Vital Surveillances

# National Monitoring for Radioactivity in Foods — China, 2012–2019

Fei Tuo[1]; Qiang Zhou[1]; Baolu Yang[1]; Xuan Peng[1]; Jing Zhang[1]; Quanfu Sun[1,#]

## ABSTRACT

**Introduction**: For investigating the potential contaminations from the applications of nuclear energy and techniques, the radioactivity of both natural and artificial radionuclides in foods in China were surveyed during the period of 2012–2019, and the public's exposure to radiation due to the consumption of these foods were estimated.

**Methods**: The surveillance was conducted using the National Monitoring Network for Radioactivity in Food from 2012 to 2019. Food samples were collected, and radioactivity was determined using HPGe gamma-ray spectrometer by local institutes.

**Results**: From 2012 to 2019, a total of 6,129 food samples including those collected around nuclear power plants and uranium mines were collected and analyzed, and no samples with activity concentrations of $^{238}$U, $^{228}$Ra, $^{226}$Ra, $^{40}$K, or $^{137}$Cs were found to exceed Chinese national standards. Among the 7 types of surveyed foods, the natural radionuclide levels of tea and seaweed were relatively high, and the activity concentration of $^{137}$Cs in milk and dairy products was higher than that of other foods.

**Conclusions and Implications for Public Health Practice**: The results of all the surveyed samples were within the scope of Chinese national standards. Different regions should improve monitoring systems, establish corresponding food emergency warning systems, and prepare strategies and measures for handling public health accidents.

## INTRODUCTION

With the rapid development and applications of nuclear energy and techniques, the potential radioactive contamination of foods has attracted great public concern. In 2012, the National Monitoring Network for Radioactivity in Food was established by the National Health Commission of the People's Republic of China, and the National Institute for Radiological Protection (NIRP) of China CDC was assigned to operate, maintain, and improve the network. From 2012 to 2019, with the help of provincial institutes, a total of 6,129 food samples that were categorized into 7 types of common foods in China were collected, and both the natural and anthropogenic originating radionuclides in the samples were analyzed.

## METHODS

According to the notifications, relevant technical documents, and operating manuals issued by the National Health Commission of the People's Republic of China, the relevant provincial monitoring institutes carried out food sample collection, preparation, processing, and radionuclide measurement every year. The technical principles for the collection and preservation of food samples were also carried out in accordance with the relevant standards (*1*).

Seven categories of foods including milk and dairy products, vegetables, tea, cereals and grains, livestock and poultry meat, fish and seafood, and seaweed were sampled. Foods were selected based on the main diet reported in relevant specification for health survey of residents (*2*). Other considerations such as potential risk for concentrating radionuclides and potential sentinels for specific types of agriculture or aquaculture (e.g. tea) were also considered. All foods were produced or sold locally.

Vegetables were collected in the open vegetable gardens in suburban areas. Fish and seafood as well as seaweed were collected or supplied by assistants of local fisheries. Samples were collected within a radius of 30 kilometers around nuclear power plants and uranium mines. Based on the radionuclide being studied and the laboratory conditions, the processing methods of the food samples could be prepared as fresh, ash, or dry samples before measuring. The dry-fresh ratio or ash-fresh ratio was recorded, and the results was expressed in fresh weight. The radionuclide activity concentration in the sample should be converted to the date of sampling in order to easily compare the results obtained by different processing methods.

All measurements were performed using low background gamma spectroscopy with standard coaxial HPGe detectors housed in Pb shielding with Cu, Cd, and/or plastic linings. Methods for analyzing radionuclides and the risk assessment of radioactive contamination in foods were based primarily on national standards (*3*–*5*). Measurements were performed in multiple laboratories with the typical relative efficiency of detection system ranging from 30% to 66% [relative to a 3"×3" NaI(Tl) crystal], and the typical energy resolution ranging from 1.60 keV to 2.28 keV at 1,332 keV ($^{60}$Co).

The nuclear data in Monograph 5 of the Bureau International des Poids et Mesures (*6*) were recommended to be used in the analysis. To determine the background gamma ray spectrum due to naturally occurring radionuclides in the environment around the detector, a similar empty container was usually counted in the same geometry as the samples. Peak detection efficiencies were calculated automatically by computer systems interfaced with multichannel analyzers. The absolute efficiency calibration of the detectors was determined using standard samples from the National Institute of Metrology (NIM) in Beijing, China. All internal and certified reference materials were prepared in the same containers as samples. Density correction was also performed by calculation software for samples where the density and matrix material were different from the standard. The expanded uncertainty $\mu_{total}$ ($K$=2) of the activity concentration was estimated by using the equation from the standard (*5*).

To ensure the accurate and reliable measurements, workloads for quality assurance were strictly implemented. All the instruments involved in the measurements were verified by the NIM, and all laboratories participated in the annual inter-comparison exercises organized by NIRP. NIRP was responsible for drafting the annual monitoring manual, training, and on-site guidance.

## RESULTS

From 2012 to 2019, a total of 6,129 food samples were collected and measured. Table 1 lists the mean values of radionuclides in different types of foods during the period of 2012–2019. Among all types of foods, tea had the highest mean concentrations of $^{238}$U and $^{228}$Ra at 2.88 Bq/kg and 1.75 Bq/kg, respectively, milk and dairy products were found with the highest mean concentrations of $^{226}$Ra and $^{137}$Cs at 1.13 Bq/kg and 0.79 Bq/kg, respectively, and seaweed had the highest concentration of $^{40}$K at 371 Bq/kg.

Table 2 shows the mean activity concentrations of different radionuclides in samples around the nuclear power plants during 2012–2019. Among the samples, the mean activity concentrations of $^{238}$U and $^{40}$K in seaweed were the highest, the mean activity concentrations of $^{228}$Ra and $^{226}$Ra in tea were the highest, and high activity concentration of $^{137}$Cs was found both in milk and tea.

Table 3 shows the mean activity concentrations in samples around the uranium mines during 2012–2019. The mean activity concentrations of $^{238}$U, $^{40}$K, and $^{226}$Ra in tea were the highest, the mean activity concentration of $^{228}$Ra in seaweed was the highest, and the mean activity concentration of $^{137}$Cs in milk and dairy products was the highest.

In 2 independent sample *t*-tests that were performed on data in Tables 2–3, differences in the radionuclide contents of fish and seafood were found between the two regions that were not statistically significant ($\alpha$ =0.05), and the content of $^{226}$Ra in milk and dairy products, $^{40}$K in vegetables, and $^{226}$Ra and $^{228}$Ra in

TABLE 1. Mean concentration (Bq/kg, wet weight) of radionuclides in different foods of China, 2012−2019.

| Food | No. of samples | $^{238}$U mean (95%CI) | $^{228}$Ra mean (95%CI) | $^{226}$Ra mean (95%CI) | $^{40}$K mean (95%CI) | $^{137}$Cs mean (95%CI) |
|---|---|---|---|---|---|---|
| Milk and dairy products | 646 | 2.15 (1.95−2.35) | 0.57 (0.51−0.63) | 1.13 (1.00−1.26) | 228.00 (218.90−237.10) | 0.79 (0.64−0.94) |
| Vegetables | 2,203 | 0.55 (0.51−0.59) | 0.29 (0.27−0.31) | 0.39 (0.29−0.49) | 102.00 (98.30−105.70) | 0.08 (0.07−0.09) |
| Tea | 430 | 2.88 (2.49−3.27) | 1.75 (1.52−1.98) | 1.09 (0.98−1.20) | 305.00 (282.60−327.40) | 0.33 (0.29−0.37) |
| Cereal | 1,264 | 1.76 (1.63−1.89) | 0.50 (0.46−0.54) | 0.62 (0.57−0.67) | 105.00 (98.00−112.00) | 0.20 (0.17−0.23) |
| Livestock and poultry meat | 653 | 0.94 (0.77−1.11) | 0.43 (0.36−0.50) | 0.46 (0.40−0.52) | 96.90 (82.63−111.17) | 0.23 (0.18−0.28) |
| Fish and seafood | 802 | 0.95 (0.84−1.06) | 0.94 (0.82−1.06) | 0.55 (0.47−0.63) | 67.50 (63.97−71.03) | 0.04 (0.037−0.042) |
| Seaweed | 131 | 2.47 (1.56−3.38) | 1.11 (0.90−1.32) | 0.56 (0.44−0.68) | 371.00 (265.68−476.32) | 0.03 (0.027−0.033) |

TABLE 2. Mean concentration (Bq/kg, wet weight) of radionuclides around nuclear power plants in China, 2012−2019.

| Food | No. of samples | $^{238}$U mean (95%CI) | $^{228}$Ra mean (95%CI) | $^{226}$Ra mean (95%CI) | $^{40}$K mean (95%CI) | $^{137}$Cs mean (95%CI) |
|---|---|---|---|---|---|---|
| Milk and dairy products | 202 | 1.09 (0.91−1.27) | 0.30 (0.27−0.33) | 1.20 (0.78−1.62) | 185.00 (169.00−201.00) | 0.32 (0.27−0.37) |
| Vegetables | 1,023 | 0.34(0.31−0.37) | 0.31 (0.28−0.34) | 0.23 (0.20−0.26) | 99.80 (96.24−103.36) | 0.05 (0.04−0.06) |
| Tea | 90 | 2.07(1.50−2.64) | 2.67 (1.98−3.36) | 1.51 (1.19−1.83) | 335.00 (282.11−387.89) | 0.32 (0.25−0.39) |
| Cereal | 336 | 0.95(0.85−1.05) | 0.60 (0.50−0.70) | 0.40 (0.36−0.44) | 92.90 (81.78−104.02) | 0.09 (0.08−0.10) |
| Livestock and poultry meat | 369 | 0.63 (0.42−0.84) | 0.31 (0.24−0.38) | 0.34 (0.25−0.43) | 68.30 (64.75−71.85) | 0.06 (0.04−0.08) |
| Fish and seafood | 768 | 0.96 (0.85−1.07) | 0.95 (0.82−1.08) | 0.55 (0.47−0.63) | 67.50(63.85−71.15) | 0.04 (0.038−0.042) |
| Seaweed | 109 | 2.49 (1.47−3.51) | 1.07 (0.84−1.30) | 0.57 (0.43−0.71) | 382.00 (257.90−506.09) | 0.03 (0.026−0.034) |

TABLE 3. Mean concentration (Bq/kg, wet weight) of radionuclides around the uranium mines in China, 2012−2019.

| Food | No. of samples | $^{238}$U mean (95%CI) | $^{228}$Ra mean (95%CI) | $^{226}$Ra mean (95%CI) | $^{40}$K mean (95%CI) | $^{137}$Cs mean (95%CI) |
|---|---|---|---|---|---|---|
| Milk and dairy products | 250 | 2.99 (2.60−3.38) | 0.55 (0.49−0.61) | 1.22 (1.00−1.44) | 268.00 (253.74−282.26) | 1.18 (0.87−1.49) |
| Vegetables | 590 | 0.99 (0.86−1.12) | 0.25 (0.22−0.28) | 0.76 (0.39−1.13) | 94.60 (85.08−104.12) | 0.17 (0.13−0.21) |
| Tea | 156 | 4.18 (3.37−4.99) | 2.22 (1.80−2.64) | 1.30 (1.10−1.50) | 405.00 (369.38−440.62) | 0.46 (0.38−0.54) |
| Cereal | 447 | 1.88 (1.62−2.14) | 0.45 (0.39−0.51) | 0.70 (0.60−0.80) | 143.00 (126.68−159.32) | 0.40 (0.33−0.47) |
| Livestock and poultry meat | 280 | 1.39 (1.09−1.67) | 0.65 (0.50−0.80) | 0.60 (0.53−0.67) | 137.00 (104.09−169.91) | 0.47 (0.36−0.58) |
| Fish and seafood | 27 | 0.58 (0.38−0.78) | 0.65 (0.30−1.00) | 0.58 (0.36−0.80) | 71.40 (59.00−83.81) | 0.05 (0.04−0.06) |
| Seaweed | 2 | 1.91 | 2.38 (1.26−3.50) | 0.78 (0.41−1.15) | 15.0 | – |

Note: "–" means not detected.

tea between the two regions were also not statistically significant (α =0.05). However, the differences of radionuclides in the remaining foods between the 2 regions were statistically significant (α =0.05).

## DISCUSSION

Assessing radionuclide contamination in food is an important consideration for food safety as understanding the levels of radionuclide content in food and their ranges are helpful for quantifying the risk of public exposure. This study presented the latest and most comprehensive national survey results in food from 2012 to 2019, which can be used as baseline data for food safety risk assessments. The radioactive survey also covered food around nuclear power plants and uranium mines, which is conducive to improving the ability and level of nuclear accident emergency monitoring.

Based on survey results and combining the food consumption data (*7*) and the dose coefficients given by ICPR (*8*), the annual committed effective dose of $^{238}$U, $^{228}$Ra, $^{226}$Ra, $^{40}$K, and $^{137}$Cs from ingestion were estimated to be 20.03, 110.24, 54.70, 242.72, and 0.84 μSv, respectively. The results were all below the limit values of the national standard. National monitoring results showed relatively higher levels of natural radionuclides in tea and seaweed than in other types of foods. This suggested that more attention should be paid to analyze the radioactivity levels in these foods, and the radiation doses due to the public consumption of these foods.

Cesium is an artificial radionuclide that researchers are usually concerned about. Similar to international studies, milk remains a suitable sentinel for artificial radioactivity Cesium in Chinese terrestrial agriculture (*9*–*10*). The results of milk and dairy products can serve as an indicator of artificial radionuclides like $^{137}$Cs, which is of great significance in emergency food monitoring. The contents of $^{137}$Cs in milk and tea in this survey were far lower than the national limit concentration standard (*11*) and complied with the detected activity concentrations in foods with the Codex Alimentarius guideline levels (*12*). This indicated they did not represent a radiological risk.

Data from nuclear power plants and uranium mines showed that the measured radionuclide concentrations were below national standards and did not pose a threat to public health. The differences in the radionuclides content of fish and seafood between the two places were not statistically significant, possibly due to the fluidity of the water and the wide range of activities of fish and seafood. The numbers of some food samples were small in these areas, and an appropriate increase in sample size will be considered in future surveillance.

Radionuclides in foods are an invaluable source of data for undertaking risk assessments for public health. The result of such surveys should be promptly released to the public, so that the public can understand the status of food safety. The National Monitoring Network for Radioactivity in Food can continue to provide a scientific basis for the health administrative department or disease control and prevention's decision making and improve early warning and control capabilities.

**Acknowledgments**: This work was supported by the National Health Commission. The authors would like to thank each local CDC and the prevention and treatment institution for occupational diseases for their hard work and reporting data.

**Conflict of interest**: No conflicts of interest were reported.

**doi:** 10.46234/ccdcw2020.146

# Corresponding author: Quanfu Sun, sunquanfu@nirp.chinacdc.cn.

---

[1] National Institute for Radiological Protection, Chinese Center for Disease Control and Prevention, Beijing, China.

Submitted: March 28, 2020; Accepted: June 11, 2020

## REFERENCES

1. IAEA. Measurement of radionuclides in food and the environment. Vienna: International Atomic Energy Agency (IAEA); 1989 Technical Report Series No. 295. https://inis.iaea.org/collection/NCLCollectionStore/_Public/20/041/20041399.pdf.
2. National Health and Family Planning Commission of the People's Republic of China. WS/T 440–2014 Specification for health survey of residents in the vicinity area of nuclear power plant. Beijing: China Standard Press, 2014.(In Chinese).
3. National Health and Family Planning Commission of the People's Republic of China. GB 14883.1–2016 National Food Safety Standard -- General rules for the examination of radioactive substances in foods. Beijing: China Standard Press, 2017 . (In Chinese).
4. General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Ministry of Health of the People's Republic of China. GB/T 16145-1995 Gamma spectrometry method of analysing radionuclides in biological samples. Beijing: China Standard Press, 2004 . (In Chinese).
5. General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, Standardization Administration of China. GB/T 11713-2015 General analytical methods of high-purity germanium gamma spectrometer. Beijing: China Standard Press, 2016 . (In Chinese).
6. Bureau International des Poids et Mesures. Monographie BIPM-5, table of radionuclides. https://www.bipm.org/en/publications/scientific-output/monographie-ri-5.html. [2020-03-28].
7. Ministry of Health of the People's Republic of China. GBZ/T 200.4-2009 Reference individuals for use in radiation protection—Part 4: Dietary component and intakes of elements. Beijing: People's Medical Publishing House, 2009 . (In Chinese).
8. International Commission on Radiological Protection. Compendium of dose coefficients based on ICRP Publication 60. ICRP Publication 119. Ann. ICRP 41 (Suppl l). 2012. http://www.icrp.org/docs/P%20119%20JAICRP%2041(s)%20Compendium%20of%20Dose%20Coefficients%20based%20on%20ICRP%20Publication%2060.pdf.
9. Hermanspahn N. Environmental radioactivity in New Zealand and Rarotonga: annual report 2006. 2007. https://www.moh.govt.nz/notebook/nbbooks.nsf/0/AA1E1E2081AEB42F4C2565D7000E0CB5/$file/environmental%20radioactivity%20new%20zealand%20raratonga%20annual%20report%202006.pdf. [2020-03-28].
10. Ministry for Primary Industries. Radionuclide testing in imported foods survey: imported foods monitoring programme. Wellington: Ministry for Primary Industries; 2013. Technical Paper No: 2013/26.
11. Ministry of Health of the People's Republic of China. GB 14882-1994 Limited concentrations of radioactive materials in foods. Beijing: China Standard Press, 1994. http://www.csres.com/detail/58809.html. (In Chinese).
12. Codex Alimentarius Commission. General standard for contaminants and toxins in food and feed. Codex Stan 193-1995. Codex Alimentarius. http://www.codexalimentarius.org/download/standards/17/CXS_193e2015.pdf.