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# Radionuclides in mushrooms and soil-to-mushroom transfer factors in certain areas of China

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ABSTRACT

Activity concentrations of $^{238}$U, $^{226}$Ra, $^{228}$Ra, $^{137}$Cs and $^{40}$K in 64 mushroom samples collected in China from Yunnan, Fujian and Heilongjiang Provinces, were measured. Gamma-ray emissions were determined by using high-purity germanium (HPGe) γ spectrometry. The range of concentrations (Bq kg$^{-1}$ dry weight) for $^{238}$U, $^{226}$Ra, $^{228}$Ra, $^{137}$Cs and $^{40}$K in all investigated mushroom samples were from 0.12 to 12, 0.05 to 7.5, 0.14 to 14, MDC(<0.01) to 339, and 396 to 1880, respectively. Activity concentrations of $^{137}$Cs in mushrooms showed some variation between species sampled at the same site. To calculate soil to mushroom transfer factors, levels of radionuclide in 15 paired soil samples and mushrooms were also investigated. The median transfer factors for $^{238}$U, $^{226}$Ra, $^{228}$Ra, $^{137}$Cs and $^{40}$K were 8.32 × 10$^{-2}$, 3.03 × 10$^{-2}$, 6.69 × 10$^{-2}$, 0.40 and 1.19, respectively. The results were compared with values of other areas.



## 1. Introduction and objectives

Mushrooms are often considered as excellent bioindicators for evaluation of environmental pollution, since they are known to accumulate metals and other elements (De Castro et al., 2012). Most radionuclides can also be bioaccumulated by mushrooms. Mushrooms are being researched in many studies related to radioecology. $^{137}$Cs in wild mushroom species can be detected consistently, due to atmospheric radioactive fallout in aerosol particle and precipitation form, initially as a result of the explosion of nuclear devices in the atmosphere, and subsequently the Chernobyl nuclear accident in 1986 (De Castro et al., 2012; Martine and Ramsey, 2008; Justin et al., 2013; Lehto et al., 2013; Baeza and Guillen, 2006; Vetikko et al., 2010). China is vast in territory, $^{137}$Cs values in mushrooms can be used to trace and evaluate fallout of radioactive from past and future nuclear accidents.

Furthermore, mushrooms are also consumed by man and directly eaten by animals. The European mushrooms in 1986–2010 may have given humans a greater amount of $^{137}$Cs compared to any other kind of food (Saniewski et al., 2016). Regular consumption of some types of mushroom species or animals that eat them may pose a human health concern (Martine and Ramsey, 2008). Therefore, it is important to have information on radioactivity concentration of mushrooms originated from China.

The aim of this study was to evaluate $^{238}$U, $^{226}$Ra, $^{228}$Ra, $^{137}$Cs and $^{40}$K activity concentrations in selected mushroom species and determine their transfer factors. Activity concentrations were determined in 64 mushroom samples. To calculate soil to mushroom transfer factors, 15 mushroom samples and their corresponding surface soil (0–5 cm) were collected to analyze their activity concentration.

## 2. Material and methods

### 2.1. Mushroom sampling and sample pre-treatment

A total of 64 wild mushroom samples were taken in this study, of which 59 were collected from pinewood ecosystem located in the around area of Nanhua county (100°52′E, 25°8′N), and Mangshi (98°24 E, 24°22 N), Yunnan Province. Mean altitude of the sampling sites was about 1100–1980 m, and they were about 100–200 km west from Kunming, capital of Yunnan. Three samples were collected from Heilongjiang Province, and two were collected from Fujian Province. All the sampling sites are far from Nuclear Power Plants (NPPs) or any nuclear installation areas. Geographical position of sampling site is shown in Fig. 1.

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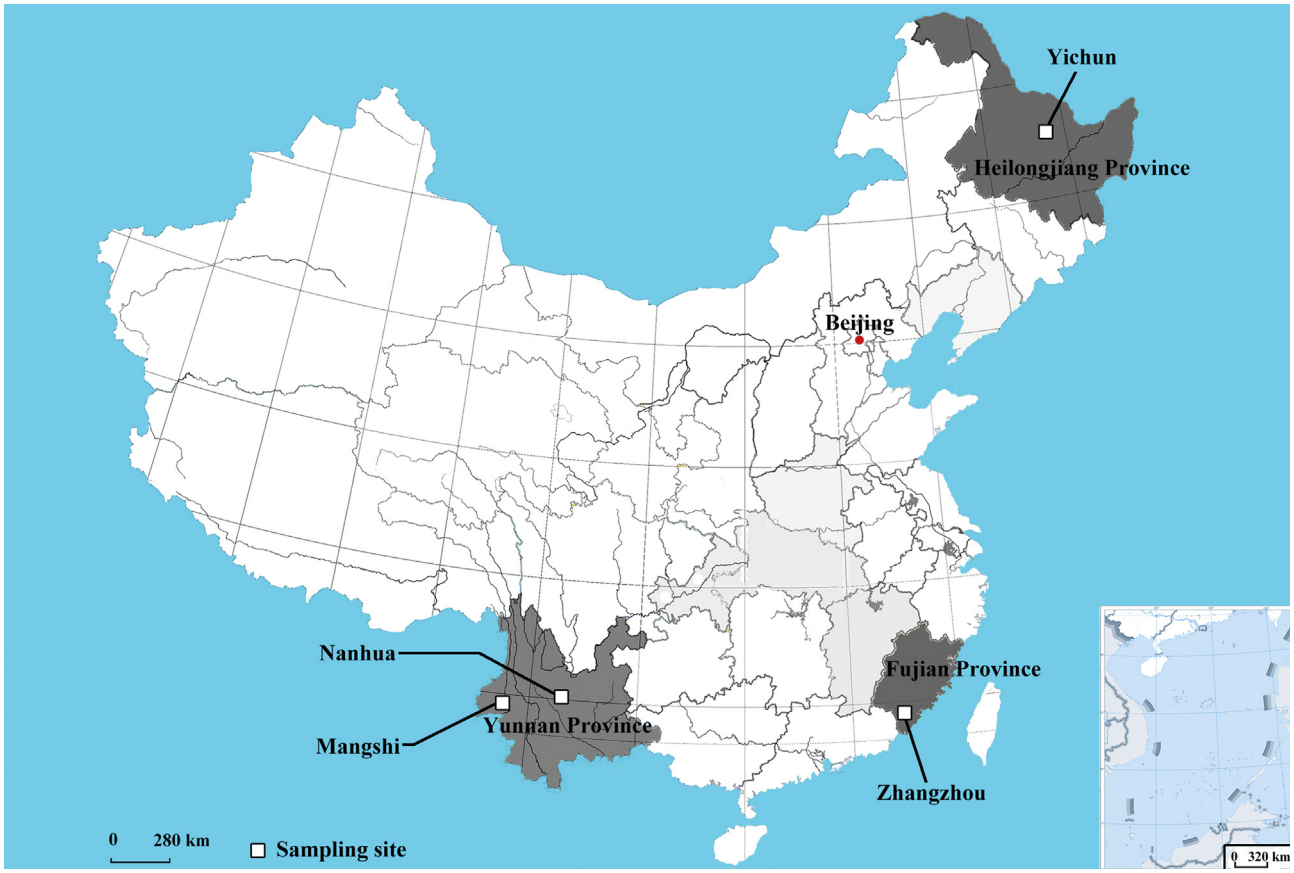


**Fig. 1.** Geographical position of sampling site.

After collection, the species of the mushrooms were identified at the Institute of Microbiology of the Chinese Academy of Sciences (IMCAS), and soil particles were removed from the fruiting bodies by washing with water. The collected mushrooms were named according to national standard for terms of mushroom (GB, 2006).

Samples were dried at 100 °C in an oven, and ground into powder. After this, they were homogenized in a domestic blender with Ti blades. Wet weight/dry weight conversion value is around 10–15. About 140 g dried mushrooms for each sample were weighed and placed in a polyethylene bottle (75 mm diameter by 70 mm height). In order to ensure that $^{222}$Rn did not escape, the top of the bottles were bound with adhesive tape to ensure a seal. The bottles were stored for approximately four weeks before the respective counting to allow for equilibrium of radium daughters.

### 2.2. Soil sampling and sample pre-treatment

In order to determine the soil to mushroom transfer factors, surface soil (0–5 cm) samples were collected concurrently with the five kinds of high productivity mushroom species mentioned above, and then they were placed separately in labeled polythene bags. There was vegetation and litter on the soil, during sampling they were removed. The latitude and longitude of each soil sampling site were recorded by GPS. The samples were then transferred to the laboratory, and types of soil were identified at School of Environment, Beijing Normal University. This identification indicated that all of the soils belonged to red soil. Red soil is a soil group of the Chinese Soil Genetic Classification, equivalent to Ferralsols (in Chinese Soil Taxonomy), Ferralsols (in World Reference Base for Soil Resources, WRB) or Ultisols (in US Soil Taxonomy). After the stones and pebbles were removed, soil samples were transferred to a porcelain dish and oven-dried overnight at about 110 °C. The dried samples were ground with mortar and pestle and then passed through a sieve with sample size less than 0.25 mm. The sieved samples were dry-weighed and sealed in a polyethylene bottle (75 mm diameter by 70 mm height), bound with adhesive tape to ensure that $^{222}$Rn did not escape. They were also set aside for at least four weeks to reach radioactive equilibrium before measurement.

### 2.3. Gamma spectrometry

The activities of gamma emitters in mushrooms were determined by a Compton effect suppressing gamma spectroscopy, the model was GR6019 (CANBERRA), using a N-type detector with 53% efficiency for 3″ × 3″ NaI(Tl) crystal, a 1.71 keV energy resolution for the 1332 keV $^{60}$Co peak, and a peak-to-Compton ratio of 57.5:1. This detector was coupled to a Compton effects suppressing device which enabled a reduction of the background, largely due to the Compton scatter of photons from $^{40}$K present in the samples, by a factor of 2 in the 661.6 keV energy region of the $^{137}$Cs emission. The software Genie 2000® was used for spectral analysis.

Efficiency data for this system was determined by using a set of simulated vegetation standard radionuclide sources from NIM (National Institute of Metrology, Beijing, China), the product code of standard radionuclide source was 14NDM/70-080501. By using the radionuclide solution from Eckert & Ziegler Analytics (EZA), NIM produced the simulated vegetation standard radionuclide source and maintained its traceability to NIST (National Institute of Standards and Technology, USA) by taking part in the inter-comparison