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Baseline

Natural radioactivity level in beach sand along the coast of Xiamen Island, China

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ABSTRACT

The activity concentration of ^{40}K, ^{232}Th and ^{226}Ra was determined in beach sand samples collected from Xiamen Island, China using gamma ray spectrometry. The activity concentrations of ^{40}K, ^{232}Th and ^{226}Ra in the beach sand range from 197.4 to 487.6, 6.5 to 41.4 and 7.9 to 25.7 Bq kg^{-1} with the mean of 401.0, 11.3 and 14.1 Bq kg^{-1}, respectively, which are lower than the averages of Chinese soil and world soil. The radium equivalent activity values in all beach sand samples are lower than the recommended limit of 370 Bq kg^{-1}. The external hazard index values are less than unity. The outdoor air absorbed dose rate and the corresponding annual effective dose rate of beach sand investigated are lower than the world-wide average.

Natural radionuclides are widespread in the earth's environment and they exist in various geological formations like soil, rock, plant, sand, water and air with varying concentrations depending on the geographical conditions and geological formations (UNSCEAR, 2000; Tzortzis et al., 2004; Abbady et al., 2006; Abd El-mageed et al., 2011; Malain et al., 2010, 2012; Ramasamy et al., 2013; Agbalagba et al., 2014; Bala et al., 2014; Saleh and Shayeb, 2014). The knowledge of concentration and distribution of natural radionuclides is of interest since it provides useful information in the monitoring of environmental radioactivity and the evaluating of radiation exposure. Human exposure to ionizing radiation is one of the scientific subjects that attract public attention, since radiation of natural origin is responsible for most of the total radiation exposure of the human population.

Beach sands, the inorganic silicon-rich coarse materials, are weathering-resistant remainders of geological formations, which may have come to their place after transport by winds, rivers, and glaciers to the coast, and are deposited on the beaches by actions of waves and currents (De Meijer et al., 2001; Seddeek et al., 2005). The beauty of the coastal ecosystems coupled with a rather high accessibility and many services offered by these ecosystems makes coasts an attention for the world's population. People settle on the coasts to live as well as leisure, recreational activities and tourism (Ramasamy et al., 2013). Therefore, it is necessary to determine the natural radioactivity level of beach sand in coastal areas for radiation protection.

In recent decades, a lot of researches on natural radioactivity level in beach sand have been done all over the world (Kannan et al., 2002; Freitas and Alencar, 2004; Alencar and Freitas, 2005; Veiga et al., 2006; Örgün et al., 2007; Rao et al., 2009; Malain et al., 2010, 2012; Al-Trabulsy et al., 2011; Korkulu and Özkan, 2013; Tari et al., 2013; Özmen et al., 2014), while the data about natural radioactivity of beach sand in China are limited (Lu and Zhang, 2008). The main objectives of this work were to determine the activity concentrations of natural radionuclides in beach sand of Xiamen Island in southeastern China and to analyze the associated radiation hazard. The data generated in this study may contribute to the natural radioactivity level database of beach sand in coastal areas of China and provide the reference for local radiation protection.

Xiamen, a modern international port city, is located in Fujian province of southeast China (Fig. 1). The climate of Xiamen city is a typical south subtropical oceanic monsoon climate, with annual average temperature of 21 °C, annual average precipitation of 1200 mm and the annual average sunlight of 1960 h. It is called "the Eastern Hawaii" by people from all over the world. As an international port scenic city, Xiamen attracts large numbers of visitors each year due to its moderate climate and beautiful scenery. Xiamen Island (118°04′21″–118°49′50″E, 24°24′58″–24°32′47″N) is the main part of Xiamen city. Its length from south to north is 13.7 km and width from west to east is 12.5 km. The Golden Coastline with ~10 km length located in the southeast of Xiamen Island is the famous tourist spot of Xiamen city. There are six main scenery spots along the Golden Coastline of Xiamen Island known for their clean beaches and beautiful sceneries, i.e.

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Xiangshan (XS), Huizhan Center (HZC), Yefengzhai (YFZ), Wanyuepo (WYP), Zhenzhuwan (ZZW) and Baicheng (BC) (Fig. 1).

A total of 30 beach sand samples were collected from six scenic spots (XS, HZC, YFZ, WYP, ZZW and BC) among the Golden Coastline of Xiamen Island in Fujian province, China (Fig. 1). Five sand samples were collected randomly in the different direction of each scenic spot. At every sampling site, the sand samples were collected from the surface layer (0–20 cm) on four corners of a square area corresponding 4 m^2 and mixed to a composite sample of 1 kg by a quartile method. The collected sand samples were stored in polyethylene bags for transport and storage. All samples were transported to the laboratory and dried for ~24 h in oven at 110 °C, then crushed, and sieved through a 1 mm mesh. Finally, the dried samples were weighed and sealed in gas-tight, radon impermeable, cylindrical polyethylene plastic containers (7.0 cm height and 6.5 cm diameter) for at least 4 weeks before counting to ensure radioactive equilibrium between radium and thorium and their decay daughters (Lu et al., 2014). After that period, the sand samples were analyzed for natural radionuclide activity concentration using gamma ray spectrometry.

The activity concentrations of natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K in the samples were determined by a 3 × 3 in. NaI(Tl) gamma ray spectrometric system with excel 8% energy resolution (^{137}Cs 661.6 keV) (Ramasamy et al., 2013; Agbalagba et al., 2014; Bala et al., 2014; Lu et al., 2014). The detector, maintained in a vertical position in a lead cylindrical shield of 10.5 cm thickness and 38 cm height, was coupled to a 1024 microcomputer multi-channel pulse height analyzer and the system was calibrated for the γ-energy range 50 keV–3.2 MeV. The lead shield contained an inner concentric cylinder of copper (0.3 mm thickness) to absorb X-rays generated in the lead (Issa et al., 2014). To determine the background distribution in the environment around the detector, an empty sealed container was counted at the same manner and in the same geometry as the samples. 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 (El-Taher et al., 2010), whereas ^{40}K activity was measured directly through its gamma ray energy peak of 1460.8 keV. The detection system was calibrated using the standard materials supplied by Beijing Research Institute of Uranium Geology of China. The standard sources for ^{226}Ra and ^{232}Th (in secular equilibrium with ^{228}Th) were prepared using known activity contents and mixing with the matrix material of phthalic acid powder. In order to avoid the loss of gaseous daughter products of ^{226}Ra and ^{232}Th which may lead to disturbance in radioactive equilibrium, the prepared

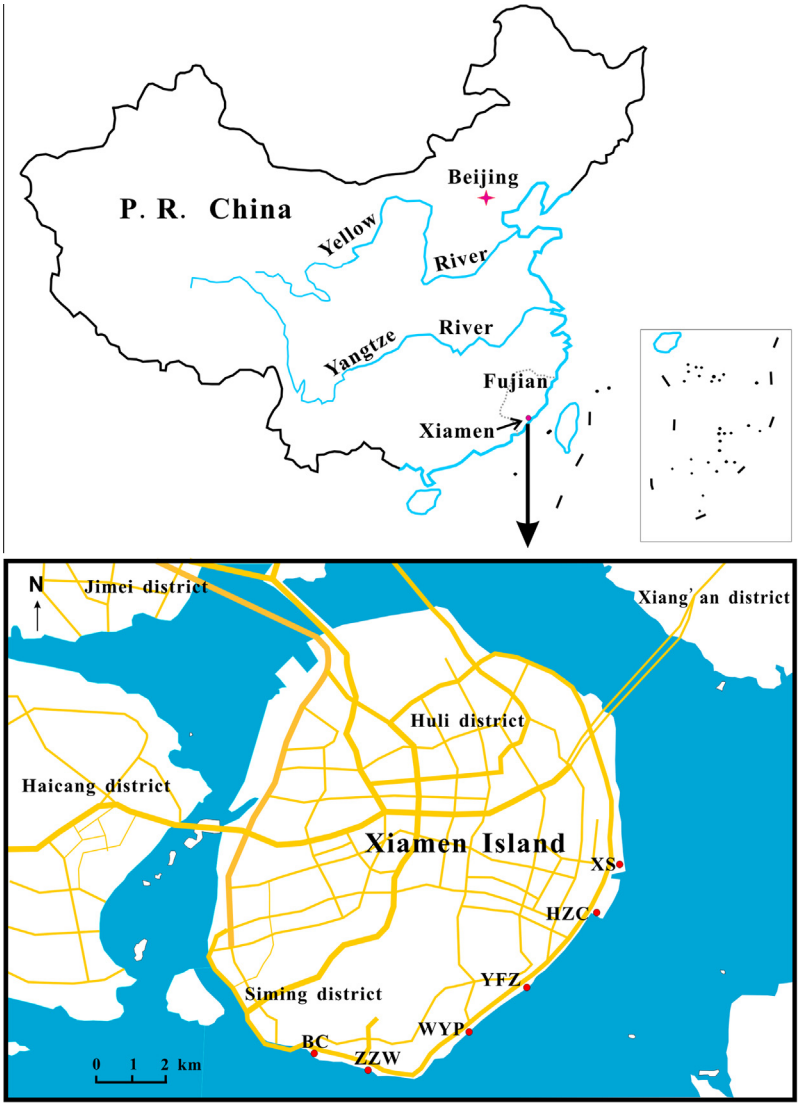

Fig. 1. Location of the study area and sampling sites.

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