Radioactivity and radiation hazard assessment of Cauvery River, Tamilnadu, India

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Background: Natural radiation is constantly present in the environment and is emitted from a variety of natural and artificial sources. It affects human body and environment. Materials and Methods: The activity concentrations of 238U, 232Th and 40K have been determined by Gamma ray spectrometer with an HPGe detector in sediments of Cauvery River, Tamilnadu, India. Results: The absorbed dose rate, radium equivalent concentration, external (Hex) and internal (Hin) hazardous indices are calculated from criteria formula and compared with the international recommended limits. The radioactive heat production rate and activity concentration index are also calculated. The observed dose rate measurements from ERDM (Environmental Radiation Dosi Meter) at 1m above the ground level at each site of the both rivers are measured and correlated with calculated absorbed dose rate. Conclusion: From the various parameters and correlation between them, the Cauvery River does not pose a radiological hazard except the site no. 21, 22, 23, 30, 31 and 35. Iran. J. Radiat. Res., 2011; 8(4): 211-222

Keywords: Sediments, radioactivity, absorbed dose rate, hazardous indices, RHP, activity concentration index.

INTRODUCTION

The knowledge of the natural radioactivity of building materials is important for the determination of population exposure to radiations, as most of the residents spend about 80% of their time in indoor. Building materials contribute to natural radiation exposure in two ways. First, by gamma radiation, from ²³⁸U, ²³²Th and ⁴⁰K and their decay products to an external whole body dose exposure and secondly by radon exhalation to an internal dose exposure due to deposition of radon decay products in the human respiratory tract. Elevated dose rates in indoor may arise from high

activities of natural radionuclides in building materials. In India dwellings are constructed with concrete mixed with nearly 60% sand separated from river sediments, which may contain highly occurred concentrations of natural radionuclides (1).

Radiation is present in every environment of the Earth's surface, beneath the Earth and in the atmosphere. According to UNSCEAR (2) (1993) about 87% of the radiation dose received by mankind is due natural radiation sources and the anthropogenic remaining is due to radiation. It is well known that natural radioactivity is present in rocks, soils, sediments, water and fish. Rocks and soil contain small quantities of the radioactive elements of 238U and 232Th with their daughter products. The concentration of elements considerably varies depending on the rock formation. The major sources of external radiation are ²³⁸U, ²³²Th, ⁴⁰K and their decay products. The human population is exposed to a natural background radiation level that is contributed by components three viz., cosmic rays, radioactivity terrestrial and radioactivity. The contribution from these components varies with location 2002). The altitude (Ajayi, terrestrial component is due to the radioactivity of uranium (238U), thorium (232Th) and their progeny radio isotopes and potassium-40 (40K) that is present in environmental

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materials like rocks, soils, sediments, buildings, rivers and ground water. Although these materials contain low-level radioactivity (LLR) the accumulated dose can be high. Measurements of the radiation exposure and radiation levels have been developed recently (2, 3).

The aim of this study was to determine the concentrations of natural radioactivity in Cauvery river sediments and to estimate the radium equivalent, hazardous index, volumetric heat production rate and activity concentration index, which is related to the external g-dose rates. The results were compared with the findings of similar studies carried out in other countries. In the present study an attempt has been made to determine the concentration and effects of ²³⁸U, ²³²Th and ⁴⁰K in sediments collected from Cauvery river.

MATERIALS AND METHODS

Cauvery River, which is located between Karnataka and Tamil Nadu in India covered

over 600 km are shown in figure 1. Each site is separated by a distance of 20km approximately. At each site, a sampling area of 1m (2) was considered and totally 6 wet samples were taken from 2 feet depth for analysis. Each sample has about 2 kg. Then the sample was dried in an oven at 100-110°C for about 24 hours and sieved through a 2-mm mesh to remove stone, pebbles and other macro-impurities. The homogenized sample was placed in a 250 ml airtight PVC container. The inner lid was placed in and closed tightly with outer cap. The container was sealed hermitically and externally using cellophane tape and kept aside for about a month to ensure equilibrium between Ra and its daughter products before being taken for gamma ray spectrometric analysis.

Activity concentration determination involves measurements of either alpha or beta or gamma radiations from the samples. Due to the inherent properties of the gamma rays like high penetrating power and the interaction process with matter, the

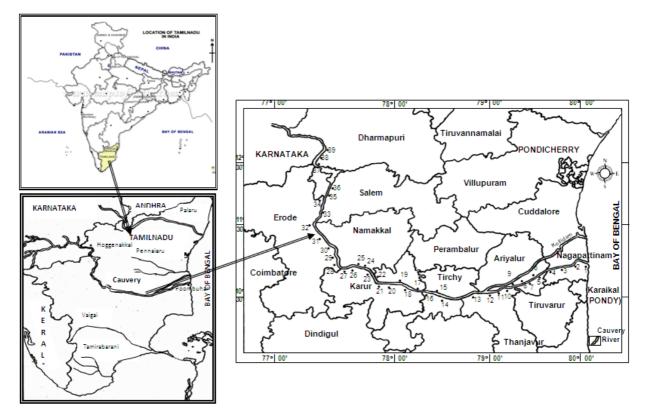


Figure 1. Map of different locations of Cauvery river.

measurement of gamma radiation offers useful information than that of α and β radiations.

The activity concentrations of primordial radio nuclides (238U, 232Th and 40K) in the samples were determined by employing a high-resolution hyper pure germanium (HPGe) gamma ray spectrometer system consisting of a p-type intrinsic germanium coaxial detector (type: 1GC 30; Volume 133cc; PGT make) mounted vertically and coupled to a 4K multi channel analyzer (ORTEC MODEL 7 450). The detector was housed inside a massive lead shield to reduce the background of the system. It was calibrated using a standard solution of ²²⁶Ra in equilibrium with its daughters (obtained from NBS, USA), mixed with simulated soil matrix and counted in the same geometry as that of the soil samples. Three IAEA standard reference materials (a standard ofknown radioactivity-soil-6, Uranium ore sample - RGU1 and Thorium ore sample - RGTh 1) were also used for checking the calibration of the system. The energy resolution of 2.0KeV and relative efficiency of 33% at 1.33 Mev was achieved in the system.

Each sample, after the equilibrium, is kept on top of the HPGe detector and counted for period of 10000 s. The activity concentration of ²³⁸U was evaluated from the gamma ray 609 KeV of ²¹⁴Bi peak, while 911 KeV gamma line of ²²⁸Ac peak was used to determine ²³²Th, ⁴⁰K activity concentration was determined from ⁴⁰K peak at 1461 KeV. The activity concentration of each radionuclide in the sample was determined using the total net counts under the selected photo peaks after subtracting appropriate background counts, and applying appropriate factors for photo peak efficiency, gamma intensity of the radio nuclide and weight of the sample. The analysis of the gamma spectra obtained was performed using the dedicated software Microsoft Excel. At each sampling site the ambient gamma radiation level was measured using a digital environmental radiation dosimeter (ERDM) which

comprised NaI (1.75" × 2") detector (ECIL brand –SM-141D) with a reading range of 1 - 10000 nGyh⁻¹. The ERDM is calibrated regularly before starting the survey using standard sources ¹³⁷Cs and ⁶⁰Co. The ERDM readings are recorded at 1m above ground level. Five readings were taken at each site and the average was recorded.

Calculation of radiation hazard parameters

UNSCEAR ⁽²⁾ (1988) has given the dose conversion factors for converting the activity concentrations of ²³⁸U, ²³²Th and ⁴⁰K into doses (nGyh⁻¹ per Bqkg⁻¹) as 0.427, 0.662 and 0.043 respectively. Using these factors, the absorbed dose rate is calculated using the equation.

$$D = (0.427 C_{IJ} + 0.662 C_{Th} + 0.043 C_{K}) nGyh^{-1}$$
 (1)

Where C_U , C_{Th} and C_K are the activity concentrations (Bqkg⁻¹) of uranium, thorium and potassium in sediments respectively.

Normally river sediments are used in building construction; so selection of the materials is also very important. The total activity does not provide as an exact indication of the radiation hazard associated with the materials. As the concentration and distribution of ²³⁸U, ²³²Th and ⁴⁰K in sediments and soils is not uniform throughout the world so uniformity in respect of exposure to radiation has been defined in terms of the radium equivalent activity given by the equation ⁽⁴⁾.

$$Ra_{eq} = C_{U} + A C_{Th} + B C_{K}$$
 (2)

where C_u , C_{Th} and C_K are the activity concentration of ²³⁸U, ²³²Th and ⁴⁰K (Bqkg⁻¹) respectively and, A and B are constants. For the safe utilization of materials, the annual limit on the external gamma ray dose (1.5mSv), this corresponds to the value of 370Bqkg⁻¹ for radium equivalent.

The other quantities indicating the radiological hazards are external (H_{ex}) and internal (H_{in}) hazard indices and are defined by the following relations $^{(4)}$.

$$H_{ex} = C_{U}/370 + C_{Th}/259 + C_{K}/4810 \le 1$$

 $H_{in} = C_{U}/185 + C_{Th}/259 + C_{K}/4810 \le 1$ (3)

where C_U , C_{Th} and C_K are the activity concentrations of U, Th and K in $Bqkg^{\text{-}1}$. The internal exposure to radon (^{222}Rn) and its decay products is controlled by internal hazard index (H_{in}) and for safe use; this index must be less than unity.

During the last few decades, the assessment of the amount of radioactive elements. the major internal heat source of the earth, was the subject of several studies due to its importance modeling the thermal in the lithosphere. evaluation of radioactive isotopes ²³⁸U, ²³²Th and ⁴⁰K contribute most of the terrestrial heat flow. These elements are fundamental for understanding the nature of the mantle, crust of the earth and their heat generating potential.

In the present study, an attempt has been made to find out the radioactivity heat produced in different sites using the relation given by Rybach (1988) (5).

$$A = 10^{-5} \rho (9.52 C_U + 2.56 C_{Th} + 3.48 C_K) \mu Wm^{-3}$$
 (4)

where A is radioactive heat production rate expressed in μWm^{-3} , ρ is the sample density in Kgm⁻³, C_U and C_{Th} are the uranium and thorium concentration in ppm and C_K is the total potassium concentration in %.

The building materials act as sources of radiation and also as shields against outdoor radiation (2). In massive houses made of different building materials such as stone, bricks, concrete or granite, the factor that mainly affects the indoor absorbed dose is the activity concentrations of natural radionuclides in those materials, while radiation emitted by sources outdoors is efficiently absorbed by the walls. Consequently, dose rates in air indoors will be elevated accordingly to the concentrations of naturally occurring radionuclides used in construction materials. According to the EC, an activity concentration index (I_{yr}) is calculated that is given by the following expression (1):

$$I_{Yr} = A_{U}/150 + A_{Th}/100 + A_{K}/1500$$
 (5)

where A_{Th} , A_U and A_K are actual values of the activities per unit mass (Bq.Kg⁻¹) of

²³²Th, ²³⁸U, and ⁴⁰K in the building materials considered.

RESULTS AND DISCUSSION

Activity concentration of primordial radionuclides

The activity concentration of the radio nuclides 238 U, 232 Th and 40 K in Bqkg⁻¹, corresponding absorbed dose rates in nGyh⁻¹ and annual effective equivalent dose in μ Svy⁻¹ of the sediment samples collected from Cauvery River are listed in table 1.

As listed in table 1, the activity concentrations obtained in this study ranged from 1.29 ± 0.1 to 21.49 ± 0.8 Bqkg⁻¹ with a mean of 5.31±0.4 Bqkg⁻¹, 6.33±0.6 to 224.79±2.6 Bq kg⁻¹ with a mean value of 34.04±1.4 Bqkg⁻¹ and 178.18±18.6 to 1698.48±30.1 Bqkg⁻¹ with a mean value of 401.11±24.3 Bqkg⁻¹ for ²³⁸U, ²³²Th and ⁴⁰K respectively and are shown in figure 2. Comparatively similar range of concentrations of 238U, 232Th and ⁴⁰K are observed by many authors ⁽⁶⁻⁹⁾ (table 2) in soil with an exception of beach sand samples, where observed values are significantly higher (6,10). In the present study, activity concentrations are almost lower than the other countries like China, Greece, France and Bangladesh (table 3) except site no. 30 and 31.

The mean activity concentration of ²³⁸U 0.15times of the international isrecommended limit (3) (35 Bqkg-1) and 0.36 times of the all India average value (11) (14.8 Bqkg⁻¹), whereas the mean ²³²Th activity concentration is 1.13 and 1.86 times of the international recommended limit (30 Bqkg-1) and all India average value (18.3 Bqkg⁻¹). The mean concentration of ⁴⁰K is 1.01 times of the international recommended limit (400 Bqkg⁻¹). This shows that the ⁴⁰K activity concentration dominates over ²³⁸U and ²³²Th activities like what normally isotope happens in soil. The low concentration of ⁴⁰K may be attributed to leaching, because of the heavy rainfall near Cauvery river area (12) (table 4).

Table 1. The Activity concentration, calculated absorbed dose rates, observed dose rates and the annual effective equivalent dose of Cauvery river sediments.

S.	Location	Lattitude		U	Th	K	Absorbed	Observe	Annual
No.	Location	Lattitude	Longitude	BqKg ⁻¹	BqKg ⁻¹	BqKg ⁻¹	dose rate	d dose	effective
110.				bqixg	DqKg	Dqrxg	nGyh ⁻¹	rate	equivalent
							поуп	nGyh ⁻¹	dose
								noyn	mSvy ⁻¹
1	Poombhuhar	11°09′00N	80°12′60E	6.15±0.7	13.23±0.9	398.91±21.4	28.02±1.4	90	0.17
2	N.N. Chavady	11°07′60N	80°05′00E	3.52 ± 0.4	14.38±1.2	428.62±24.1	28.89±1.6	95	0.18
3	Mayiladuthurai	11°05′60N		5.21±0.5	16.92±1.3	448.62±26.1	32.05±1.8	100	0.20
4	kuttalam	11°03′60N		2.63±0.3	15.32±1.5	432.62±27.4	29.27±1.9	85	0.18
5	Aduthurai	11°01′60N	79°28′60E	1.32 ± 0.2	16.94±1.4	442.6±22.3	30.15±2.1	90	0.18
6	Thirubhuvanam	10°59′00N	79°25′60E	2.62 ± 0.3	18.78±0.9	429.63±21.4	31.29±2.4	80	0.19
7	Kumbakonam	10°58′00N	79°22′60E	3.13±0.4	22.87±1.2	416.47±24.3	33.49±2.0	70	0.20
8	Swamimalai	10°57′60N	79°18′60E	3.78±0.4	26.73±1.4	380.24±25.6	34.62±2.4	65	0.21
9	Pappanasam	10°55′60N	79°16′00E	4.32±0.5	34.79±1.6	401.15±26.2	40.77±2.6	60	0.25
10	Kabisthalam	10°54′60N	79°10′00E	4.63±0.5	28.72±1.5	385.36±21.4	36.44±2.5	64	0.22
11	Tiruvaiyar	10°52′60N	79°05′00E	5.61±0.6	22.72±1.3	373.93±23.2	32.63±2.3	68	0.20
12	Thirukkattupalli	10°50′60N	78°58′00E	1.98 ± 0.2	13.44±0.8	377.27±22.6	25.44±1.9	63	0.16
13	Kallanai	10°51′00N	78°47′60E	4.32±0.5	33.20±1.4	410.94±24.7	40.20±2.4	72	0.25
14	Trichy	10°51′60N	78°43′60E	3.38±0.4	21.73±1.1	398.48±21.5	32.12±1.8	85	0.20
15	Srirangam	10°52′00N	78°40′60E	2.56±0.3	10.85±0.8	385.05±20.4	24.41±2.2	97	0.15
16	Mukkombur	10°53′60N	78°32′60E	1.64 ± 0.2	19.32±1.3	383.42±26.2	29.22±2.6	56	0.18
17	Gunaseelam	10°54′60N		2.32 ± 0.3	14.62±1.1	368.42±24.3	25.94±2.3	60	0.16
18	Kulithalai	10°55′60N	78°25′00E	2.67 ± 0.3	12.49±1.6	353.25±25.8	24.11±2.1	64	0.15
19	Thottiyam	10°55′00N	78°20′60E	2.16 ± 0.3	26.32±1.8	385.76±24.2	33.91±2.4	68	0.21
20	Krishnarayapuram	10°55′00N	78°16′60E	1.88 ± 0.2	38.75±1.7	402.22±22.1	42.24±2.8	72	0.26
21	Mayanoor	10°55′60N	78°13′60E	3.01 ± 0.4	82.93±2.1	307.61±20.3	66.18±2.4	220	0.40
22	Kattuputhur	10°47′60N	78°06′60E	4.03±0.6	73.47±1.8	438.60±24.2	66.35±2.6	190	0.41
23	Puliyur	10°37′60N		6.96±0.5	67.40±1.6	548.20±26.4	68.53±2.5	230	0.42
24	Vangal	10°45′60N	77°58′60E	3.90 ± 0.2	25.53±0.8	304.98±20.1	30.68±1.6	63	0.19
25	Velayutham-	10°48′60N	77°56′00E	1.89 ± 0.3	14.44 ± 0.6	304.73±21.2	22.91±1.4	58	0.14
26	palayam	10°52′60N	77°55′60E	1.46 ± 0.2	14.16±0.6	278.63±20.0	21.43±1.8	50	0.13
27	Pothanoor	11°04′60N		1.29 ± 0.1	15.98±0.7	256.71±19.8	21.54±1.7	47	0.13
28	Noyyal	11°09′60N		4.95±0.5	20.50±1.2	294.62±21.2	27.55±1.9	70	0.17
29	Kodumudi	11°20′60N		8.88±0.6	28.93±1.4	256.38±23.6	32.84 ± 2.7	69	0.20
30	Solasiranmani	11°26′60N		17.62±0.8	152.63±2.2	420.86±27.8	120.71±1.8	240	0.74
31	Valajapettai	11°20′60N		21.49±0.8	224.79±2.6	529.44±28.6	171.99±2.4	350	1.05
32	Erode	11°26′60N		8.88 ± 0.3	12.61±0.8	321.71±21.8	25.48±1.6	48	0.16
33	Bavani	11°32′60N		2.94±0.2	8.35±0.6	488.91±24.3	27.48±1.8	66	0.17
34	Kalvadangam	11°37′60N	77°45′00E	11.87±0.2	18.71±0.9	178.18±18.6	24.39±2.1	59	0.15
35	Ammapettai	11°42′00N		12.97±0.3	24.03±1.2	1698.48±30.1	93.54±2.4	170	0.57
36	Thekkanoor	11°48′00N		3.91±0.4	6.33±0.6	197.58±15.4	14.11±1.6	61	0.09
37	Mettur	11°56′60N		4.67±0.5	20.41±1.2	210.62±18.2	23.77±1.6	72	0.15
38	Kulathur	11°56′60N	77°53′00E	8.65±0.5	43.71±1.8	250.40±20.3	41.69±1.8	81	0.25
39	Kaveripuram	12°34′00N	77°58′00E	12.16±0.6	50.85 ± 2.1	353.66±23.2	52.08±2.4	93	0.32
Max	Hoggenakal			21.49±0.8	224.79±2.6	1698.48±30.1	171.99±2.4	350	1.05
Min				1.29±0.1	6.33±0.6	178.18±18.6	14.11±1.6	47	0.09
Mean				5.31±0.4	34.04±1.4	401.11±24.3	40.73±1.8	96.10	0.25

Table 1 shows the calculated absorbed dose rate due to the presence of ²³⁸U, ²³²Th and ⁴⁰K in sediments. The mean absorbed dose rate is 0.79 times of international recommended limit (51 nGyh⁻¹). The contribution by each of the radio nuclides ²³⁸U, ²³²Th and ⁴⁰K in nGyh⁻¹ to the absorbed dose rate is 5.5% (2.26 nGyh⁻¹), 55.34% (22.54 nGyh⁻¹) and 42.33% (17. 24 nGyh⁻¹) respectively.

In situ gamma dose rate at 1m above the ground has also been measured using the ERDM in each location and the values are tabulated in table 1. The observed dose rates is positively correlated with calculated absorbed dose rate with strong correlation coefficient (R=0.92) as shown in figure 3. The ERDM dose rates (observed) are nearly two times higher than the absorbed dose rate values. This difference may be due to

background contribution from cosmic rays high energy beta particles and X rays. In determining the annual effective equivalent dose at each location, the living style of the people or outdoor occupancy factor of a location was considered. A typical resident in a location, both male and female would spend about 8hrs of the day in an office (or) classroom or laboratory, 12 hrs indoors and the remaining 4hrs outdoors. This applies to the greater part of the population in a location who are either office workers or

pupils/students. Hence 20/24 or 0.83 was adopted as the outdoor occupancy factor (80%) with the conversion factor of 0.70SvGy⁻¹ to convert absorbed dose rate in air (nGyh⁻¹) to indoor annual effective equivalent dose (mSvy⁻¹) for this study. The mean indoor annual effective equivalent dose is 0.74 times with that of the international recommended limit 0.34 mSvy⁻¹. But the site no. 21, 22, 23, 30, 31 and 35 shows higher values, which is higher than the international recommended limit (3, 13).

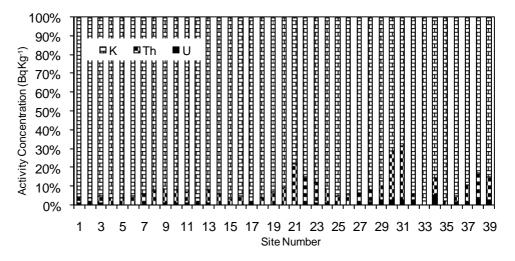


Figure 2. Graph of activity concentration in different locations of Cauvery River.

Table 2. The mean activity concentrations (BqKg-1) of ²³⁸U, ²³²Th and ⁴⁰K for different states of India.

Sl.	Location	²³⁸ U	²³² Th	⁴⁰ K	Reference
No.	Location	BqKg ⁻¹ BqKg ⁻¹ BqKg ⁻¹		BqKg ⁻¹	Reference
	Soil				
1	Kalpakkam, T.N	5-71	15-776	200-854	Kannan <i>et al.</i> (2002) ⁶
2	Bhuvaneswar, Orissa	18-30	33-80	213-247	Vijayan and Behera (1999) ⁷
3	Coonoor(Ooaty), T.N.	BDL-49	4-224	14-731	Selvasekarapandian <i>et al.</i> (1999a) ⁸
4	Gudalore, T.N.	17-62	19-272	78-596	Selvasekarapandian <i>et al.</i> (2000) ²¹
5	Narora, U.P.	32-65	46-90	469-756	Verma <i>et al.</i> (1998) ⁹
6	Rawatbhata, Rajasthan	17-40	27-67	127-49	Verma <i>et al.</i> (1998) ⁹
7	Udagamandalam,	0-88	26-226	96-444	Selvasekarapandian <i>et al.</i> (1999b) ²²
	(Ooty taluk), T.N.				-
8	Ullal, Karnataka	546	2971	268	Radhakrishna <i>et al.</i> (1993) ¹⁰
9	Uttarpradesh	12-25	20-25	538-1018	Mishra and Sadasivam (1971) ¹¹
	_				
	Beach Sand				
10	Kalpakkam, T.N	36-258	352-3872	324-405	Kannan <i>et al.</i> (2002) ⁶
11	Ullal, Karnataka	374	158	158	Radhakrishna et al. (1993) ¹⁰
					·
	River sediment				
12	Cauvery river, T.N.	5.31	34.04	401.11	Present study
	•				·

Sl. No.	Country	²³⁸ U BqKg ⁻¹	²³² Th BqKg ⁻¹	⁴⁰ K BqKg ⁻¹	Reference
1	China	62	90	524	Zigiang <i>et al.</i> (1998) ²³
2	USA	34	36	472	Delune <i>et al.</i> (1986) ²⁴
3	Republic of Ireland	37	26	350	Mc Aulay and Moran (1988) ²⁵
4	Greece	214	43	1130	Travidan <i>et al</i> . (1996) ²⁶
5	France	37	38	599	Lambrechts <i>et al.</i> (1992) ²⁷
6	Bangladesh	38	66	272	Mantazul <i>et al.</i> (1999) ²⁸
7	Taiwan	18	28	479	Chu <i>et al</i> . (1992) ²⁹
8	Egypt	17	18	316	Ibrahiem <i>et al.</i> (1993) ³⁰
9	Kuwait	36	6	227	Saad <i>et al.</i> (2002) ³¹
10	Nigeria	16	24	35	Arogunjo <i>et al.</i> (2004) ³²
11	World	35	30	400	UNSCEAR (2000) ³

Table 3. The mean activity concentrations (BqKg-1) of ²³⁸U, ²³²Th, and ⁴⁰K for different countries in the world.

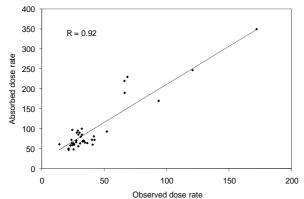


Figure 3. Correlation between absorbed dose rate and observed dose rate.

Radiological hazards

The calculated Rag values from equation (2) are presented in table 5. It is observed that the site no. 31 shows maximum of Bqkg⁻¹ 383.71 ± 6.3 and minimum 28.18±4.2 Bqkg⁻¹ in site no.36. For the estimation of radiological consequences instead of comparing the average values, maximum value is taken into account. The maximum Ra_{eq} value of Cauvery (383.71±6.3 Bqkg⁻¹) river is slightly higher than the international recommended limit (6) (370 Bqkg-1). Rizzo et al. (14) reported the Raeg value of sedimentary silicic sand varies from 10 to 53 Bqkg⁻¹ with a mean of 34±14 Bqkg⁻¹ for 6 samples. The mean value of silicic sand is two times lower than the present study and ten times lower than the international recommended value (370 Bqkg⁻¹). In the present study the low concentration of Ra_{eq} value may be related to the transportation

of radioactive materials by weathering, sedimentation and maximum water flow due to heavy rainfall in its origin.

From table 4, the maximum values of H_{ex} and H_{in} are observed in site no. 31 (1.036±0.53, 1.094±0.48). The hazard indices are to be higher than unity, which may cause harm to people living in this region.

Radioactive heat production (RHP)

In the present study, the heat production rate ranges from $0.1858\pm0.07~\mu Wm^{-3}$ (site no.36) to $3.0389\pm0.75~\mu Wm^{-3}$ (site no.31) with a mean value of $0.5568\pm0.06~\mu Wm^{-3}$. This shows that the low RHP rate (below $1\mu Wm^{-3}$) except site no. 21, 22, 23, 30, 31 and 35 are observed. The overall heat generation mainly depends on 232 Th amount (71.41%). However, an increase in the concentrations of 238 U, 232 Th and 40 K reflects the integrated effect of heat production rate $^{(5, 15)}$

Activity concentration index

According to the European Union ⁽¹⁶⁾, building materials should be exempted from all restrictions concerning their radioactivity. The excessive gamma radiation due to those materials causes the increase of the annual effective dose received by an individual by a maximum value of 0.3 mSvy⁻¹. Effective doses exceeding the dose criterion of 1 mSvy⁻¹ should be taken into account in terms of radiation protection. The estimated activity concentration index is calculated

and listed in table 3. Values of index I \leq 1 correspond to 0.3 mSvy⁻¹, while I \leq 3 correspond to 1 mSv/y. Thus, the activity concentration index should be used only as a screening tool for identifying materials which might be of concern to be used as covering material ⁽¹⁾. In the present study, the calculated gamma activity concentration index ranges from 0.28 (site no. 36) to 3.82 (site no. 31). The entire measured samples exhibit I<1 except site nos. 21, 22, 23, 30, 31

and 35, which corresponding to a recommended annual effective dose criterion of 0.3 mSvy⁻¹. This indicates that the Cauvery River sediments can be safely used as building materials except site nos. 21, 22, 23, 30, 31 and 35.

Correlation between activity concentrations

Correlation between the activity concentrations of the three elements (238U, 232Th

Table 4. Hazard indices, radium equivalent, radioactive heat production rate, Activity utilization index of Cauvery river sediments.

Site No.	H _{ex}	$\mathbf{H}_{ ext{in}}$	Ra _{eq} BqKg ⁻¹	RHP µWm ⁻³	Activity concentration index
1	0.1506±0.01	0.1673±0.03	55.78±5.2	0.3166±0.05	0.58
2	0.1541±0.02	0.1637 ± 0.04	57.09±5.6	0.2846±0.07	0.64
3	0.1727±0.04	0.1867 ± 0.06	63.94±6.5	0.3263±0.06	0.66
4	0.1562 ± 0.06	0.1633 ± 0.02	57.85±5.4	0.2765±0.03	0.65
5	0.1610±0.07	0.1646 ± 0.03	59.62±5.2	0.2861±0.08	0.68
6	0.1689 ± 0.03	0.1760 ± 0.01	62.56±5.8	0.3237±0.05	0.65
7	0.1833±0.04	0.1918 ± 0.04	67.90±6.1	0.3780 ± 0.04	0.64
8	0.1925±0.02	0.2027 ± 0.05	71.28±7.3	0.4265 ± 0.08	0.62
9	0.2294 ± 0.05	0.2411 ± 0.06	84.96±6.5	0.5416±0.09	0.71
10	0.2035 ± 0.06	0.2160 ± 0.03	75.37±5.6	0.4698 ± 0.04	0.64
11	0.1806 ± 0.03	0.1958 ± 0.07	66.89±6.3	0.4152±0.06	0.57
12	0.1357 ± 0.04	0.1410 ± 0.09	50.25±5.2	0.2711±0.03	0.57
13	0.2253±0.07	0.2370 ± 0.03	83.44±4.8	0.5276±0.06	0.71
14	0.1759 ± 0.06	0.1850 ± 0.02	65.14±5.3	0.3719±0.05	0.61
15	0.1289 ± 0.02	0.1358±0.06	47.72±6.8	0.2358±0.07	0.58
16	0.1587±0.04	0.1632 ± 0.04	58.79±5.9	0.3155±0.09	0.59
17	0.1393±0.06	0.1456 ± 0.03	51.59±5.2	0.2744 ± 0.02	0.55
18	0.1289±0.07	0.1361 ± 0.05	47.73±4.8	0.2591±0.04	0.53
19	0.1877±0.09	0.1935±0.02	69.50±6.5	0.4245±0.05	0.63
20	0.2383±0.08	0.2434 ± 0.03	88.26±7.1	0.5790±0.06	0.77
21	0.3923±0.02	0.4004 ± 0.05	145.29 ± 4.2	1.1539±0.56	1.42
22	0.3857±0.02	0.3966±0.04	142.86±4.3	1.0316±0.42	1.27
23	0.3930±0.04	0.4118 ± 0.05	145.55±4.6	1.0180±0.48	1.21
24	0.1725±0.01	0.1831±0.02	63.89±3.8	0.4107±0.03	0.53
25	0.1242 ± 0.03	0.1293±0.02	46.00±3.9	0.2603±0.06	0.46
26	0.1165±0.02	0.1205±0.03	43.16±4.1	0.2285±0.08	0.43
27	0.1186±0.02	0.1220±0.04	43.91±4.2	0.2773±0.09	0.41
28	0.1538±0.04	0.1672±0.05	56.95±4.6	0.3741±0.05	0.47
29	0.1890±0.05	0.2130±0.01	69.99±4.7	0.5242±0.07	0.51
30	0.7244 ± 0.08	0.7720 ± 0.02	268.29±5.8	2.0820±0.62	2.55
31	1.0361±0.53	1.0941±0.48	383.71±6.3	3.0389±0.75	3.82
32	0.1396±0.03	0.1636±0.03	51.68±3.8	0.3834±0.06	0.45
33	0.1418±0.04	0.1498 ± 0.02	52.53±4.2	0.2552±0.07	0.78
34	0.1414±0.07	0.1734 ± 0.04	52.35±4.3	0.4509 ± 0.02	0.34
35	0.4809±0.09	0.5160±0.06	178.12±6.4	0.8380±0.05	2.74
36	0.0761±0.06	0.0867 ± 0.01	28.18±4.2	0.1858±0.07	0.28
37	0.1352±0.08	0.1478 ± 0.09	50.07±4.8	0.3493±0.09	0.39
38	0.2442±0.03	0.2676±0.08	90.44±6.5	0.6473±0.04	0.72
39	0.3027±0.05	0.3356±0.07	112.11±7.2	0.9009±0.06	0.85
Max	1.0361±0.53	1.0941±0.48	383.71±6.3	3.0389±0.75	3.82
Min	0.0761±0.06	0.0867±0.01	28.18±4.2	0.1858±0.07	0.28
Mean	0.2292±0.04	0.2436 ± 0.05	84.89±5.6	0.5568±0.06	0.89

and ⁴⁰K) is shown in figures 4 to 6. The correlation between ²³⁸U and ²³²Th is found to be weak (R = 0.73) which indicates that the presence of monazite mineral in sediments is less likely. The 232Th values are almost less than unity, because ²³²Th activities are usually greater than ²³⁸U activities in the crust of origin of the rivers. This implies that relative mobility of uranium (largely dissolved) and thorium (largely particulated) depends upon prevailing hydrological region. The adsorption of uranium by clay minerals, insoluble oxides, oxihydroxides and organic matters may be due to leaching of sediments from weathering, erosion and transport in the surfacial environments. Uranium is quite soluble in oxidizing natural waters, whereas thorium is much less soluble. This indicates that the water flow of

Cauvery river is maximum (17).

According to Abdel Hady et al. (18), the ⁴⁰K/²³²Th ratio has a special significance and varies with clay mineral type. Because, the concentration of 40K and 232Th depends upon the relative amounts of the feldspars, mica and clay minerals. During the weathering process, ²³²Th and ⁴⁰K react differently. ⁴⁰K is more soluble and is easily carried away in water, whereas ²³²Th tends to remain. Ratios of 40K/232Th vary considerably from feldspar (low) to kaolinite (high). In the present study, higher value (site nos. 33 and 35) of 40K/232Th may indicate the presence of feldspars or clay or combination of both as maximum. These results were confirmed by FTIR analysis (19). The activity ratio of 40K/238U and 40K/232Th give no obvious trend with poor correlation.

Table 5. Comparison of present results with the corresponding world average values.

Radiological parameters	Present results (Average)	World average	Ratio of the Present average/world average	
²³⁸ U Bqkg ⁻¹	5.31	33	0.16	
²³² Th Bqkg ⁻¹	34.04	45	0.75	
⁴⁰ K Bqkg ⁻¹	401.11	420	0.96	
Absorbed dose rate	40.73	51	0.79	
Indoor Annual effective dose equivalent mSvy ⁻¹	0.25	3.4	0.71	
Internal hazard index, Bqkg ⁻¹	0.23	0.5	0.46	
External hazard index, Bqkg ⁻¹	0.24	0.5	0.48	
Radium equivalent activity Bqkg ⁻¹	84.89	129.7	0.65	
Radiation heat production rate µWm ⁻³	0.5568	1	0.55	
Activity concentration index	0.89	1	0.89	

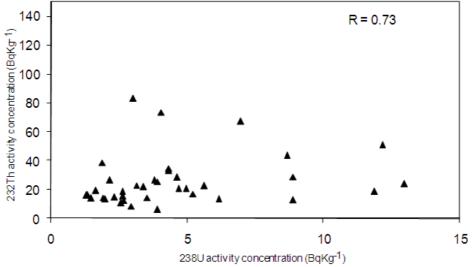


Figure 4. Correlation between ²³⁸U and ²³²Th.

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The linear correlation between Ra_{eq} and 232 Th activity as shown in figure 7 may indicate the river starting from laterite origin. Similar findings have also been

reported in literature for lateritic soil samples of Karnataka ⁽¹⁰⁾ and Taiwan ⁽²⁰⁾. The Karnataka state is the origin of Cauvery River.

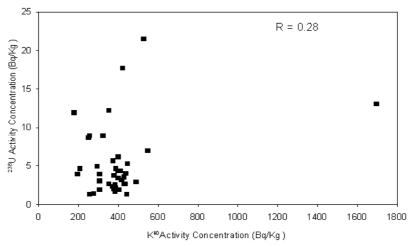


Figure 5. Correlation between ⁴⁰K and ²³⁸U.

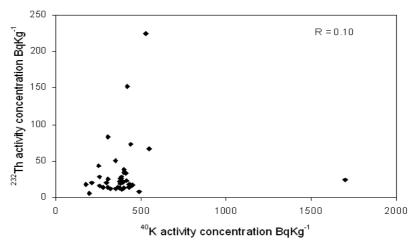


Figure 6. Correlation between ⁴⁰K and ²³²Th.

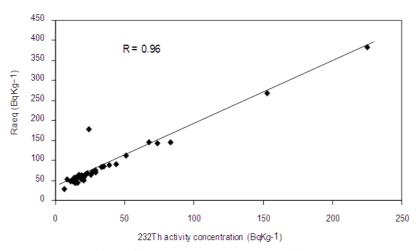


Figure 7. Correlation between Raeq and ²³²Th.

CONCLUSION

It is clear from the data of the gamma ray spectroscopic analysis in the present study of sediment samples that the levels of mean activity concentration of ²³⁸U, ²³²Th and 40K for Cauvery river is lower than the international recommended limit. The mean annual effective equivalent dose is 0.71 times with that of international recommended limit (70µSvy⁻¹). In the present study, the mean value of Ra_{eq}, H_{ex} and H_{in} found are lesser than the international recommended limit of 370 Bqkg⁻¹, 1 and 1 respectively and the mean value of activity concentration index and RHP rate is also lesser than the international recommended limit. Therefore Cauvery river sediments do not pose source of radiation hazard when used as building materials. Among all the sites, the site no. 21, 22, 23, 30, 31 and 35 show the higher values of absorbed, observed, annual effective equivalent dose, radium equivalent, hazard indices, activity concentration index and RHP rate. This implies that inhabitance of those areas are subjected to increase radiation exposure, which is harmful to human health. So those sites can be avoided for building construction.

REFERENCES

- Ferdoas S AI Saleh and Badriah Al-Berzan (2007) Measurements of natural radioactivity inSome kinds of marble and granite used in Riyadh region. *Journal Nuclear Radiation Physics*, 2: 25.
- UNSCEAR (1988) United Nations Scientific Committee on the effects of Atomic Radiation United Nations (New York).
- UNSCEAR (2000) United Nations Scientific Committee on the effects of Atomic Radiation United Nations (New York).
- Beretka J and Mathew PJ (1985) Natural radioactivity of Australian building materials waste and bi-products. Health Physics, 48: 87-95.
- Rybach L (1988) Handbook of terrestrial heat flow density determinations Kluwer Dordredut. Determination of heat production rate In Haenel R Rybach L Stegena L (Eds), 125-142.
- Kannan V, Rajan MP, Iyengar MAR, Ramesh R (2002) Distribution of natural and anthropogenic radionuclides in soil and beach sand samples of Kalpakkam (India)

- using hyper pure germanium (HPGe) gamma ray spectrometry. Applied Radiation and isotopes, **57:** 109.
- Vijayan V and Behera SN (1999) Study of natural radioactivity in soils of Bhubaneswar proceedings of the eight national symposium on environment Indira Gandhi Centre for Atomic Research Kalpakkam India June. 22-25: 146-147.
- Pandian S, Muguntha Manikandan N, Sivakumar R, Balasubramanian S, Venkatesan T, Meenakshi Sundaram V, Raghunath VM, Gajendran V (1999a) Gamma radiation dose from radionuclides in soil samples of Udagamandalam (Ooty) in India. Radiation Protection Dosimetry, 82: 225-228.
- Verma PC, Gurg RP, Sundaram M, Sharma LN(1998) Natural radioactivity in Rawatbhata and Narora soils proceedings of the seventh national symposium on environment Indian School of Mines Dhanbad-826004 India February 5-7: 132-134.
- Radhakrishna AP, Somashekarappa HM, Narayana Y Siddappa KA (1993) New natural background radiation area on the South West coast of India. *Health Physics*, 65: 390-395.
- Mishra VC and Sadasivan S (1971) Natural radioactivity levels in Indian soils. J Sci Ind Res, 30: 59-62.
- 12. Narayana Y, Somashekarappa HM, Karunakara N, Avadhani DN, Mahesh HM, Siddappa K (2001) Natural radioactivity in the soil samples of coastal Karnataka of South India. Health Physics, 80: 25-33.
- 13. Ajayi OS (2002) Evaluation of absorbed dose rate and annual effective dose equivalent due to terrestrial gamma radiation in rocks in a part of Southwestern Nigeria. *Radiation Protection Dosimetry*, **98**: 441.
- 14. Rizzo S, Brai M, Basile S, Bellia S, Hauser S (2001) Gamma activity and geochemical features of building materials estimation of gamma dose rate and indoor radon levels in Sicily. Applied Radiation and Isotopes, 55: 259-265.
- 15. Ribeiro FB and Roque A (2001) Vertical distributions of uranium thorium and potassium and of volumetric heat production rates in the sediments of the São Francisco Basin Central Brazil. *Applied Radiation and Isotopes*, **55**: 393.
- 16.EC (1999) European Commission Report on "Radiological protection principles concerning the natural radioactivity of building materials". Radiation Protection, 112.
- 17. Chung Y and Chang WC (1996) Uranium and thorium isotopes in marine sediments of northeastern Taiwan. *Marine Geology*, **133**: 89-102.
- 18. Abdelhady EE, El Sayed AMA, Ahmed AA, Hussein AZ (1994) Natural radioactivity of basement younger granite rocks from the eastern desert. Radiation Physics and Chemistry, 44: 223-224.
- 19. Ramasamy V, Murugesan S, Mullainathan S (2004) Characterization of minerals and relative distribution of quartz in Cauvery river sediments from Tamilnadu, India - A FTIR study. *Bull Pure Appl Sci, 23F (1-2), 1-7.*
- 20.Yu-Ming L, Pei-Huo L, Ching-Jiang C, Ching-Chung H (1987) Measurement of Terrestrial gamma radiation in Taiwan Republic of China. Health Physics, 52: 805-811.
- 21. Pandian S, Sivakumar R, Manikandan NM, MeenakshiSundaram V, Raghunath VM, Gajendran V (2000) Natural radionuclide distribution in soils of Gu-

S. Murugesan, S. Mullainathan, V. Ramasamy, et al.

- dalore India. Applied Radiation and Isotopes, 52: 299-306.
- 22. Pandian S, Sivakumar R, Manikandan NM, Meenakshisundaramm V, Raghunath VM, Gajendran V (1999b) Measurements of natural radioactivity levels in soil in Coonoor Proceedings of the Eighth National Symposium on Environment Indira Gandhi. Centre for Atomic Research Kalpakkam India, June 22-25: 160-163.
- 23. Ziquiang P, Yin Y, Mingqiang G (1988) National radiation and radioactivity in China. *Radiation Protection Dosimetry*, **24:** 29-38.
- 24. Delune RD, Jones GL, Smith CJ (1986) Radionuclide concentrations in Louisiana soils and sediments. *Health Physics*, 51: 239-244.
- McAulay IR and Moran D (1988) Natural radioactivity in soil in the Republic of Ireland. Radiation Protection dosimetry, 224: 47-49.
- 26.Travidon G, Flouro H, Angelopoulos A, Sakellioou L (1996) Environmental study of the radioactivity of the spas in the Island of Ikaria Greece. *Radiation Protection Dosimetry*, **63:** 63-67.
- 27. Lambrechts A, Foulquier L, Garnier-Laplace J (1992)

- Natural radioactivity in the aquatic components of the main French Rivers. *Radiation Protection Dosimetry*, **45**: 253-256.
- 28. Mantazul IC, Alam MN, Hazari SKS (1999) Distribution of radionuclides in the river sediments and coastal soils of Chittagong Bangladesh and evaluation of the radiation hazard. Applied Radiation and Isotopes, 51: 747-755.
- 29. Chu TC, Weng PS, Lin YM (1992) Distribution of naturally occurring radionuclides in Taiwanese rocks. *Radiation Protection Dosimetry*, **45**: 281-283.
- Ibrahim NM, Abd El, Ghani AH, Shawky SM, Ashraf EM, Farouk MA (1993) Measurement of radioactivity levels in soil in the Nile Delta and middle Egypt. Health Physics, 64: 297-299.
- 31.Saad HR and Al-Azmi D (2002) Radioactivity concentrations in sediments and their correlation to the coastal structure in Kuwait. Applied Radiation and Isotopes, 56: 991-997.
- 32. Arogunjo AM, Farai IP, Fuwape IA (2004) Dose rate assessment of terrestrial gamma radiation in the delta region of Nigeria. *Radiation Protection Dosimetry*, 108: 73-77.