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Assessment of Radioactivity in Textile Sludge Incorporated Bricks

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Textile sludge generated from the textile industry is potentially reused in manufacturing bricks. Radiological hazard to the environment while using any kind of new material in the construction industry needs to be predicted to ensure its safety for domestic use. This paper reports the effect of radiation from textile sludge-incorporated bricks. Primordial radionuclides such as Uranium- 238 (^{238}U), Thorium- 232 (^{232}Th), and Potassium- 40 (^{40}K)., are present in raw materials used in the manufacturing of various building materials. In the present investigation, textile sludge-incorporated bricks were studied. It was observed that the content of ^{238}U was less than 20.6 Bq/kg (Becquerel per kg), ^{232}Th was less than 38.3 Bq/kg, and ^{40}K less than 168 Bq/kg compared to the permissible limit of 32 Bq/kg, 45 Bq/kg and 420 Bq/kg respectively, as prescribed by UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). The activity concentration of primordial radionuclides ranged between 48 Ba/kg to 88 Ba/kg, which was also well below the permissible limit of 370 Bq/kg. Parameters like internal and external hazards index, radium equivalent activity (Ra_{eq}), annual effective dose rates, and absorbed dose rates were investigated. The results of all these parameters obtained for sludge-incorporated bricks were found to be less than unity, the permissible limit declared by the UNSCEAR. The study concludes that the sludge-incorporated bricks do not pose any radiation hazard and are suitable for use as construction material.

Keywords: Bricks, Building materials, Gamma radiation Radioactivity, Radiological hazard, Textile sludge waste

1 Introduction

The Textile industry plays a vital role in the industrial development of India where the textile industry is a top foreign exchange earner. According to records of the Tamilnadu State Pollution Control Board (TNPCB) in India, there are 830 textile processing units in Tirupur (located at 11.7 North latitude and 77.5 East longitude), India. Eight Common Effluent Treatment Plants (CETPs) have been developed by these industries as Tirupur produces about 200 tonnes of textile sludge per day. Unutilized textile sludge is disposed of in landfills which leads to soil contamination, surface and groundwater pollution. The government formed the State Industries Promotion Corporation of Tamil Nadu (SIPCOT) with a total land area of 3600 acres. Nearly 20 textile units jointly built an effluent treatment plant to handle and dispose of textile sludge[1].Textile sludge is used by many companies to manufacture various construction materials such as tiles, bricks, and concrete.Many researchers[1-5] studied the potential reuse of textile sludge waste in the manufacturing of bricks. Some have used it in the manufacturing of cement concrete flooring tiles and non-structural concrete elements as a partial replacement for cement[6]. These researches ended with favourable results. Various guidelines were specified to ensure their useas good construction material. The author of this paper studied the performance of Sludge incorporated fly ash bricks[1]. cast according to the Bureau of Indian Standards[7] (BIS). The results revealed that textile sludge incorporated bricks showed good compressive strength up to 25% replacement and could be used as construction material.

As the above research throws some light on the strength characteristics of construction materials using textile sludge, it becomes essential to study its radiation effect to ensure safe usage. Building materials formed by rocks[8] and soil[9] contain various amounts of natural radioactive nuclides. These natural radionuclides are omnipresent. Environmental radioactivity is responsible for approximately 85% of the radiation received by humans[10] (United Nations Scientific Committee on the Effects of Atomic Radiation - UNSCEAR).Hence it is very important to

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know the radiation activity concentration in building materials to assess its radiological hazard to human health. The main sources of such exposure are Uranium-238(^{238}U), Thorium-232(^{232}Th), and Potassium-40(^{40}K). Studies were carried out by various researchers to evaluate the radiation concentration present in various natural materials used in the construction industry[11-15].Assessment of radiological hazards from granite samples was studied by Darwish *et al.*[16]and commercial flooring materials by Senthil kumar *et al.*[17]Specific activities (A) of ^{226}Ra, ^{232}Th and ^{40}K radio nuclides, Radium equivalent activities (Ra_{eq}), external and internal hazard indices (H_{ext}, H_{int}), external and internal level indices (I_g, I_a), activity utilization index (I), exposure rate (ER) were tabulated and the maximum permissible limits were specified. Radiation present in the Soil of Tiruchirappalli district, India was studied by Pillai *et al.*[18] and a detailed report was presented for the benefit of society. World Health Organization (WHO) regularly insists on monitoring Radon in buildings.

Hencea study of the radiological effect of any new material introduced in the construction industry becomes vital. In the present study, textile sludge used to manufacture fly ash bricks was analyzed for its radiation effect. "The worldwide average concentration of ^{232}Th, ^{40}K and ^{226}Ra in the earth's crust is 45 Bq/kg (Becquerel per kg), 412 Bq/kg and 32 Bq/kg respectively" (UNSCEAR)[19]. The results of activity concentrations of primordial in textile sludge, conventional fly ash bricks, and sludge incorporated bricks were compared with the world average values suggested by UNSCEAR[19].

2 Materials and Methods

2.1 Textile sludge

Textile sludge was collected in the form of semi-dried cakes from dumping sites attached to a Common Effluent Treatment Plant located in the State Industries Promotion Corporation of Tamil Nadu (SIPCOT), India. The sludge had roughly 30% moisture. The sludge was dried in a hot air oven for 24h at 100°C. After complete drying of the sample, it was ground into fine powder in a clean and controlled environment. It was then sieved through a 250μ sieve retaining 150μ.

SEM-EDX analyses using Scanning Electron Microscope (SEM) were performed to arrive at the elemental composition of textile sludge. An extensive experimental investigation was undertaken on conventional fly ash bricks and sludge incorporated bricks by varying the sludge proportions by the author as described in Velumani *et al.*[1]. The investigation showed satisfactory results. A further attempt was made to study the effect of radiological hazards in sludge incorporated bricks. Fig. 1 shows a raw textile sludge sample.

2.2 Proportioning of materials for textile sludge brick

The sample description and proportions adopted as per guidelines[7,20] are tabulated in Table 1.

2.3 Sample preparation for radiation test

Samples prepared for radiation test are divided into three categories as in Table 2

Large samples of grain were crushed to produce a fine powder with particles of less than 250μ size. The sample obtained after sieving was kept outdoors in the sun and air-dried for several days. Once the

Fig. 1 — Raw textile sludge sample.

Table 1 — Mix combinations for the production of fly ash sludge bricks

Specimen code	Description	Sludge %	Fly ash %	Quarry dust %	Lime %	Total %
CFB	Conventional	0	60	25	15	100
SIB 5%	Sludge Incorporated	5	55	25	15	100
SIB 10%	Sludge Incorporated	10	50	25	15	100
SIB 15%	Sludge Incorporated	15	45	25	15	100
SIB 20%	Sludge Incorporated	20	40	25	15	100
SIB 25%	Sludge Incorporated	25	35	25	15	100

moisture in the sample was completely dried, it was heated in an oven at 110°C until it reached unsaturated, oven-dry density conditions. An impermeable airtight container of 6 cm diameter and 9.5 cm height was sterilized. The samples were packed and sealed in the container as shown in Fig. 2. This was to prevent the emission of radiogenic gases, thoron (220Rn) and radon (222Rn). The samples were stored for 30 days before gamma-ray spectrometric analysis to ensure that 226Ra and short-life degradation products could reach a radioactive balance.

2.4 Gamma radiation test

The Digi base gamma-ray spectrometer, an ORTEC –made (U.S) 3″ × 3″ NaI (Tl) detector (Model: 905-4) as shown in Fig. 3 was used to measure gamma radiation emitted by the raw textile sludge and the brick incorporated with textile sludge. Gamma radiation was measured using a ɤ -ray spectrometer coupled with a 14-pin photomultiplier tube, 8K ADC stem, digital multichannel analyzer (MCA), 3” x 3” NaI detector, Preamplifier, HV power supply, and MAESTRO-32 software and a USB

Table 2 — Specimen Description

Category	Sample Designation	Description
	TTS1	Raw textile sludge sample packed and sealed - Sample 1
	TTS2	Raw textile sludge sample packed and sealed - Sample 2
I	TTS3	Raw textile sludge sample packed and sealed - Sample 3
	TTS4	Raw textile sludge sample packed and sealed - Sample 4
	TTS5	Raw textile sludge sample packed and sealed - Sample 5
	CFB 1	Conventional fly ash brick powder packed and sealed - Sample 1
	CFB 2	Conventional fly ash brick powder packed and sealed - Sample 2
II	CFB 3	Conventional fly ash brick powder packed and sealed - Sample 3
	CFB 4	Conventional fly ash brick powder packed and sealed - Sample 4
	CFB 5	Conventional fly ash brick powder packed and sealed - Sample 5
	SIB 5%	Textile sludge incorporated brick (5%) powder packed and sealed (average of 5 samples)
	SIB 10%	Textile sludge incorporated brick (10%) powder packed and sealed - (average of 5 samples)
III	SIB 15%	Textile sludge incorporated brick (15%) powder packed and sealed - (average of 5 samples)
	SIB 20%	Textile sludge incorporated brick (20%) powder packed and sealed - (average of 5 samples)
	SIB 25%	Textile sludge incorporated brick (25%) powder packed and sealed (average of 5 samples)

Fig. 2 — Packed and Sealed containers under Equilibrium condition.

Fig. 3 — Radiation Counting system with NaI detector.

connection. To reduce background radiation, the detector was hermetically sealed and mounted on a 10 cm thick lead shielding.

The inner surfaces of the plumbing shield were lined with both copper (0.8mm) and cadmium sheets, to minimize X-ray fluorescence (1.5mm thick). Standard reference materials including RGU-1 (Uranium ore), RGTh-1 (Thorium ore), and RGK-1 (Potassium sulfate) having activities of 1065 Bq, 1608 Bq, and 4810 Bq obtained from the International Atomic Energy Agency (IAEA) was used to check the system's calibration. These standards were obtained by the same author as described by Senthil Kumar *et al.*[21] from the Radiological Safety Division, Indira Gandhi Atomic Research Center, Kalpakkam. The sample container was placed above the detector for a counting period of 20,000 sec. Similarly, the peak area of references was determined by the same geometry. The background and samples were counted to minimize counting error for 20,000 seconds. The background measurements were subtracted to get net sample counts. The gama-emitting concentration of ^{40}K was measured at 1461ke V, with ^{238}U and ^{232}Th measured at ^{214}Bi (1764 keV) and ^{208}Tl (2614.6 keV), respectively, using gamma-emitting products.

The detection limit of the NaI(Tl) detector system for primordial radionuclides is shown in Table 3 and the laboratory experimental setup in Fig. 3.

Table 3 - Detection limit of NaI (Tl) detector

Primordial	Limit(Bq/kg)
^{238}U	2.03
^{232}Th	4.7
^{40}K	18.9

3 Results and Discussion

3.1 Activity concentration of primordial radionuclides

UNSCEAR[22] recommended 370 Bq/kg as the permissible limit for building materials. Ra_{eq} can therefore be calculated by equation (1) prescribed by Sroor*et al.*[23]

$$Ra_{eq}(Bq\ kg^{-1}) = A_U + 1.43A_{Th} + 0.077A_K \quad \ldots (1)$$

Where, A_U, A_{Th}, and A_K are the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K respectively. Activity concentrations of primordials in the three categories of samples are tabulated in Table 4. For the general public, Ra_{eq} is reported to have a safe value of less than 370 Bq/kg for any natural radioactive material, limiting the annual efficient dose to 1 mSv as per UNSCEAR[24]

3.2 Comparative study on activity concentration of primordials for three categories of samples

The measured gamma radiation levels from the three categories of samples were compared to discover the radioactive effect of textile sludge on the brick. Each category of 5 samples was tested to arrive at the accurate mean value of gamma radiation which

Table 4 — Activity concentrations of primordial radionuclides in different categories of bricks

Sample code	Activity concentration of primordials (Bq/kg) ^{238}U	^{232}Th	^{40}K	Ra.Eq (Bq/kg)
Category- I (Raw textile sludge bricks)				
TTS1	BDL	41.7 ± 10	196.5 ± 43	74.8
TTS2	3.5 ± 1	43.2 ± 11	101.8 ± 47	72.7
TTS3	5.5 ± 4	37.8 ± 10	91.2 ± 40	66.7
TTS4	18.4± 5	24.7 ± 10	137.9 ± 45	64.4
TTS5	BDL	66.6 ± 10	199.1 ± 42	110.2
Mean ± SD	6.29±6	42.8± 13	145.3± 42	77.76± 4
Category –II (Conventional fly ash bricks)				
CFB1	18.5 ± 43	65.3 ± 9.1	196.1 ± 37.9	127.0
CFB2	15.4 ± 3.8	24.7 ± 7.8	189.6 ± 34	65.0
CFB3	9.9 ± 3.8	^{25}.8 ± 7.8	249.4 ± 34.5	66.0
CFB4	29.8 ± 3.9	7.8 ± 7.0	184.0 ± 33.1	55.15
CFB5	22.9 ± 4.1	44.8 ± 8.3	163.1 ± 35.6	99.60
Mean ± SD	19.3± 12	33.6± 1.5	196± 12	69.35± 0.6
Category- III (Sludge incorporated Bricks)				
SIB1	2.2 ± 3.6	25.2 ± 7.6	126.4 ± 31	47.96
SIB2	5.3 ± 3.6	37.3 ± 8.0	132.1 ± 32	68.81
SIB3	7.5 ± 3.7	38.0 ± 8.0	140.6 ± 32.6	72.66
SIB4	20.6 ± 3.8	38.3 ± 7.6	164.7 ± 33.3	88.05
SIB5	20.6 ± 3.7	37.2 ± 7.2	168.0 ± 32.0	86.73
Range	2.2 to 20.6	25.2 to 38.3	126.4 to 168.0	47.96 to 88.05
Permissible Limit (UNSCEAR)[24]	32	45	420	370

was then used for further comparison of the three categories of samples. The comparative graph of categories I and II is shown in Figure. 4 along with the permissible limit. Figure. 5 reveals the activity concentration with their permissible values for category III. Figure. 4 and Figure. 5 reveal that the activity concentration of U-238, Th-232 and K-40 are well within the permissible limits.

It is evident from Fig. 5, that the activity concentration of ^{238}U for category III (Sludge incorporated brick) was very low compared to categories I &II. In fly ash brick powder, activity concentration of ^{238}U ranged from 9.9 to 29.8 Bq/kg. Due to the further addition of textile sludge to the brick, activity concentration of ^{238}U was reduced and was found to range between 2.2 and 20.6 Bq/kg.

Activity concentration of ^{232}Th for the sludge incorporated brick (Category III) was slightly higher than in Categories I& II. But the value was within the world average prescribed by UNSCEAR[19].Activity concentration of ^{40}K for the sludge-incorporated brick was lower than that of conventional bricks. It was evient from the investigations that the textile sludge incorporated brick had a very low effect on radioactivity

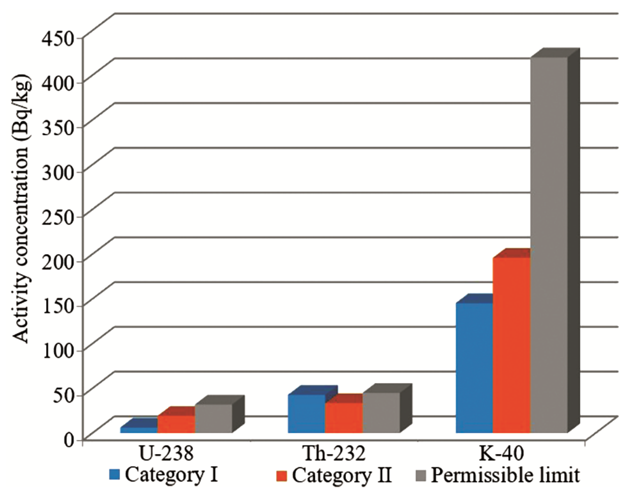

Fig. 4 — Activity concentration of ^{238}U, ^{232}Th and ^{40}K in flyash brick powder (category I and II).

3.3 Absorbed gamma dose rates

For uniform distribution of natural radionuclides (^{238}U, ^{232}Th, and ^{40}K), which was calculated according to the UNSCEAR[19] guidelines, the absorbed gamma dose (D) rates from gamma radiation in the air were 1m over ground surface. It is given by the following equation (2)

$$D(nGyh^{-1}) = 0.462 A_U + 0.604 A_{Th} + 0.0417 A_K \quad \ldots (2)$$

Where, activity concentrations of ^{232}Th, ^{238}U, and ^{40}K are represented by A_{Th}, A_U, and A_K, respectively.

3.4 Annual effective dose rate

As suggested by UNSCEAR[10], the absorbed dose rate was converted to an annual effective dose using a conversion factor (0.7 $SvGy^{-1}$) with an indoor occupancy factor of 0.8. (UNSCEAR 2008) as seen in equations (3) and (4)

Indoor annual effective dose:

$$E_{in} = (AD\ (nGyh^{-1}) \times 8760\,hy^{-1} \times 0.8 \times 0.7 SvGy^{-1} \times 10^{-6}) \leq 1 \quad \dots (3)$$

Outdoor annual effective dose:

$$E_{out} = (AD\,(nGyh^{-1}) \times 8760\,hy^{-1} \times 0.2 \times 0.7 SvGy^{-1} \times 10^{-6}) \leq 1 \quad \dots (4)$$

Where *AD*=Annual Dose

3.5 Radioactivity level index

Gamma radiation hazard levels associated with natural radionuclides in building materials was assessed with the use of a radioactivity level index, I_y. The maximum permissible limit of gamma radiation assessed by the radioactivity level index was unity.

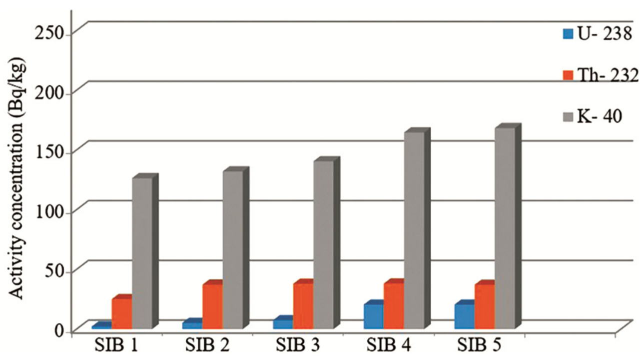

Fig. 5 — Activity concentration of ^{238}U, ^{232}Th and ^{40}K in textile sludge incorporated bricks (Category III).

The following equation (5) was prescribed by UNSCEAR[19] to calculate I_y.

$$I_Y = \frac{A_U}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \leq 1 \quad \dots (5)$$

Where, the activity concentrations of ^{232}Th, ^{238}U, and ^{40}K are represented by A_{Th}, A_U, and A_K, respectively.

3.6 External hazard index (H_{ex})

Gamma radiation emitted by radionuclides greatly influences the calculation of the external hazard index which is obtained from the Ra_{eq} expression [equation 6] that allows the maximum value of 370 Bq kg^{-1}.

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad \dots (6)$$

Table 5 shows the value for Radium equivalent activity, annual effective dose rate, absorbed gamma dose rate, radioactivity level index, and the external hazard index.

Parameters such as radium equivalent activity, absorbed dose rate, and external and internal hazard indexes were used to assess radiological hazards. It was observed that all five assessment test values were below the value of unity. Hence, it was calculated from the above calculations that textile sludge incorporated bricks would not produce any radiological hazard to the environment.

Table 5 — Evaluation of the radiological Hazard Index

Sample Code	Absorbed gamma dose rate(D) ($nGyh^{-1}$)	Indoor effective dose rate(E_{in}) (mSv y^{-1})	Outdoor effective dose rate(E_{out}) (mSv y^{-1})	Radioactivity level index(I_y)	External hazard index (H_{ex})
Category- I (Raw textile sludge)					
TTS1	34.3	0.1683	0.0421	0.5610	0.200
TTS2	31.9	0.1565	0.0391	0.5348	0.1970
TTS3	29.17	0.1431	0.0358	0.4938	0.1798
TTS4	29.17	0.1431	0.0358	0.5220	0.1738
TTS5	51.86	0.2544	0.0636	0.8196	0.3040
Mean ± SD	36 ± 25	0.17 ± 0.28	0.03±0.006	0.5862±0.2	0.2±0.004
Category- II (Conventional Fly ash bricks)					
CFB1	56.16	0.275	0.068	0.5610	0.20
CFB2	29.93	0.146	0.036	0.5348	0.1970
CFB3	30.55	0.149	0.037	0.4938	0.1798
CFB4	26.15	0.128	0.032	0.5220	0.1738
CFB5	44.44	0.218	0.054	0.8196	0.3040
Mean ± SD	38 ± 43	0.18±0.013	0.045±0.006	0.5862±0.026	0.2109±0.02
Category- III (Sludge incorporated bricks)					
SIB1	21.51	0.200	0.050	0.3509	0.1295
SIB2	30.49	0.2411	0.0602	0.4964	0.1858
SIB3	32.28	0.2262	0.0566	0.5237	0.1962
SIB4	39.52	0.1849	0.0462	0.6301	0.2378
SIB5	39.01	0.1536	0.0384	0.6216	0.2343
Mean ± SD	32±0.56	0.2±0.04	0.05±0.07	0.5246± 0.08	0.1967±0.02
Limit	-	<1	<1	<1	<1

4 Conclusion

The present study examined the reuse of textile sludge as building material as also its radiological hazard. The following observations were made from the study:

- A database on natural radioactivity in textile sludge incorporated bricks was generated for the first-time using Gamma-ray spectrometry.
- Activity concentration of Primordial radionuclides such as Uranium- 238, Thorium- 232, and Potassium- K in sludge bricks was measured using gamma-ray spectrometry.
- The radium equivalent activity of conventional fly ash bricks and sludge incorporated bricks was well below the maximum permissible limit of 370 Bq/kg recommended for building materials.
- The values of absorbed gamma dose, Indoor effective dose rate, Outdoor effective dose rate, radioactivity level index and external hazard index were less than 1 which was well within the recommended safety levels.
- Overall, sludge-incorporated bricks were found to be safe radiologically and did not pose any health hazard.

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