have been monitored continuously for several years, with their radioactivity levels remaining stable. Radionuclide analysis confirmed that the primary contributors are natural uranium or radium-226. No industrial activities were found near these points that could introduce radioactive contamination. Because these locations are in mineral-rich regions of China, the elevated levels are inferred to result from geological formations.

Additionally, gross beta measurements include contributions from potassium-40, a naturally occurring beta emitter present in a fixed ratio to stable potassium. When the national standard guideline level of 1 Bq/L for gross beta is exceeded, the contribution of potassium-40 should be subtracted following a separate determination of total potassium (*1*–*2*). Monitoring data showed that gross beta activity concentrations – after subtracting potassium-40 – remained consistently below 1 Bq/L.

Natural radionuclides such as uranium and thorium decay series elements and potassium-40, which are commonly found in rocks and soils at low concentrations, may leach into groundwater. Therefore, they are more commonly found in drinking water derived from groundwater sources than surface water (*1*).

Based on the survey results, combined with drinking water consumption data (*2*) and dose coefficients given by the United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR (*14*), the annual effective dose from drinking water can be estimated. Generally, if the gross alpha activity concentration is below 0.5 Bq/L and gross beta below 1 Bq/L, no further action is required, as the annual dose from ingesting such water will not exceed 0.1 mSv, representing a very low health risk (*1*–*2*). However, to assess public radiation exposure in China, additional analyses of specific radionuclides – such as uranium, radium-226/228, and lead-210 – are required.

The monitoring points in this survey were distributed nationwide, providing preliminary baseline data on the radioactivity levels in drinking water. However, the data primarily covered urban and rural water sources from major cities (including areas near nuclear power plants), while smaller cities were excluded. This limits the detailed understanding of regional variations in radioactivity, necessitating additional monitoring points for more refined analysis.

Survey results demonstrate that China's drinking water poses an extremely low radioactivity risk, with minimal health implications for the public through water consumption. As a critical component of water safety assurance, long-term radioactivity monitoring is critical to enable timely water quality assessments, early warnings, and effective emergency response. It is imperative to enhance radionuclide-specific analyses and conduct comprehensive risk assessments in sensitive areas, particularly in the vicinity of nuclear facilities and associated mining operations.

Conflicts of interest: No conflicts of interest.

Acknowledgments: Each provincial CDC/occupational institute for reporting data.

doi: 10.46234/ccdcw2025.194

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Submitted: June 01, 2025
Accepted: August 28, 2025
Issued: September 05, 2025

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