Measurement of natural radionuclides in bricks and brick-making clays from Cuddalore district, Tamilnadu, India

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Abstract In India, bricks as building materials are mainly prepared by clay using the deposited sediments of rivers, and the radionuclide contents in bricks and brick-making clays should vary with origin and geological condition. In this paper, the radionuclide contents of these materials from river bank areas of Cuddalore district, Tamilnadu India are measured by gamma ray spectrometer using NaI(Tl) detector, and compared with those of other countries. The radiation hazard indices, which are evaluated by radium-equivalent (Ra_{eq}) activity, are lower than that of NEA-OECD.

Key words Natural radioactivity, Building materials, Gamma-ray spectrometer, Ra_{eq} activity.

1 Introduction

The uranium and thorium series, and ^{40}K are mainly natural radionuclides in soil, building materials and recycled industrial waste[1,2]. It is important to calculate radioactive parameters and contents in the construction materials due to public exposure. About 80% components in public and residential materials in India are bricks[3], prepared mainly by deposited clay sediments of rivers. Thus, the radionuclide content of raw materials and bricks varies with origin and the geological conditions[4].

The radioactive concentrations in the normal construction clays are usually ppm U and Th, and less than 4% K. The radioactive clays, however, can be more than 10-ppm U, 20-ppm Th, and 5% K, and it is necessary to determine the radioactive value of construction clays. If the concentration of natural radionuclide at the residential and public places exceed 30-ppm U_{eq}(uranium-equivalent), it should be believed that mankind be exposed in the radioactive environment, such as radon exhalation from buildings of high-radium levels. In this study, the natural radioactivity in clays and the bricks collected from areas of river bed at Cuddalore District, Tamilnadu, India were measured. Results show that the average Ra_{eq} (radium-equivalent) activities in the bricks were less than 370 $Bq \cdot kg^{-1}$, all hazard indices are 0.11 to 0.19.

2 Materials and methods

The gamma-ray spectrometer was employed to calculate the activity of ^{226}Ra, ^{232}Th and ^{40}K in the building materials. The bricks and brick-making clays along two river bank areas of the Cuddalore district were powdered into grains of the same size, and the samples were transferred to a porcelain dish and dried at 110ºC. After the sieve of 150 Sv, the samples were weighed and sealed in a 250-mL plastic container for a month in order to ensure the radioactive equilibrium between ^{226}Ra, ^{222}Ra and its progeny. Radiometric analyses were carried out using γ-ray spectrometer in

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the laboratory of Radiological Safety Division, Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam, Tamilnadu, India. The NaI(TI) detector (3"×3") and a 8 K multi-channel analyzer were used to record the γ-spectra. The 250-mL standard sources of uranium (1997.56 Bq), thorium (1237.28 Bq) and KCl (5181.39 Bq) from IAEA were used to calibrate the γ-ray spectrometer. The counting time of a sample was 20000 s, and the minimum detectable activities (MDA) were 13.25, 8.5, and 1 Bq·kg^{-1} for ^{40}K, ^{226}Ra and ^{232}Th, respectively.

The ^{238}U concentration was determined by the following γ-rays: 351.9 keV of ^{214}Pb; 609.3, 768.4, 1120.3, 1238.1 and 1764.5 keV of ^{214}Bi; and 186 keV of ^{226}Ra. The ^{232}Th concentration was measured by 338.4, 911.1, 968.9 and 974 keV of ^{228}Ac; 538.3 and 2614 keV of ^{208}Ti. The ^{40}K content was evaluated by its 1460.7-keV γ-rays. The γ-ray efficiency factor was given by $E_\gamma = a_1 + a_2E$ after correcting background and Compton scatter contributions, where a_1 and a_2 are fit parameters, E is the γ-ray energy and E_γ is in the natural logarithm. The efficiencies of ^{232}Th, ^{226}Ra and ^{40}K in the samples were programmed in the spectrometer computer, so as to calculate their average activity.

3 Theoretical Calculations

The radiation hazards of ^{226}Ra, ^{232}Th and ^{40}K are widely expressed by the Ra_{eq} in Eq.(1), which means that 1 Bq·kg^{-1} ^{226}Ra, 0.7 Bq·kg^{-1} ^{232}Th and 13 Bq·kg^{-1} ^{40}K produce the same γ-ray dose rates[4]. The annual radiation dose is calculated by Eq.(2)[4].

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K \quad (1)$$

$$A_{Ra}/740 + A_{Th}/520 + A_K/9620 \le 1 \quad (2)$$

where, A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the materials, respectively.

4 Results and Discussion

4.1 Radioactivity in brick samples

Table 1 Activity concentrations (Bq·kg^{-1}) of ^{232}Th ^{226}Ra and ^{40}K, and Ra_{eq}, and annual dose, in bricks at Cuddalore, India.

River bed	Name	^{232}Th	^{226}Ra	^{40}K	Ra_{eq}	Annual dose / mSv
Vellaru	MNB	38.31	15.61	243.64	89.15	0.11
	VRB	38.64	16.55	203.39	87.46	0.11
	GNB	40.54	19.45	260.28	97.46	0.13
	KMB	36.08	19.85	235.37	89.56	0.12
	KKB	37.44	19.83	257.60	93.20	0.12
	ANB	37.00	19.99	266.75	93.43	0.12
Kedilam	SVB	48.86	16.42	448.57	120.82	0.16
	PTB	48.49	22.23	445.93	125.90	0.16
	APB	54.03	23.85	454.21	136.08	0.18
	KPB	57.65	21.48	486.14	141.35	0.19

Table 1 shows that the activity concentration of ^{232}Th, ^{226}Ra, and ^{40}K in bricks from the Vellaru river bed are 36.08–40.54, 15.61–19.99, and 203.39–266.75 Bq·kg^{-1}, respectively. For bricks of Kedilam river bed, their concentrations are 48.49–57.65, 16.42–23.85, and 445.93–486.14 Bq·kg^{-1}, respectively. For their average values of activity in the two river beds, the ^{226}Ra are 18.54 and 20.99 Bq·kg^{-1}, which is less than world average of 50 Bq·kg^{-1}[5], the ^{232}Th is 38.00 and 52.25 Bq·kg^{-1}, and the ^{40}K is 244.50 and 458.71 Bq·kg^{-1}, which is less than world average of 500 Bq·kg^{-1}[5]. Somlai *et al.*[11] recommended that the usable dwelling materials was less than 370 Bq·kg^{-1} Ra_{eq}. In this paper, the Ra_{eq} of local bricks is 107.4 Bq·kg^{-1}, indicating that there is no unacceptable radiological hazard. The annual radiation dose of the bricks is 0.11 to 0.19.

Table 2 Comparison of activity concentration and radium equivalent (Bq·kg^{-1}) in brick making clays at different country.

Countries	No	A_{Ra}	A_{Th}	A_K	Ra_{eq}	Ref.
Australia	25	41	89	681	220	[6]
China	–	41	52	717	171	[7]
Egypt	1	20	14	204	56	[8]
The Netherlands	14	38	41	560	141	[9]
Srilanka	24	35	72	585	183	[4]
Bangladesh	–	108.8	58.1	234.1	209.9	[10]
This work	10	19.5	43.7	330.2	107.4	–

Table 2 shows that the total activities of the radionuclides and Ra_{eq} index for brick-making clays are compared with that of other countries. The 43.70

Bq·kg^{-1} ^{232}Th is comparable with that of China and the Netherlands, but this is higher than that of Australia, Srilanka and Bangladesh, and lower than of Egypt. The 19.52 Bq·kg^{-1} ^{226}Ra is more than that of Egypt, and the 330.18 Bq·kg^{-1} ^{40}K is comparable with that of Egypt and Bangladesh.

4.2 Radioactivity in brick making clays

Clays usually contain nine kinds of natural radio-nuclides, in which the ^{232}Th, ^{226}Ra, and ^{40}K are primary. As shown in Table 3, the concentrations of ^{232}Th, ^{226}Ra, and ^{40}K in the brick-making clays of the Vellaru river bed are 31.98–40.21, 14.36–18.78, and 221.35–265.1 Bq·kg^{-1} with an arithmetic mean of 37.17, 16.37, and 247.79 Bq·kg^{-1}, respectively. And the concentrations of ^{232}Th, ^{226}Ra, and ^{40}K in the brick -making clays of the Kedilam river bed are 33.56 – 49.32, 16.54–19.98, and 335.47–471.89 Bq·kg^{-1} with the mean of 44.04, 18.05, and 401.74 Bq·kg^{-1}, respectively. These activities in the clay samples of both Vellaru and Kedilam river bed are less than those of Ref.[1] (50, 50, and 500 Bq·kg^{-1}, respectively), and the radium Ra_{eq} is lower than that of the recommended 370 Bq·kg^{-1}, indicating no radiological hazards.

Table 3 Activity concentration (Bq·kg^{-1}) of natural radio-nuclide in brick-making clays at Cuddalore district, India.

Sites	Name	^{232}Th	^{226}Ra	^{40}K	Ra_{eq}
Vellaru	MNC	35.98	14.36	247.36	84.85
	VRC	39.33	16.30	249.73	91.77
	GNC	39.95	14.55	256.10	92.09
	KMC	40.21	18.78	253.82	95.82
	KKC	35.60	16.02	249.40	86.13
	ANC	31.98	18.25	221.35	81.02
Kedilam	SVC	45.69	17.85	471.89	119.52
	PTC	47.60	17.86	407.17	117.28
	APC	33.56	16.54	335.47	90.36
	KPC	49.32	19.98	392.45	120.72

Table 4 Comparison of activity concentration and radium equivalent (Bq·kg^{-1}) in brick-making clays at different areas.

Places	No.	A_{Ra}	A_{Th}	A_K	Ra_{eq}	Ref.
Sicily, Italy	7	34±8	38±17	513±192	127±41	[12]
Cario region	16	16.8	18.7	354	70.8	[13]
Dhaka	–	33±7	16±4	574±111	100±39	[14]
This work	10	17	39.9	309.3	97.95	–

Table 4 shows that the average activities of the radionuclides and the Ra_{eq} in brick-making clays are compared with that of other areas. The 39.9 Bq·kg^{-1} ^{232}Th is comparable with that of Sicily, and lower than that of Cario region and Dhaka city. The 17 Bq·kg^{-1} ^{226}Ra is lower than that of Sicily and Dhaka except for 16.8 Bq·kg^{-1} of Cario region. The 309.3 Bq·kg^{-1} ^{40}K is lower than that of other countries.

5 Conclusions

In summary, the Ra_{eq} in bricks were less than 370 Bq·kg^{-1} and the hazard indices of all the samples are 0.11 to 0.19. These bricks and brick-making clays are safe as construction materials at Cuddalore District, Tamilnadu, India.

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