# Radioactive analysis and radiological hazards of sand in Weifang, China

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▶ ***Short report***

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## ABSTRACT

***Background:*** The activity concentrations of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in sand used as building material in Weifang of China were investigated for evaluating the radiation hazard. ***Materials and Methods:*** Sand samples were collected from Weifang and their radioactivity levels were measured using gamma-ray spectrometry. The radiation hazard for residents was assessed by radium equivalent activity ($Ra_{eq}$), indoor air absorbed dose rate ($D$), annual effective dose ($AED$) and excess lifetime cancer risk ($ELCR$). ***Results:*** The activity concentrations of $^{226}Ra$, $^{232}Th$ and $^{40}K$ ranged from 11.7 to 23.0, 33.6 to 126.1 and 353.2 to 924.8 Bq kg$^{-1}$ with averages of 15.5, 70.3 and 802.9 Bq kg$^{-1}$, respectively. All $Ra_{eq}$ values were lower than the limit of 370 Bq kg$^{-1}$. The mean value of $D$ was higher than the world population-weighted average of 84 nGy h$^{-1}$, while the mean $AED$ and $ELCR$ values were below the internationally accepted values. ***Conclusions:*** The use of sand in construction of dwellings is considered to be safe for inhabitants.

***Keywords:*** *Gamma-ray spectroscopy, natural radioactivity, radiation hazard, excess lifetime cancer risk, sand.*

## INTRODUCTION

Natural radionuclides $^{226}Ra$, $^{232}Th$ and $^{40}K$ widely spread in rock, soil, sediment and building materials (1-3). Building materials are the main source of indoor gamma radiation besides terrestrial and cosmic radiations as individuals spend about 80% lifetime at home and/or office (2). $^{226}Ra$, $^{232}Th$ and $^{40}K$ concentrations in building materials depend on their geochemical compositions (4-6). It is important to measure the activity concentrations of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in building materials from different places for estimating the radiological hazards to residents.

Weifang, the world's kite metropolis, is located at the east of Shandong province of China (figure 1), with a population of approximately 9,086,000. The aims of this work were to measure the activity concentrations of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in sand used as building materials in Weifang using gamma-ray spectrometry and to assess the corresponding radiological hazards to individuals using radium equivalent activity, indoor air absorbed gamma dose rate, annual effective dose and excess lifetime cancer risk. The obtained results were compared with the recommended values and the similar studies carried out in other areas.

## MATERIALS AND METHODS

### *Samples*

Thirteen sand samples were collected randomly from local supplies and construction sites of Weifang, China. Each sample was ground to a finer power with a particle size < 0.16 mm and dried at 110°C for 24 h in an oven to ensure that moisture was completely removed (7-10). The dried samples were weighted and stored in gas-tight, radon impermeable and polyethylene containers to prevent the escape of $^{222}Rn$ and $^{220}Rn$ from the samples (8). The containers were

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kept more than 4 weeks to ensure radioactive equilibrium [7,8].

***Measurement of radioactivity***

The activity concentrations of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in the sand were determined using a 3 × 3 inch NaI (Tl) gamma-ray spectrometric system with >8% energy resolution ($^{137}Cs$ 661.6 keV) [7]. The detector, maintained in a lead cylindrical shield of 10.5 cm thickness and 38 cm height, was coupled to a 1024 multichannel pulse height analyzer and the system was calibrated for the gamma-energy range from 50 keV to 3.2 MeV [7]. The activity of $^{232}Th$ was measured by 238.6 keV and 2614 keV gamma rays emitted from $^{212}Pb$ and $^{208}Tl$, respectively. The activity $^{226}Ra$ 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 [7-9]. The standard sources of $^{226}Ra$ and $^{232}Th$ were prepared using known activity contents and mixing with the matrix material of phthalic acid powder [8]. The standard source of $^{40}K$ used analytical grade potassium chloride (99.99% purity) of known mass and the same geometry. All samples were counted for 300 min and each sample was counted twice before an average was calculated. The relative errors of twice measurement data for $^{226}Ra$, $^{232}Th$ and $^{40}K$ in all samples are <5%. Excel 2010 and SPSS 19.0 for windows were used to analyze the data.

## RESULTS AND DISCUSSION

The activity concentrations of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in the investigated sand samples ranged from 11.7 to 23.0, 33.6 to 126.1 and 353.2 to 924.8 Bq kg$^{-1}$ with averages of 15.5, 70.3 and 802.9 Bq kg$^{-1}$, respectively, as shown in figure 2. The average concentration of $^{226}Ra$ in the sand samples was lower than the corresponding average value of Chinese soil (37.6 Bq kg$^{-1}$) and the worldwide population-weighted average value (32 Bq kg$^{-1}$) in soil [2]. The mean values of $^{232}Th$ and $^{40}K$ concentrations of sand from Weifang were higher than the average values of Chinese soil (54.6 and 584 Bq kg$^{-1}$, respectively)

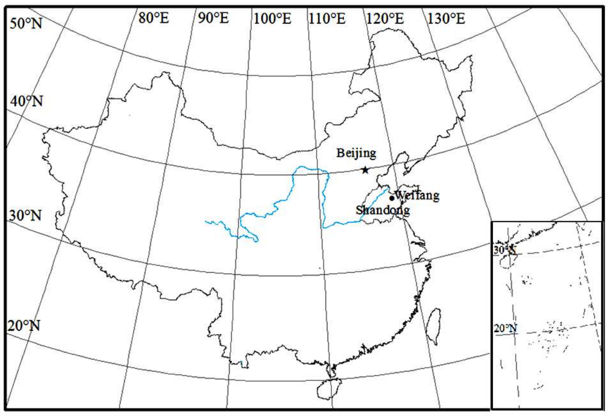


**Figure 1.** The location of Weifang, China.

and the worldwide population-weighted average value in soil (45 and 420 Bq kg$^{-1}$, respectively) [2]. $^{40}K$ is the largest contributor to the total activity, which accounts for approximately 84-93% of the total activity. Table 1 shows the comparison of the activity concentrations of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in sand of Weifang with other reports [3,5-13]. The natural radioactivity level in sands from different areas are not uniform, which would be due to the differences of their sources and chemical compositions.

Radium equivalent activity ($Ra_{eq}$) [3], indoor air absorbed dose rate ($D$) [14], annual effective dose ($AED$) [2] and excess lifetime cancer risk ($ELCR$) [15] were calculated to assess radiological hazards associated with the sand samples used as building materials. The duration of life in the calculation of $ELCR$ is Chinese datum (75 years) (http://en.worldstat.info/Asia/China). The $Ra_{eq}$ values in the sand, ranging from 90.4 to 264.3 Bq kg$^{-1}$ with an average of 177.9 Bq kg$^{-1}$ (figure 2), were lower than the allowed limit of 370 Bq kg$^{-1}$ in building materials for safe use recommended by Organization for Economic Cooperation and Development [2]. The values of $D$ and $AED$ for all studied sand samples in Weifang ranged from 79.14 to 223.17 nGy h$^{-1}$ with an average of 155.85 nGy h$^{-1}$ and from 0.39 to 1.09 mSv y$^{-1}$ with an average of 0.76 mSv y$^{-1}$, respectively (figure 3). The values of $D$ and $AED$ in the most sand samples (except one sample) were higher than the worldwide average value (84 nGy h$^{-1}$ and 0.41 mSv y$^{-1}$) and the average value of China (99 nGy h$^{-1}$ and 0.49 mSv y$^{-1}$) [2], while the values



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of $AED$ in the most sand samples (except one sample) were lower than the recommended limit of 1 mSv y$^{-1}$ [14]. The values of $ELCR$ for the investigated samples ranged from 1.46 × 10$^{-3}$ to 4.09 × 10$^{-3}$ with an average of 2.87 × 10$^{-3}$. According to the above-mentioned recommended limit (1 mSv y$^{-1}$) of $AED$, the maximum $ELCR$ should not exceed 3.75 × 10$^{-3}$ for indoor exposure. The average $ELCR$ for the investigated sand samples is less than this maximum.

**Table 1.** Comparison of activity concentrations and radium equivalent activity ($Ra_{eq}$) in sands from different areas.

| Areas | Activity concentration (Bq kg$^{-1}$) | | | $Ra_{eq}$ (Bq kg$^{-1}$) |
|---|---|---|---|---|
| | $^{226}$Ra | $^{232}$Th | $^{40}$K | |
| Xining, China [7] | 21.5 | 32.7 | 764.1 | 121.7 |
| Urumqi, China [8] | 22.4 | 25.1 | 789.3 | 119 |
| Baotou, China [9] | 16 | 26 | 736 | 110 |
| Punjab, Pakistan [10] | 24 | 39 | 462 | 112 |
| Bangladesh [11] | 14.1 | 25.0 | 158.4 | 62.1 |
| Malaysia [12] | 60 | 13 | 750 | 136 |
| India [13] | 43.7 | 64.4 | 455.8 | 170.8 |
| Namakkal, India [3] | 2.27 | 21.72 | 352.8 | 59.68 |
| Najaf, Iraq [5] | 43.57 | 1.98 | 135.02 | 56.54 |
| Karbala, Iraq [5] | 44.21 | 2.06 | 108.73 | 55.26 |
| Pakistan [6] | 30.5 | 53.2 | 531.3 | 143.8 |
| **Weifang, China (Present study)** | **15.5** | **70.3** | **802.9** | **177.9** |

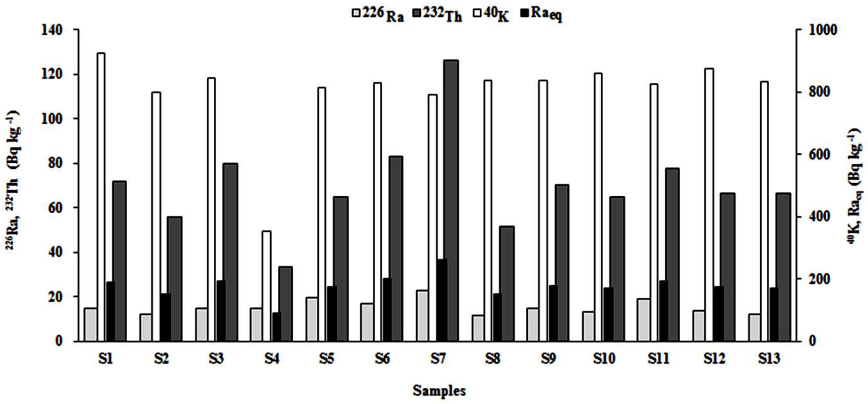


**Figure 2.** The activity concentrations of $^{226}$Ra, $^{32}$Th and $^{40}$K and radium equivalent activity ($Ra_{eq}$) in the sand samples.

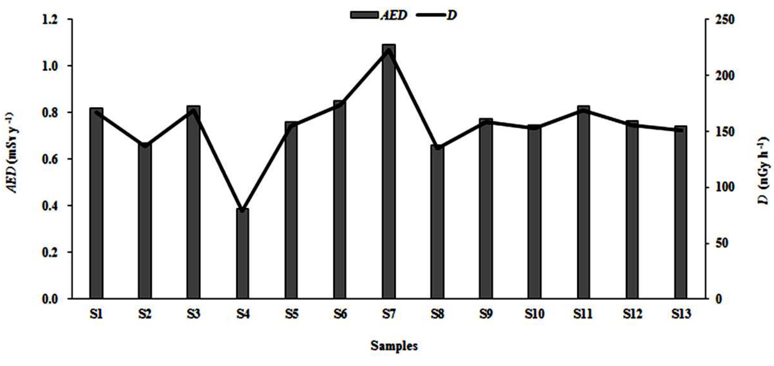


**Figure 3.** The absorbed dose rate indoor ($D$) and annual effective dose ($AED$) in the sand samples.

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## CONCLUSION

The mean concentrations of $^{232}$Th and $^{40}$K in sand from Weifang of China were higher than, while the mean concentration of $^{226}$Ra was lower than the average concentration of Chinese soil and the worldwide population-weighted average value in soil. From the analysis of radiological parameters, one can conclude that sand samples collected from Weifang, China can be safely used as building materials and do not pose significant radiation hazards to inhabitants.

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***Conflict of interest***: *Declared none.*

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