Radioactivity level of soil around a coal-fired thermal power plant of northwest China

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► ***Short Report***

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ABSTRACT

Background: The activity concentrations of natural radionuclides in soil around a coal-fired thermal power plant of northwest China were investigated for assessing the radioactivity level. ***Materials and Methods***: Soil samples were collected around the coal-fired thermal power plant and their radioactivity levels were determined using gamma ray spectrometry. Radiation hazards were assessed by radium equivalent activity (Ra_{eq}), air absorbed dose rate (*D*) and annual effective dose equivalent (*AEDE*). ***Results***The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K ranged from 24.7 to 89.8, 38.4 to 122.3 and 206.7 to 573.8 Bq kg^{-1} with an average of 49.7, 63.5 and 396.3 Bq kg^{-1}, respectively. The mean Ra_{eq} value was less than the recommended limit, while the mean values of *D* and *AEDE* were slightly higher than the corresponding world average. ***Conclusion:*** The coal-fired thermal power plant enhanced the natural radiation of surrounding soil environment.

Keywords: *Radioactivity, gamma ray spectrometry, radiation hazard, soil; coal-fired thermal power plant.*

INTRODUCTION

All living organisms are continuously exposed to ambient ionizing radiation, which has always existed naturally [(1)]. Natural radionuclides are widely spread in rock, soil and sediment [(1-3)]. Natural radioactivity of soil and associated radiation hazard depend primarily on geological and geographic conditions of the region [(1-4)]. Moreover, human activities can influence the radioactivity level of soil. The knowledge of natural radioactivity in soil is important for evaluating the radiation exposure to the population and is useful to set the standards and national guidelines in the light of international recommendations [(5)].

In modern times, the demand for electricity throughout the world is ever increasing with the economic growth and advanced standard of human living [(5,6)]. Coal, the most abundant natural resource, plays an important role in electricity generation. Natural radionuclides will discharge into the surrounding of coal-fired thermal power plant (CFTPP) with coal combustion. In recent decades, numerous works were conducted on natural radioactivity of soil around CFTPP [(5, 7-12)]. Due to the diversity of coal and deducting technology in each power plant, as well as the difference of the meteorological conditions, it is necessary to investigate the natural radioactivity of soil around different CFTPP.

Xitulvye CFTPP with a 120 m stack is situated at southwest of Baotou city (figure 1). Baotou, an important industrial city in northern China, has a typical temperate continental semi-arid climate, with annual average temperature and precipitation of 6.5°C and 240-400 mm, respectively. ^{226}Ra, ^{232}Th and ^{40}K activity concentrations in soil around Xitulvye CFTPP were determined in the study for evaluating the influence of thermal power plant on local environmental radioactivity. The results could be useful for radiation protection and environmental management.

MATERIALS AND METHODS

Samples

Soil samples were collected around Xitulvye CFTPP, China (figure 1). At every sampling location, four samples were collected from the surface layer (0-15 cm) of four corners of a square area (2 m × 2 m) and then mixed. Each sample weighed 1.5 kg. Thirty-six samples were collected around the CFTPP, at a distance of 300, 800 and 1500 m in this manner (figure 1). At the lab, the collected samples were dried in an oven at 105-110 °C until a constant weight was achieved. The dried samples were ground and sieved through a fine mesh to remove plant materials and pebbles etc. The ground samples were weighed and stored in cylindrical plastic containers. The containers were sealed and stored for at least four weeks to reach secular equilibrium between ^{226}Ra and ^{232}Th and their progenies [6].

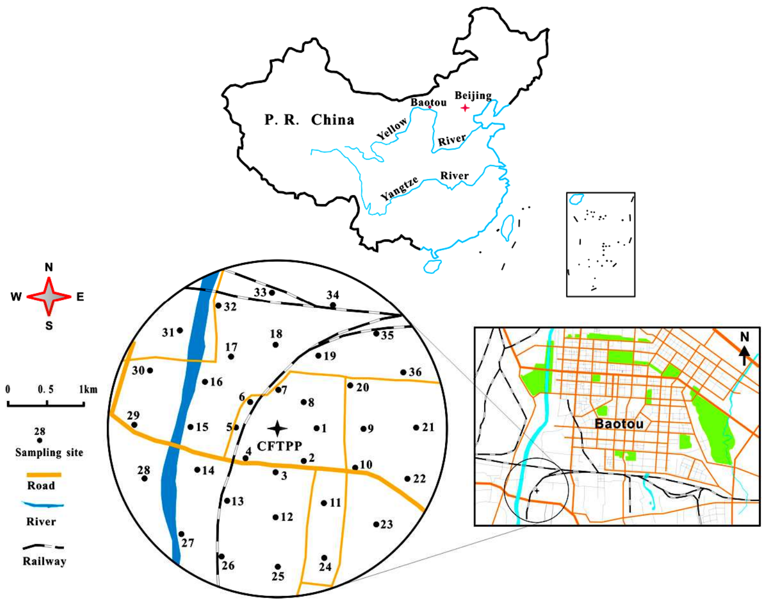

Figure 1. Location of Xitulvye coal-fired thermal power plant (CFTPP) and sampling site.

Radioactivity measurement

A 3×3 inch NaI (Tl) detector with excel 8% energy resolution (^{137}Cs 661.6 keV) and 20% counting efficiency coupled to a 1024 multichannel analyzer was used for radioactivity measurement [5]. The activity of ^{232}Th was determined by 238.6 keV and 2614 keV gamma rays emitted from ^{212}Pb and ^{208}Tl, respectively. The activity of ^{226}Ra was measured by 609.3 and 1764.5 keV gamma rays emitted from ^{214}Bi, whereas ^{40}K activity was measured directly through its gamma ray energy peak of 1460.8 keV. All samples were counted for 300 min [5]. Each sample was counted four times before an average was calculated. Excel 2010 and SPSS 19.0 for windows were used to analyze the data.

RESULTS AND DISCUSSION

Table 1 shows the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soil around Xitulvye CFTPP. It can be found that ^{40}K was the major contributor (50.3-89.4%) of the total activity (the sum of ^{226}Ra, ^{232}Th and ^{40}K) in the samples. ^{226}Ra and ^{232}Th mean concentrations in the investigated soil were higher than the soil average of Baotou [13], China and World [1], while ^{40}K mean concentration was lower than the soil average of Baotou [13], China and World [1]. The concentrations of ^{226}Ra and ^{232}Th in the soil decrease with the distance increasing from sampling sites to the CFTPP, whereas ^{40}K is contrary (table 1). This is particularly evident in the samples collected from the southeast of

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Xitulvye CFTPP. These may be related with wind direction and the deposition of fly ash. The predominant wind direction of the study area is northwest. Four fly ash samples were simultaneously collected from Xitulvye CFTPP and their ^{226}Ra, ^{232}Th and ^{40}K activity concentrations varied from 85.7 to 93.7, 124.5 to 132.3 and 143.2 to 290.9 Bq kg^{-1} with an average of 89.9, 128.6 and 165.6 Bq kg^{-1}, respectively. The discharging and depositing of fly ash to the surrounding environment during coal combustion will enhance ^{226}Ra and ^{232}Th and dilute ^{40}K in the surrounding soil of the CFTPP. Comparison of natural radionuclide in soil around Xitulvye CFTPP with other CFTPPs from different countries including China [5,7-12,14,15] is in table 2.

Table 1. Natural radioactivity in soil samples around Xitulvye coal-fired thermal power plant (CFTPP).

Soil	Activity concentration (Bq kg^{-1})			Ra_{eq} (Bq kg^{-1})	*D* (nGy h^{-1})	*AEDE* (mSv y^{-1})
	^{226}Ra	^{232}Th	^{40}K			
300 m to CFTPP	66.5-89.8 (77.4±8.6)	89.2-122.3 (102.1±11.0)	206.7-254.7 (226.4±16.7)	213.7-281.2 (240.8±22.6)	96.8-126.5 (108.6±10.0)	0.119-0.155 (0.133±0.012)
800 m to CFTPP	42.6-71.3 (56.2±10.7)	47.9-92.1 (65.4±15.9)	246.9-389.8 (329.8±41.3)	141.1-224.8 (175.1±30.5)	65.6-102.0 (80.3±13.3)	0.080-0.125 (0.098±0.016)
1500 m to CFTPP	24.7-42.3 (30.2±6.2)	38.4-47.9 (42.8±3.1)	436.9-573.8 (531.2±39.9)	121.9-146.9 (132.2±7.3)	57.9-69.1 (62.6±3.2)	0.071-0.085 (0.077±0.004)
Study area	24.7-89.8 (49.4±20.8)	38.4-122.3 (63.5±25.4)	206.7-573.8 (396.3±133.0)	121.9-281.2 (170.6±47.2)	57.9-126.5 (78.7±20.1)	0.071-0.155 (0.097±0.025)
Baotou [13]	25.9	37.4	530.8	120.3 [a]	60.7 [b]	0.074 [a]
China [1]	32	41	440	124.5 [a]	62	0.076 [a]
World [1]	32	45	420	128.7 [a]	59	0.07

The digit in parenthesis is mean±SD

[a] The value was calculated by the mean activity of radionucles in soil; [b] Li et al. (1990) [16].

Table 2. Comparison of natural radioactivity in soil around different coal-fired thermal power plant.

CFTPP, Country	Activity concentration (Bq kg^{-1})			References
	^{226}Ra	^{232}Th	^{40}K	
Cayırhan, Turkey	47.00	32.54	646.29	(7)
Afsin-Elbistan, Turkey	33	36	379	(8)
Agios Dimitrios, Greece	26.8	36.8	492.6	(9)
West Macedonia, Greece	24.3	21.3	340.7	(12)
Ajka, Hungary	129	26.9	337	(11)
India	37.0	69.6	396.0	(10)
Phalai, Vietnam	76	235	850	(14)
Ninhbinh, Vietnam	70	230	830	(14)
Baoji, China	32.12	49.77	720.57	(15)
Baqiao, China	36.1	51.1	733.9	(5)
Xitulvye, China	**49.7**	**63.5**	**396.3**	**Present study**

Radium equivalent activity (Ra_{eq}) [3-5], outdoor air absorbed dose rate (*D*) [4,5] and annual effective dose equivalent (*AEDE*) [3-5] were calculated to evaluate the radiological hazard of radionuclides in soil to local inhabitants and the results are shown in table 1. The Ra_{eq} values in the soil were lower than the recommended limit of 370 Bq kg^{-1} [1], while exceeded the mean Ra_{eq} values of Baotou soil, Chinese soil and worldwide soil, calculated by the mean activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K. The *D* values in most samples were higher than the population-weighted average of global primordial radiation of 59 nGy h^{-1} [1], the

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means of natural gamma radiation dose rate of China (62.0 nGy h^{-1}) [1] and Baotou (60.7 nGy h^{-1}) [16]. The *AEDE* values in the investigated soil varied from 0.071 to 0.155 mSv y^{-1} with mean of 0.097 mSv y^{-1}, which was slightly higher than the mean value of Baotou and China, as well as the external worldwide average annual effective dose rate (0.07 mSv y^{-1}). ^{226}Ra and ^{232}Th were significantly correlated with *D* and *AEDE* at P<0.01, indicating that the radiological hazard of the soil were mainly caused by ^{226}Ra and ^{232}Th.

CONCLUSION

^{232}Th and ^{226}Ra mean concentrations in soil around Xitulvye CFTPP were higher than, while ^{40}K mean concentration was lower than the average concentration of Baotou soil and Chinese soil and the worldwide population-weighted average in soil. The study showed that Xitulvye CFTPP influenced its surrounding soil radioactivity level and enhanced the local natural radiation. So the emissions management of CFTPP ash should be strengthened and the natural radioactivity of soil around Xitulvye CFTPP should be monitored periodically.

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Conflicts of interest: *Declared none.*

REFERENCES

1. UNSCEAR-United Nations Scientific Committee on the Effects of Atomic Radiation (2000) Sources and effects of Ionizing radiation. Report to the General Assembly with Scientific Annexes. United Nations, New York.
2. Usikalu MR, Maleka PP, Malik M, Oyeyemi KD, Adewoyin OO (2015) Assessment of geogenic natural radionuclide contents of soil samples collected from Ogun State, South western, Nigeria. *Int J Radiat Res, **13:** 355–361*.
3. Ajayi OS and Ibikunle SB (2013) Radioactivity of surface soils from Oyo state, South Western Nigeria. *Int J Radiat Res, **11:** 271–278*.
4. Rahman S, Matiullah, Mujahid SA, Hussain S (2008) Assessment of the radiological hazards due to natural occurring radionuclides in soil samples collected from the north western areas of Pakistan. *Radiat Protect Dosim, **128:** 191–197*.
5. Lu X, Zhao C, Chen C, Liu W (2012) Radioactivity level of soil around Baqiao coal-fired power plant in China. *Radiat Phys and Chem, **81:** 1827–1832*.
6. Ferdous J, Begum A, Islam A (2015) Radioactivity of soil at proposed Rooppur Nuclear Power Plant site in Bangladesh. *Int J Radiat Res, **13:** 135–142*.
7. Cevik U, Damla N, Nezir S (2007) Radiological characterization of Cayırhan coal-fired power plant in Turkey. *Fuel, **86:** 2509–2513*.
8. Cevik U, Damla N, Koz B, Kaya S (2008) Radiological characterization around the Afsin-Elbistan Coal-fired power plant in Turkey. *Energ Fuels, **22:** 428–432*.
9. Karamanis D, Ioannides K, Stamoulis K (2009) Environmental assessment of natural radionuclides and heavy metals in waters discharged from a lignite-fired power plant. *Fuel, **88:** 2046–2052*.
10. Mishra UC (2004) Environmental impact of coal industry and thermal power plants in India. *J Environ Radioact **72:** 35–40*.
11. Papp Z, Dezső Z, Daróczy S (2002) Significant radioactive contamination of soil around a coal-fired thermal power plant. *J Environ Radioact, **95:** 191–205*.
12. Tsikritzis LI (2004) Chemometry of the distribution and origin of ^{226}Ra, ^{228}Ra, ^{40}K and ^{137}Cs in the soil near the lignite fired plants of West Macedonia (Greece). *J Radioanal Nucl Chem, **261:** 215–220*.
13. Zhang B, Li W, Fu Z, Chen J, Zheng L, Du X, Fu S, Zhang W, Zhang W (1991) Survey of natural radionuclide contents in soil in Inner Mongolia. *Radiat Protect **11(5):** 370–374* (in Chinese).
14. Duong PV, Thanh VT, Dien PQ, Binh NT (1995) Application of nuclear activation analysis (NAA) and low-level gamma counting to determine the radionuclide and trace element -pollutant releases from coal-fired power plants in Vietnam. *Sci Total Environ, **173/174:** 339–344.*
15. Wang L and Lu X (2007) Natural radionuclide concentrations in soils around Baoji coal-fired power plant, China. *Effect Deffect Solids, **162:** 677–683*.
16. Li W, Du X, Zhang B, Fu S, Chen J, Zhang W (1990) Investigation of environmental natural penetrating radiation level in Inner Mongolia. *Radiat Protect, **10(6):** 435-448* (in Chinese).

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