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Crustaceous lichens sensitive monitor of caesium-137 radiation level in terrestrial environment

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Abstract The activity of caesium-137 (Bq/kg) in the crustaceous lichens and other samples was determined to prove the feasibility that crustaceous lichens work as a sensitive biology monitor to record the caesium-137 (Bq/kg) radiation levels of terrestrial environment. The measurements were performed with GEM series HPGe (high-purity Germanium) coaxial detector system (ADCAM -100) made by EC & GORTEC Company in USA. It was found that the activity of caesium-137 (Bq/kg) in the crustaceous lichens was one order of magnitude higher than that found in surface soil, and was over three orders of magnitude higher than those found in the familiar biological samples. These results proved that crustaceous lichens may be one of the most sensitive biological monitors about the remote transmission and environmental radiation levels of caesium-137.

Key words Crustaceous Lichens, Sensitive Monitor, Activity of Caesium-137.

1 Introduction

Caesium-137 is a radioactive isotope with a half-life 30.2 a which is released in the atmospheric testing of nuclear weapons and operating of nuclear reactors. Its main resources lie in the middle and high latitude zones of the Northern Hemisphere and the central area of Australia (Ritchie and Mchenry 1990; Walling and He 1999). Due to its longer half-life, Caesium-137 diffuses worldwide by atmosphere circulation and falls to the ground in the forms of dry deposition and wet deposition, then it is strongly and rapidly adsorbed by organic particles and soil particles (Zhao *et al.* 1999). Due to the long period of atmospheric nuclear tests and other nuclear activities, caesium-137 had accumulated in the terrene and polluted the terrestrial environment. Wang *et al.* (2001) reported that the average dose rate of caesium-137 gamma radiation in the terrestrial environment of China was $7 - 18 \times 10^{-10}$ Gy · h^{-1}, which accounted for 1% - 3% of the gross-gamma radiation dose rate in the terrestrial environment. This is equal to the radiation level of any inartificial radionuclide. And so, it is necessary to monitor the Caesium-137 radioactivity in order to know the radiation level of the terrestrial environment. Zhu (1994) considered that it was not feasible to monitor the radioactive isotope with even lower energy by increasing the sample quan-

tity, prolonging the testing time, or developing more advanced instruments. Some sensitive biology which can accumulate radioactive isotope will work in monitoring terrestrial radiation level.

The crustaceous lichens are the communities of epiphytes and algae. The algae produce organic materials, while epiphytes adsorb water and envelop the algae. Epiphytes and algae benefit each other (David and Francis 1975). The crustaceous lichens consist of epidermis stratum, algae stratum and marrow stratum. The concentration mechanism of crustaceous lichens is related to their physiological characteristics and habitat: First, crustaceous lichens have wide tolerance. They can endure coldness and drought, and grow in most places in the world except the cities and districts which are polluted seriously. Secondly, crustaceous lichens are not vascular bundle plants and have larger surface acreage. The mode of crustaceous lichens obtaining nutriment from the environment is the surface-adsorption processes, which make crustaceous lichens absorb the aerosol substance easily. Thirdly, crustaceous lichens occur extensively on the surface of bare bedrock and gravels of very steep cliff, hardly covered by snow and ice. Thus crustaceous lichens can absorb and accumulate caesium-137 throughout the year. Besides, the longer growth period of crustaceous lichens also helps to accumulate caesium-137 sufficiently from the circumstance. The purpose of this paper is to show that the crustaceous lichen is a proper monitor to record the caesium-137 (Bq/kg) radiation levels in the terrestrial environment.

2 Experment

7 samples from Antarctica were collected during the 9th Chinese Antarctic Research Expedition in 1993, including 2 samples of crustaceous lichens, 2 samples of fruticose lichens (Usnea antarctica), one sample of surface moss (0 −5 cm) and 2 samples of surface soils (0 −5 cm). Table 1 represents the geographical location of the 7 samples in Antarctica. The samples were dried in an oven at 105 ℃ for 24 hours, then were pulverized and weighed, and they were kept in polyethylene bags respectively in the laboratory of the Great Wall Station. 2 samples of the crustaceous lichens were collected in the Wuling Mountain National Natural Protection Region, Hebei Province and Mianchi County, Henan Province in the summer of 1994. 2 samples of surface soils were collected in Fengning County, Hebei Province in the summer of 2002. Table 1 shows the geographical locations of these samples. These samples were hardly affected by the modern industry, and they were pretreated as the same procedures.

All the samples were weighted accurately, and were put flatly into the plastic caddies which were 75 mm in diameter and 25 mm in height. The caddies were accordant, and sealed, and put on the detector directly. The ^{137}Cs activities of the samples were measured with GEM series HPGe (high-purity Germanium of EC & G ORTEC Company in USA), which was equipped with the coaxial detector system (ADCAM -100) with energy resolution of 1.71 keV. The samples were measured at 1332 keV line of ^{60}Co and a detection efficiency of 52%. The background counting rate in the detector is about 3 cps in the energy rang of 30 −2000 keV. The detector lies in the lead shield chamber, the thickness of which is 10 cm and the inner size is 60 cm × 60 cm × 60 cm. The measuring time is according to the radiation level of the samples. The measurements ended when the counting error is less than

10%, else the measurements should be continued till the counting error gets to the line. The instrument is equipped with the analysis software A66-B32 which has the function of capturing data, scaling and analyzing. The checking of it is according to the γ-ray spectrometry analysis of environment sample the standard GB 11743-89. The measuring time for the samples was $(1-8)\times10^4$ seconds in this case, and the results were shown in table 1.

Table 1. The location and the ^{137}Cs activity * of the samples

Sample code	Geographical location		^{37}Cs/Bq/kg
	Sample site	Latitude longitude altitude	
93 - 1 Cr. lichen	Great Wall Station, Antarctic	62°13′S, 58°57′W, 10 m	58.07 ± 14.52
93 - 2 Cr. lichen	Great Wall Station, Antarctic	62°13′S, 58°57′W, 10 m	56.38 ± 14.18
93 - 3 Fr. lichen	Great Wall Station, Antarctic	62°13′S, 58°57′W, 10 m	29.04 ± 8.29
93 - 4 Fr. lichen	Great Wall Station, Antarctic	62°13′S, 58°57′W, 10 m	29.87 ± 8.45
93 - 5 Moss (0 - 5 cm)	Great Wall Station, Antarctic	62°13′S, 58°56′W, 10 m	25.07 ± 2.14
93 - 6 Soil (0 - 4 cm)	Great Wall Station, Antarctic	62°12′S, 58°57′W, 10 m	14.83 ± 1.56
93 - 7 Soil (0 - 5 cm)	Great Wall Station, Antarctic	62°13′S, 58°57′W, 10 m	6.14 ± 0.62
94 - 1 Cr. lichen	Wuling Mountain, Hebei Province	40°34′N, 117°29′E, 1900 m	311.78 ± 25.14
94 - 3 Cr. lichen	Mianchi County, Henan Province	35°10′N, 111°52′E, 200 m	294.69 ± 35.81
02 - 1 Soil (0 - 5 cm)	Fengning County, Hebei Province	41°32′N, 116°06′E, 1560 m	17.10 ± 1.61
02 - 2 Soil (0 - 5 cm)	Fengning County, Hebei Province	41°32′N, 116°06′E, 1560 m	10.68 ± 1.24

* The ^{137}Cs activity (1994) was calculated with the radioactive half-life of 30.2 years.

3 Results and discussion

According to the results shown in table 1, the ^{137}Cs has been found in the terrestrial ecosystem in Antarctica far away from the nuclear testing area. It was shown that the ^{137}Cs activities of the crustaceous lichens were over 56.38 ± 14.18 Bq/kg; the ^{137}Cs activities in Antarctic fruticose lichens were 29.04 Bq/kg; the ^{137}Cs activities in surface moss were about 25.07 Bq/kg; and those in surface soils were more lower, the activity difference had correlation with the character of soil and the content of organic materials. Baeza *et al.* (1984) measured the samples in the Livingston Island which is near the King George Island. According to his report, the ^{137}Cs activities of the fruticose lichens there were 17.2 ± 0.3 Bq/kg, the ^{137}Cs activities in surface moss were about 3.6 ± 0.1 Bq/kg, the ^{137}Cs activities in algae were less than 0.012 Bq/kg, and the ^{137}Cs activities in land freshwater and seawater were 0.33 ± 0.11 mBq/L and 0.20 ± 0.12 mBq/L respectively (Baeza *et al.* 1984). Desideri *et al.* (2003) reported that ^{137}Cs was observed in the mosses, algae and lichens in the littoral of Antarctica (75°S, 165°E), where the ^{137}Cs activities of lichens (Usnea antarctica) were 47.5–162.0 Bq/kg (ash substance), the ^{137}Cs activities in surface moss were 11.3–49.9 Bq/kg, and the ^{137}Cs activities in surface soils were 0.1–1.4 Bq/kg. It is obvious that the influence of nuclear activities has extended to the Antarctic by the atmosphere circumfluence.

The circumstances where the samples were collected in North China are all typical terrestrial ecosystems, and the places are far away from modern industry. The ^{137}Cs activities of the crustaceous lichens there were over 294.69 ± 35.81 Bq/kg, the ^{137}Cs activities in

surface moss were about 10 – 17 Bq/kg, which was related to the character and erosion of the soil. Chang Hong *et al.* (1995) reported that the ^{137}Cs activities of Gansu Province were 0.034, 0.033, 0.019, 0.10 and 0.022 Bq/kg in corn, vegetable, fruit, meat and milk. Zhu Ana (2000) reported that the ^{137}Cs activities of Qinghai Province was 0.0327 ± 0.0157, 0.0323 ± 0.0187, 0.1890 ± 0.1284, 0.0383 ± 0.0134 and 0.0052 ± 0.0024 Bq/kg in flour, cabbage, celery, milk and drinking water respectively.

4 Conclusion

It was found that the activity of caesium-137 (Bq/kg) in the crustaceous lichens in North China was one order of magnitude higher than that found in surface soil, and was over three orders of magnitude higher than those found in corn, vegetable, fruit, eggs, milk and meat. And the activity of caesium-137 (Bq/kg) in the crustaceous lichens in North China was one order of magnitude higher than that found in the Antarctica. So the crustaceous lichens may be one of the most sensitive biological monitors of caesium-137 remote transmission and environmental radiation level.

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References

Baeza A, Miro C, Paniagua JM *et al.* (1984): Natural and Artificial Radioactivity Levels in Livingston Island (Antarctic Regions). Environ. Contamin. & Toxic., 6:85.

Chang H, Bai SM, Zhao GF *et al.* (1995): Research on radionuclide level of biological samples and terrain distribution in Lanzhou. Gansu Environmental Study and Monitoring, 8(4):1 – 5 (in Chinese).

David LH, Francis R (1975): Lichens as pollution monitors. London: Edward Arnold.

Desideri D, Giuliani S, Testa C, Triulzi C (2003): ^{90}Sr, ^{137}Cs, ^{238}Pu, $^{239+240}Pu$ and ^{241}Am levels in terrestrial and marine ecosystems around Italian base in Antarctica. Journal of Radioanalytical and Nuclear Chemistry, 258(2): 221 – 225.

Ritchie JC, Mchenry JR(1990): Application of radioactive fallout ^{137}Cs for measuring soil erosion and sediment accumulation rates and patterns: A review. Journal of Environmental Quality, 19:215 – 233.

Walling DE, He Q (1999): Improved models for estimating soil erosion rates from Caesium-137 measurement. Journal of Environmental Quality, 28:611 – 622.

Wang SL, Jiang RR, Wang L (2001): Gamma dose rate contribution of artificial radioactive nuclide ^{137}Cs on the land in China. Nuclear Techniques, 24(2):144 – 148 (in Chinese).

Zhao Y, Li TJ, Xu CH(1999): ^{137}Cs level in terrestrial ecosystem around the Great Wall Station in Antarctic and the geographical sense. Progress in Natural Science, 9(2):172 – 174 (in Chinese).

Zhu Ana (2000): ^{90}Sr and ^{137}Cs level of environmental samples. Ind. Helth & Occu. Dis., 26(3):162 – 164 (in Chinese).

Zhu CS(1994): Analysis on the status of monitoring environmental radioactivity pollution in China. Chinese Journal of Radiological Medicine and Protection, 14(5):291 – 292 (in Chinese).