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Analysis and Evaluation on Radioactivity of Common Building Materials

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In order to study the hazardous elements of building materials, this paper analyzes the specific chemical composition of common building materials. The study of radioactive levels of different building materials may guide people to properly use building materials, so as to avoid health damage by radiation. This research adopts market survey, sample collection, treatment, determination and analysis, safety evaluation and others on building materials, investigates and analyzes the radioactive level of common building materials in Nanjing, and discusses reasons of high radioactive content of ceramic tiles. The experiment shows that in samples of measured building materials, the specific activity range of radionuclide content 226Ra of natural stones is 14.65-181.35Bq/kg, with an average value of 64Bq/kg. The radioactive levels of the measured natural stone samples meet type A standard of the national standard. It is concluded that the study of hazardous elements of building materials can guide people to use building materials reasonably and healthily.

1. Introduction

With the rapid development of society and economy, gradually increasing in real estates and infrastructures (Majid et al., 2013), the needs of building materials are increasing greatly annually and types of building materials are also increasing gradually (Trevisi et al., 2013). China's housing system has been gradually formed to buildings that are mainly based on bricks, concretes and new building materials from wooden houses and mud houses at Initial stage of reform and opening up (Kumar and Chauhan, 2014), people also pay great attention to indoor decoration, people also pay high attention to home environmental problems caused by this. With the emergence of buildings and decorations with environmental hazards (Nuccetelli et al., 2015), severe pollutions brought to indoor environment, also a variety of diseases brought to people who live in which, seriously affect people's health (Szabó et al., 2013). Compared to formaldehyde, benzene and other chemical substances in building materials, radioactive hazards of building materials are not easy to be perceived and unpredictable (Iwaoka et al., 2013), and their incubation periods are longer, generally, it needs several decades to discover impacts on human bodies, therefore, the investigation and research on radioactivity of building materials can guide people to properly use building materials (Ravisankar et al., 2014), and it is of great significance. In recent years, many domestic scholars conducted related researches (Trevisi et al., 2013); the purpose is to understand the radioactive levels of building materials in various areas, and guide people to use building materials reasonably and healthily (Döse et al., 2016).

The research on natural radionuclide contents of common building materials in Nanjing provides experimental data for Nanjing's natural radioactivity level (Nuccetelli et al., 2017), and it also contrasted and analyzed the same researches in other areas (Becker et al., 2014), which is aimed at providing scientific instructions for Nanjing residents selecting building materials, let residents use building materials reasonably and healthily, so as to construct a healthy home environment (Nuccetelli et al., 2015).

2. Experimental Methods

2.1 Sample collection and treatment

Sample collection: In the process of sample collection, 3 aspects are mainly taken into account: natural stones, artificial ceramic tiles and main materials for building. In which, natural stones mainly include marbles

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and granites that people mainly use; ceramic tiles mainly include artificial ceramic tiles come from different places of origin; main materials for building mainly include cements, gravels, stone powders and so on. Get 2 samples from each material, and each sample shall not be less than 3kg: one sample is used for detection, and the other sample is used for conservation and standby application.

Sample treatment: Because the selected building materials are different in kinds, so treatment modes of building materials are different. As for hard stones and ceramic tiles, firstly, break samples to small pieces, then put them into self-made grinding jars to break to small pieces, after levigating and sieving to 40 meshes, because water content in samples is less, there is no need to dry them in the dryer, so directly put them into standard jars for seal, measure after be put for 20 days. Cements, gravels and stone powders are directly put into standard jars, waiting for seal. Because each sample is not less than 3kg, and the samples' measurement quantity is large. After the grinding and sieving, the five-spot method for sieving is used to select about 250g samples to measure, which conforms to the law of statistics, the measuring results are representative, no more measurements are required.

2.2 Experimental instrument

This experiment adopts high-purity germanium Y spectrometer with the multichannel analyser that is produced by USA ORTEC Company, which is mainly N-type detector (GMX). The detector produced by ORTEC Company is strict conformance with ANSI/IEEEStd.32521996 standards of International Atomic Energy Agency, resolution, efficiency, peak-to-compton ratio, peak shape and other performance indexes of the detector can be fully guaranteed, and there are more allowances between the guarantee values and actual indexes.

Advantages of HpGe detector include high energy resolution, rapid response time and wide linearity range, and the unique advantages bring new developments and applications for the Y spectrometer. Model of N-type detector is GMXSOP4, and model of the digital instrument is DSPEC-r2.0, which adopts positive high voltage, the detecting body is large, thickness of the end-window is less, and the corresponding detection efficiency is lower, so time for samples measurement is longer.

In order to realize normal and stable operation of the instrument, indoor relative humid this experiment adopts is 40%, and the temperature is controlled within 20-25°C, which are guaranteed by means of thermostat unit and dehumidity unit of the air conditioner.

This experiment adopts calibration sources with known nuclides to calibrate energy responses of Y energy spectrum system; the energy scale range is 50keV-3000keV. Mixed standard sources are used to calibrate energies, as shown in Table 1.

Table 1: Parameters of standard source used in this experiment

Radionuclide	Net weight/g	Activity/Bq	Specific activity/Bq kg^{-1}
^{210}Pb	186.18	324.58	1743.40
^{226}Ra	-	128.46	690.00
^{137}Cs	-	201.02	1079.70
^{241}Am	-	210.38	1130.00
^{60}Co	-	189.90	1020.00

3. Analysis and Evaluation on Radionuclide of Building Materials

3.1 Analysis on differences of natural stones' radioactivity

Differences of radioactive contents in different producing areas of measured natural stone are analyzed. Among the measured stone samples, stones with the most radionuclide contents are mainly from Fujian area. In which, radioactive contents of stones in Sichuan are obviously higher than that in other areas, which is mainly caused by different geological structures and the mineral contents in different areas, which is related to the level of land-surface radiation in the area. In this experiment, mean values of 226Ra, 232Th and 40K of measured stones in Fujian are 92.00, 46.77 and 633.34 Bq/kg respectively. Compared with the measured results by Huang Lihua, 105.9, 139.5 and 1436.3Bq/kg, in which, contents of 226Ra are close to, while differences of contents of 232Th, 40K are larger, as shown in Figure 1.

As shown in Figure 2, the mean value of equivalent activity of radioactive radium of stones at different producing areas is within 21.65-207.67 Bq/kg, stones produced in Fujian are with the highest value, and stones produced in Guangxi are with the lowest value, all stones come from different areas do not exceed the international limit value 370 Bq/kg.

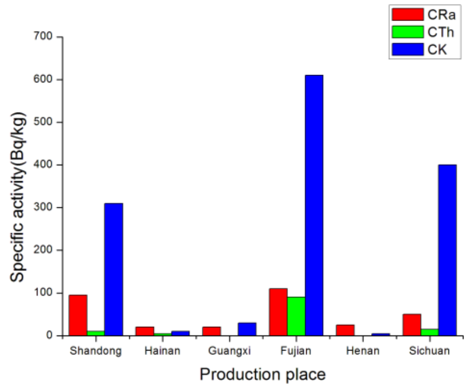

Figure 1: Mean value of radioactivity in stone from different producing area

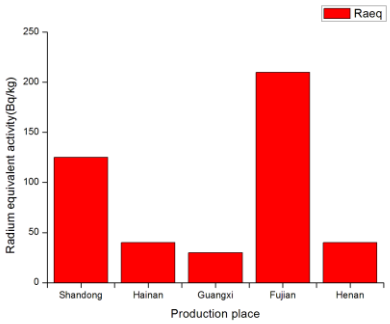

Figure 2: Mean value of radium equivalent concentration in stone from different area

Comparison of the mean value of radium equivalent activity of ceramic tiles at different producing areas is shown in Figure 3, ceramic tiles produced in Jiangxi are with the highest value, and the radium equivalent activity is 752.28 Bq/kg, which is about 2 times of the limit value; and ceramic tiles produced in Fujian are with the lowest value, and the radium equivalent activity is 396.47 Bq/kg, both of which are higher than the international limit value: 370 Bq/kg. It can be concluded from above that the radionuclide contents of different producing areas: Jiangxi> Guangdong> Shandong> Fujian.

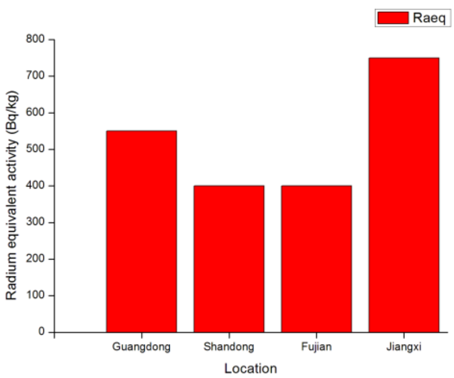

Figure 3: Mean value of radium equivalent concentration in tiles from different area

The mean value of specific radioactivity of stones in different colours is shown in Figure 4, it can be seen from the Figure the specific radioactivity: red> black> gray> green> beige> white> brown, radioactivity of dark colour series of stones is obviously higher than that of the light colour series. Main reasons for which may be the different components, for example, red stones are with more contents of potassium feldspars, and higher radioactive content of 40K is caused by which.

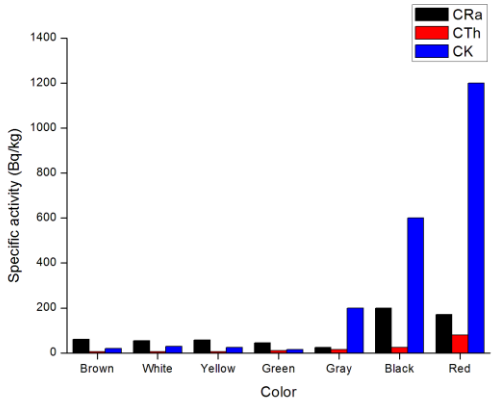

Figure 4: Mean value of radioactivity concentration in different colour stone

The mean value of radium equivalent activity of stones in different colours is: red 323.22 Bq/k}, black 155.96Bq/kg, gray 65.91 Bq/kg, green 56.92 Bq/kg, beige 63.35 Bq/kg, white 67.40 Bq/kg, brown 69.98 Bq/kg. In which, the mean value of radium equivalent activity of red stones is close to the international limited value, and they have more harms to human bodies, with higher content of radionuclide. Radioactive contents of red and black stones are higher than stones in other colours, and stones in other colours are relatively close, as shown in Figure 5.

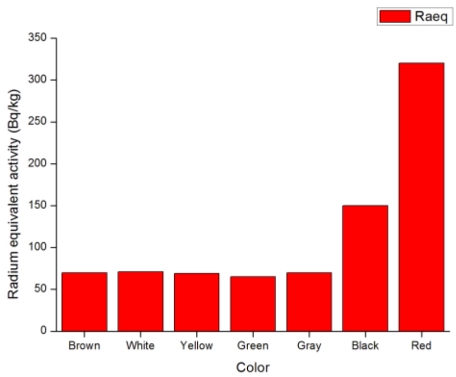

Figure 5: Mean value of radium equivalent concentration in different colour stone

3.2 Comparative Analysis on Different Types of Building Materials

This paper compared mean values of radionuclide contents of different types of building materials, as shown in Figure 6. In the UNSCEAR report in 1993, the world mean values of 226Ra, 232Th and 40K are respectively 50 Bq/kg, 50 Bq/kg and 500Bq/kg; and in the UNSCEAR report in 2000, the world mean values of 226Ra, 232Th and 40K are respectively 32 Bq/kg, 45 Bq/kg and 420Bq/kg. Among measured samples, mean values of specific activity of all types of 226Ra are higher than the world level, which are almost 2-3 times of the world level, in which, stones are with the lowest value, and ceramic tiles are with the highest value, the order of which is: Ceramic tiles>slag cements>gravels>stones>stone powders>ordinary cements. As for 40K, the specific activities of ceramic tiles and gravels are higher than the world level, others are below the world level, and the order of which is: iles>gravels>slag cements >stones>stone powders>ordinary cements.

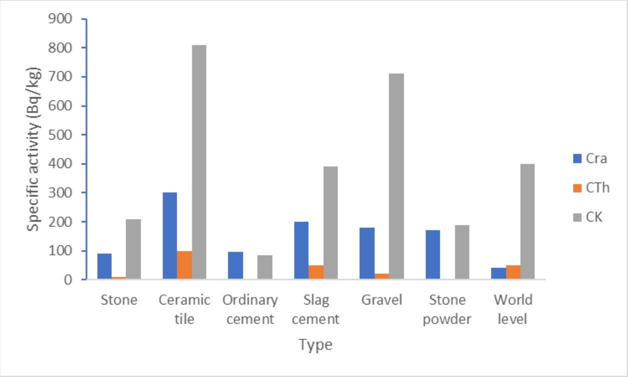

Figure 6: Mean value of radioactivity content in different building material types

3.3 Specific radioactivity of main materials for building

Radionuclide contents of measured main materials for building are shown in Table 2, specific activity range of 226Ra is 103.11-206.87 Bq/kg, and the mean value is 151.81 Bq/kg, in which, slag cements are with the highest value, and ordinary cements are with the lowest value, the value of slag cements is about 2 times of that of the ordinary cements; specific activity range of 232Th is 11.35-54.10 Bq/kg, in which, slag cements are with the highest value, and stone powders are with the lowest value; specific activity range of 40K is 92.57-734.24 Bq/kg, in which, gravels are with the highest value, and ordinary cements are with the lowest value. Radium equivalent activity of measured main materials for building are 126.54-312.65 Bq/kg, in which, slag cements>gravels>stone powders>ordinary cements.

Table 2: Mean value of radioactivity content in building main materials (Bq/kg)

Name	Number	Production place	C_{Ra}	C_{Th}	C_K	Ra_{eq}
Ordinary cement	5	Nanjing	103.11	11.4	92.57	126.54
Slag cement	9	Nanjing	206.87	54.1	361.9	312.65
Gravel	5	Nanjing	155.88	30.42	734.24	255.92
Stone powder	5	Nanjing	141.36	11.35	152.69	169.35

3.4 Evaluation on radiation dosages of main materials for building

Table 3 shows the evaluation indexes of main materials for building, according to national standard for building materials, except that slag cements are Type B products, others all conform to Type A standard of national building materials. In which, the internal exposure index is: slag cements>stone powders>gravels>ordinary cements; and the external exposure index is: slag cements>gravels>ordinary cements>stone powders. Radium equivalent activity of main materials for building does not exceed the standard. It is worth noting that the annual effective dose equivalents of ordinary cements and stone powders in main materials for bundling for residents of are less than the limit value, and slag cements and gravels of which more than the limit value, it may be caused by the higher radioactive activity of slag. Although gravels conform to Type A standard, according to the annual effective dose equivalents, they cannot be used safely.

Table 3: Evaluation index values of building main materials

Name	Ira	Ir	Type	Ra_{eq} (Bq/kg)	E(msv)
Ordinary cement	0.59	0.35	A	126.54	0.56
Slag cement	1.03	0.86	B	312.65	1.37
Gravel	0.57	0.60	A	255.92	1.16
Stone powder	0.71	0.34	A	163.35	0.76

4. Conclusions

Firstly, this paper investigated and researched radionuclide contents of common building materials in Nanjing, and analyzed the radioactive levels of building materials in markets in Nanjing, as well as conducted safety evaluation on building materials. Secondly, as for the problem of higher radioactive activity of ceramic tiles in the investigation and analysis, this paper further discussed major reasons for higher radioactive activity of ceramic tiles, and put forwarded some suggestions on reducing the level of radionuclide in artificial building materials. Radioactive levels of measured natural stones conform to Type A products of national standard, It is worth noting that the radium equivalent activity of Fujian red stones exceeds the standard; annual effective dose equivalents of black stones, Fujian red, lichi red and India brown stones on human bodies exceed 1 msv, there are considerations for using. In measured main materials for building, except that slag cements are Type B products, others all conform to the standard, there is no limit in using. In which, the annual effective dose equivalents of gravels on residents exceed the international limit value, and the use is limited. Residents shall overall consider each evaluation index when selecting building materials, do not select on in accordance with national standard for building materials, and please use when the internal and external exposure index, radium equivalent concentration and annual effective dose equivalent on residents conform to the standard.

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