

Measurement of radioactive hazards in Cauvery River sediments through grain size and magnetic separation

**Submitted in partial fulfillment of the requirements for the award of Master of
Science degree in Physics**

By

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**DEPARTMENT OF PHYSICS
SCHOOL OF SCIENCE AND HUMANITIES**

SATHYABAMA
INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **KARTHIKEYA. S (40590019)** who carried out the project entitled **“Measurement of radioactive hazards in Cauvery River sediments through grain size and magnetic separation”** under my supervision from **NOVEMBER 2021 TO MARCH 2022**

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Abstract

The Cauvery is a prominent river in Tamil Nadu, India. River sand is an important component used for the construction of buildings in India, and it is essential for irrigation, drinking, and electricity. A gamma-ray spectrometer with NaI (TI) detector is used to investigate the isotopes of uranium, thorium, and potassium (^{238}U , ^{232}Th and ^{40}K). Bigger than 125 μm in size and non-magnetic grains were separated with the help of ASTM standard sieve and strong electromagnet.

The systematic studies were carried out for the measurement of radioactive hazards in Cauvery River sediments through grain size and magnetic separation. The sand samples are collected and dried at 100°C for 24 hours. The analysis of uranium, thorium, and potassium concentration of sediments was studied using NaI(TI) detector. Using certain formulas AEDE, ELCR, RHP, H_{in} , H_{ex} , Ra_{eq} , AUI, Alpha, and gamma were calculated.

The following radiological parameters are examined. Absorbed dose (AD_{in} & AD_{out}), annual effective dose equivalent ($AEDE_{\text{in}}$ & $AEDE_{\text{out}}$), and hazard indices for calculating human radiation exposure, such as average radium equivalent (Req), external (H_{ex}), and internal (H_{in}) hazard indices are computed and correlated. In addition to the above parameters radioactive heat production (RHP), internal and external Excess Lifetime Cancer Risk ($ELCR_{\text{in}}$ and $ELCR_{\text{out}}$), Alpha (I_{α}), Gamma Index (I_{γ}), and Activity Utilization Index are calculated to assess level of radiation damages in living things. The varied parameter values for both magnetic and nonmagnetic samples suggest that the Cauvery River does not pose a radiation concern, and cancer risk is lower than the world average, except site 31. AEDE, ELCR, RHP, H_{in} , H_{ex} , Ra_{equ} , AUI, Alpha, and gamma all have lower values than the world average. This analysis shows that almost all radioactive parameters are under control by comparing the findings to the worldwide average. However, except C31, the Cauvery River does not pose a radioactive threat.

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LIST OF ABBREVIATIONS

AD	- ABSORBED DOSE RATE
in	- INDOOR
out	- OUTDOOR
Tot	- TOTAL
AEDE	- ANNUAL EFFECTIVE DOSE EQUIVALENT
ELCR	- EXCESSIVE LIFETIME CANCER RISK
H_{in}	- INTERNAL HAZARD INDEX
H_{ex}	- EXTERNAL HAZARD INDEX
AUI	- ACTIVITY UTILISATION INDEX
RHP	- RADIOACTIVE HEAT PRODUCTION
ASTM	- AMERICAN SOCIETY FOR TESTING AND MATERIALS
Ra_{equ}	- RADIUM EQUIVALENT
I_α	- ALPHA INDEX
I_γ	- GAMMA INDEX
U	- URANIUM
Th	- THORIUM
K	- POTASSIUM
NaI(Tl)	- SODIUM IODIDE THALLIUM DETECTOR
IPCD	- LITRES PER CAPITA PER DAY
MCM	- MILLION CUBIC METERS

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CHAPTER 1

1.1 INTRODUCTION

Sands beside the rivers plays a major role in building materials. To ensure the stability, hazardness, binding nature it is necessary to analyze the presence of radioactivity present in river sands. The major river sand consists of radioactive isotopes such as ^{226}Ra (^{238}U), ^{232}Th and ^{40}K . In the construction of building, sand, cements and bricks play a major role in depth sands plays major role compared with these three materials. Hence for constructing a building almost we lie on river sands. We tend to measure the radioactive dosage in the sample which is taken from the river sand as sediment. Construction sand should ideally be hard, clean, and free of organic matter, clays, shells, and chlorides. Rock, sand, soil, sediment, and water all contain natural radioactive isotopes. This analysis shows that all radioactive parameters are under control. This research is intended to enhance in the creation of environmental regulatory systems as well as give information on the geological features and formation of the materials under study. Sediment is a vital and dynamic component of the river basin, accumulating heavy metals from a variety of sources and in a variety of chemical forms (Ali et al., 2016). Adsorption, ligand exchange, and complexation are some of the physicochemical mechanisms that influence the heavy metals' stability (Bai et al., 2011; Chen et al., 2016). Heavy metals collected in the water column can be detected in sediment at levels 1,000 times greater than in water (Long & Chapman, 1985) and can stay there for a long time (Liu et al., 2020). Furthermore, if environmental circumstances change, the sediment-bound metals may be released back into the overlying waters (Liu et al., 2020).

1.2 THE RIVER CAUVERY (STUDY AREA)

The Cauvery River originates in the Western Ghats and runs eastward through Karnataka, Tamil Nadu, Kerala, and Pondicherry before discharging into the Bay of Bengal. The Cauvery River travels eastward from the Western Ghats, passing through the states of Karnataka, Tamil Nadu, Kerala, and Pondicherry on its way. Between latitudes 100 05' N and 130 30' N, and longitudes 750 30' E and 790 45' E, the basin is found. It is bordered on three sides by sea and on the other by land. The River Cauvery, which starts in Talakaveri, is the longest river in the state of Karnataka. With an 8500 square kilometers catchment area and a length of 800 kilometers, it is the

largest in the world. Despite the fact that the Cauvery River has a potential average water resource of 21358 (MCM), the surface water utilizable resource is approximately 19000(MCM). A total of 34 hydrological observation stations are located on the property. Agricultural land covers the majority of the basin, accounting for 66.21 percent of the total area, with water bodies accounting for 4.09 percent of the total area. The basin encompasses 33 parliamentary constituencies in 2009, including 18 constituencies in Tamil Nadu, 11 constituencies in Karnataka, three constituencies in Kerala, and one constituency in Puducherry. In addition to providing drinking water, the Cauvery River is also used for fishing and other household purposes by the locals. Periodic river water and sediment study and timely monitoring in the vicinity of the KRS dam are extremely important and must be carried out on a regular basis. Different anthropogenic activities, as well as the Upstream, the rate of industrialization in the catchment areas is accelerating, have had an impact on the construction of this dam **(S.Susheela F et al., 2014)**. These activities include mining, the emission of industrial waste, the smelting of as ore, the burning of fossil fuels, notably coal, the use of As-loaded water for agriculture, and the use of As-based insecticides, herbicides, and fertilizers on agricultural crops and pastures **(Karimi et al., 2009)**. The River Kaveri has a long and illustrious history that dates back to prehistoric times. Beautiful picnic areas and religious sites can be found along the river's banks. Thousands of national and international tourists visit the state each year, bringing in a significant amount of revenue. In addition to the Cauvery, there are numerous tributaries, including the Hemavathi, Arkavathy, Kapila, LakshmanaTheerth, Kabini, Lokapavani, Bhavani, Noyil, and Amaravathi. Before merging with the Bay of Bengal, it travels a distance of around 765 kilometres. Tamil Nadu and Karnataka's domestic and industrial water requirements are met by the Cauvery Waters, which are located in Tamil Nadu. For the most part, when calculating the residential and industrial requirements of both states, the Tribunal referred to the following Indian standards: Because there is a scarcity of particular data on the population of numerous towns and cities, as well as the kind of water supply distribution system in the Cauvery basin, they estimated the drinking water requirements of the urban population as follows: 135 lpcd for 25% of the urban population; (ii) 100 lpcd for the remaining 75% of the urban population. For the same reason, they don't have separate livestock data for each of the party states and the Pondicherry Union Territory. Instead, they assumed that the animal population was equivalent to the rural human population, which will be liberal,

and given 30 lpcd for animals and 40 lpcd for human beings in a total of 70 lpcd as recommended above. Radionuclides are the radioactive versions of elements that have been created. The majority of radioactive elements exist naturally in the environment, although some are created by humans, either intentionally or as consequences of nuclear reactions. It is measured in terms of half-life because each radionuclide emits radiation at a unique rate. The half-life of a radioactive atom is the amount of time it takes to decay 50% of the radioactive atoms present. This word describes the process by which a radioisotope transforms into another radioisotope, resulting in the emission of radiation in some form. Some radionuclides have half-lives as short as a few seconds, while others have millions of years or longer. The distribution of radionuclides in the Cauvery River is the primary topic of this article. There some research has been done into the radionuclides that are present in the Cauvery River's banks using river sand samples, we were able to conduct an inquiry into radionuclides, which eventually led to the discovery of highly toxic radionuclides.

1.2.1 SEDIMENT:

Sediment is a natural substance that has been weathered, eroded and is subsequently moved by wind, water, or ice, or by gravity acting on particles. Sand and silt, for example, can be carried in suspension in river water and deposited on the sea bed through sedimentation, if buried they can produce sandstone and siltstone (sedimentary rock) by hydro-fossilization. Water (sulfurization process) is the most common mode of sediment transport, although it can also be carried by wind (Aeolian process) and glaciers. Although sediment is often formed by standing or standing water in lakes and seas, beach sand and riverbed sediment are instances of transport and deposition in rivers. Aeolian transport and deposition may be seen in deserts and loess dunes. Sediments from glaciers and sedimentary soils as glacial-transported sediments Sedimentary components (i) Terracotta components derived from soil erosion are transported in the basin as soil. (ii) Chemical composition distribution; precipitates of solutions in the clarifier but are unusual chemical precipitates because they are subsequently converted to solids in the tank. (iii) Orthologous components are chemically formed in the pelvis and little/no evidence of transport in complex entities. **(Gobala Krishnan N, 2018)**. Sediment takes place from one location to every other via the procedure of erosion. Erosion is the process of removing and

transporting rock or soil. Sediment can be carried by water, ice, or wind during erosion. Water can sweep material, such as gravel or pebbles, down a creek, into a river, and eventually to the delta of that river. Sediment collects in a variety of places, including deltas, river banks, and the lowest reaches of waterfalls. As the ice carves its way across the landscape or melts, glaciers can freeze sediment and deposit it someplace else. Moraine is a kind of sediment generated and deposited by glaciers. In simple dirt storms or sandstorms, the wind may blow dust about. Sand dunes are formed by stony material being eroded by wind and colliding with various sand particles. Sediment is important because it typically adds nutrients to the soil. Sediment-rich areas are typically also rich in biodiversity. Sedimentary soil has a better yield for farming. Deltas and river banks, which produce a lot of silt, are usually the most fertile agricultural areas in a region. Layers of silt pile up and solidify into sedimentary rock over millions of years. As sand hardens, sandstone develops. For ages, sandstone has been combined with sticky cement to make concrete. Sandstone, rock salt, and coal are examples of sedimentary rock that may develop over millions of years. Sandstone is created when sand hardens and is then combined with sticky cement to build concrete, which has been done for ages.

1.2.2 SAND :

Sand is a non-cohesive natural granular substance. Sand is made up of grains ranging in size from 1/16 to 2 mm (62.5 to 2000 micrometers). Mineral grains, rock fragments, and biological sand grains are all examples of sand grains. Alluvium is a granular substance that is finer than sand. The material is coarser than gravel. The majority of sand is made up of silicate minerals or fragments of silicate rock. Quartz is by far the most abundant mineral in sand. As a result, without the qualifier, "sand" is considered to be mostly made of quartz. Sand, on the other hand, is a natural combination, thus it is never completely pure. There is no other way to describe quartz and sand as the same thing. The rock sandstone is a form of sandstone. The chemical and physical degradation of rocks is the primary source of sand which is collectively known as weathering. Physical and chemical changes are discussed separately, although in fact, they frequently occur jointly, making it difficult to distinguish between them. In general, chemical weathering plays a substantially bigger role in sand generation. It works best in hot, humid environments. Physical disability is more

common in cold and dry climates. In most cases, the weathering of bedrock that generates sand occurs in the soil. A small layer of bedrock is covered by soil, which provides moisture for rock disintegration.

1.2.3 SILT :

Alluvium is a detritus (weathered and eroded rock fragment) that is intermediate in nature between the sand and the clay. Geologists employ a more exact definition of alluvium as crumbly particles ranging in size from 1/256 to 1/16 mm (about 4 to 62 microns). On the Krumbein phi scale, this corresponds to particles between 8 and 4 phi. Alluvium is defined by other geologists as crumbly particles ranging in size from 2 to 62 microns or 9 to 4 phi units. Alluvium, according to the third definition, is a fine-grained crumbly substance made up of quartz rather than clay minerals. There is considerable agreement between the criteria since most clay mineral grains are smaller than 2 microns and most 2-to-62-micron crumbs are made up of crumbly quartz grains. The smallest particles visible to the human eye have a size of 1/256 mm or 62 microns as their top limit. [8] This also correlates to a Tanner divergence in sediment grain size distribution: particles between 120 and 30 microns are uncommon in most sediments, implying that the difference between sand and alluvium has a physical basis. The lower limit of 2 to 4 microns corresponds to the shift from predominantly shattered quartz grains to mostly clay mineral grains, as previously stated. Sand, Silt, Clay Sedimentary populations classified according to their parts, these classifications are named for the size of the main constituent particles. The smallest particles are clay (diameter $0 > 0.05$ mm) (**Gobala Krishnan N, 2018**).

1.2.4 CLAY :

Clay is a frequent sedimentary rock component. Shale is the most prevalent sedimentary rock and is primarily composed of clay. However, the majority of clay mines are filthy. Alluvium and clay are found in many natural deposits. Differences in size and minerals separate clay from other fine-grained soils. Alluvium, which is a fine-grained soil devoid of clay elements, has bigger particles than clay. In terms of particle size and other physical attributes, however, there is some overlap. Depending on the subject, the distinction between alluvium and clay varies. Segregation is thought to occur at particle sizes of 2 μ m (clay is finer than mud) by geologists and soil scientists,

4-5 μm by sedimentologists, and 1 μm by colloidal chemists. The flexibility of the soil, as evaluated by the Atterberg limit, is used by geotechnical engineers to distinguish between alluvium and clay. Clay particles less than 2 μm and bigger mud particles are classified according to ISO 14688. Humus is a soil made up of sand, silt, and less than 40% clay. This mineral is a naturally occurring crystalline material that has a specific or limited chemical composition.

Clay minerals have a plate structure and are mainly composed of silicate groups arranged in a tetrahedron and aluminate groups arranged in an octahedron. Kaolinite is the main mineral in kaolinic clay. It is a 1:1 clay mineral - the basic unit made up of a 2D layer of silicate groups closely related to the 2D layer of aluminate groups. Throughout the mineral has a tetrahedral (TO) layered structure with interlayer compaction. This tight wrapping - like the pages of a closed book - ensures that the kaolinite does not shrink when dry or swell when wet.

1.3 AGRICULTURAL IMPACT ON THE CAUVERY RIVER:

Rivers are vital to human development and are potentially major natural irrigation water sources. Pollution from home wastewater and agricultural operations ends up in rivers, causing widespread water quality degradation. The quantity of dissolved salts is an essential endpoint for irrigation water quality. Growing urbanization and corresponding agricultural output needs in the Cauvery River basin have resulted in the deterioration of water quality. The Cauvery crosses large wetlands with low rainfall and therefore transports far less water than rivers running through high-rainfall areas like as India's northeastern and western coastlines, and consequently fails to maintain the necessary flow to dilute toxic effluent. Furthermore, the Cauvery River collects more than half of the drinking water supply of downstream municipalities. As a result, monitoring the water quality of the Cauvery River is critical for determining if harvesting is sustainable. The World Health Organization has established permissible limits for drinkable water supply. To determine the reasons of water quality deterioration for agricultural purposes, a water quality analysis of the Cauvery River should be carried out.

CHAPTER 2

LOCATION, GEOLOGY AND SAMPLE COLLECTION

2.1. GEOGRAPHICAL AND PHYSIOLOGICAL FEATURES OF CAUVERY:

At an elevation of 1341 m above sea level, The River Cauvery starts at Talakaveri in the Coorg district of Karnataka. It flows through a total area of 81,000 sq.kms of which 34,273 sq.kms is in Karnataka, 43856 sq kms. is in Tamil Nadu, 2866 sq.kms is in Kerala, and 160 sq. kms is in the Union Territory of Pondicherry. The Tungabhadra sub-basin of the Krishna basin is on the north, and the Palar basin is on the south. The Western Ghats make up the Western boundary of the country. When the Nilgiris, an offshore area from the Western Ghats, move eastward they form two separate areas: the Karnataka plateau, in the north of India, and the southern Tamil Nadu plateau, in the south of India. When you live in Tamil Nadu, the Eastern part of the basin is in the range of 0 to 150 m above sea level. It slopes gently up from the sea. It splits into two parts at Shivanasamudram. The river plunges through rapids and falls 91 metres to reach the other side, where it splits again. Here, the falls are used to make electricity. Mekedatu (Goats leap) is where the two branches of the river meet after the fall and flow through a wide gorge. It goes on to form the boundary between Karnataka and Tamil Nadu for 64 Kms. At Hogennekkal Falls, the water turns to the south and enters the Mettur Reservoir, which was built in 1934. In the area near Mettur Reservoir, A river called Bhavani joins the Cauvery on the right bank about 45 Km from the reservoir. After that, It heads east to enter the plains of Tamil Nadu. "Akhandha Cauvery" is what people call the river when two more tributaries join it on the right. The river widens with a sandy bed and flows as "Akhandha Cauvery". After passing through Tiruchirapalli district, the river splits into two parts. The northern branch is called "The Coleron," and the southern branch is called "The Cauvery." From here, the Cauvery Delta starts. "Srirangam Island" is formed when the two branches meet again after about 16 Kms, when they meet again. There is a "Grand Anicut" that is said to have been built by a Chola King in the 1st Century A.D. It is on the branch of the Cauvery River. Below Grand Anicut, the Cauvery branch splits into two, Cauvery and Vennar. This is where the branch meets. In the delta, there are a lot of branches that split off from each other and form a network all over. As a whole, it

runs for 800 Kms. from its source in Karnataka to the sea. 320 of that is in Karnataka, 416 of it goes through TN, and 64 of it goes through KA and TN. In Karnataka, the basin of the Cauvery is fan-shaped, and in Tamil Nadu, it is leaf-shaped, like a flower or a leaf. Because of the shape of the basin, the run-off doesn't drain quickly, so there are no fast-moving floods there. Rainfall mostly comes from the S-W Monsoon in Karnataka, but some comes from the N-E Monsoon as well. The North-East Monsoon sends a lot of water to the basin in Tamil Nadu. All 21 tributaries of the Cauvery have catchment areas above 250 sq.kms. Amaravati rises in Kerala but largely in Tamil Nadu, and Kabini rises in both Kerala and Tamil Nadu but mostly in Karnataka, with the Catchment Area Shimsha being the largest of them all. The Bhavani is the second longest. In Tamil Nadu, it rises from Kerala and Karnataka. With 245 km of length, the Hemavathi is the seventh largest tributary in terms of catchment area. The Hemavathi, Kabini, and Bhavani are the most important tributaries in terms of flow contribution to the system. After receiving the Yagachi from the North, it turns eastward. On its way to the Cauvery, it passes Holenarasipur. A tributary of the Cauvery, the Kabini It is a 240 km long perennial river that is 150-200 m wide. Mannantoddypuzha and Panamarampuzha are two streams that rise in the Western Ghats of North Wynad, Kerala State. It flows for around 12 km between Kerala and Karnataka before entering Karnataka state, roughly 16 km downstream from their confluence. T.N.Pur, where it enters the Cauvery, is regarded as a holy place by the locals. Triveni Sangama is the name of the confluence location. The Bhavani is a beautiful perennial river in Kerala. On its way to the Cauvery, it crosses Tamil Nadu around Mannar.

2.1.1 SAMPLE COLLECTION:

To assess natural radioactivity in soil, surface soil samples are randomly obtained from the study region. The sediment samples are obtained from 39 successive locations (C1 to C39) in Cauvery River (Table 2.1). A total of around 15 kilometers separates the two locations along the Cauvery River. This area contains three locations that are around five kilometers apart. The recently dug sediment samples are manually collected from Cauvery River with the use of a plastic spade in polyethylene bags from upper surface (0–5 cm) of the river. Approximately 2 kilogram of material is contained in each sample. This research includes the sand and sediments that have been gathered from river, as well as the radioactive dosage parameters and radiological hazardous parameters that have been determined. They are extracted from remaining sand and silt collected from the Cauvery River, which has previously been utilized for the calculation of radiological parameters for bulk. These parameters are examined with the assistance of this paper, in which some of the parameters are taken into consideration as a point of comparison. These parameters are calculated based on the information in the paper described above, which is applicable to both larger than 125 microns in size grains and nonmagnetic micro grain applications (**Murugesan S et al 2011**).

The following table A shows the latitude and longitudinal coordinates of Cauvery River sites.

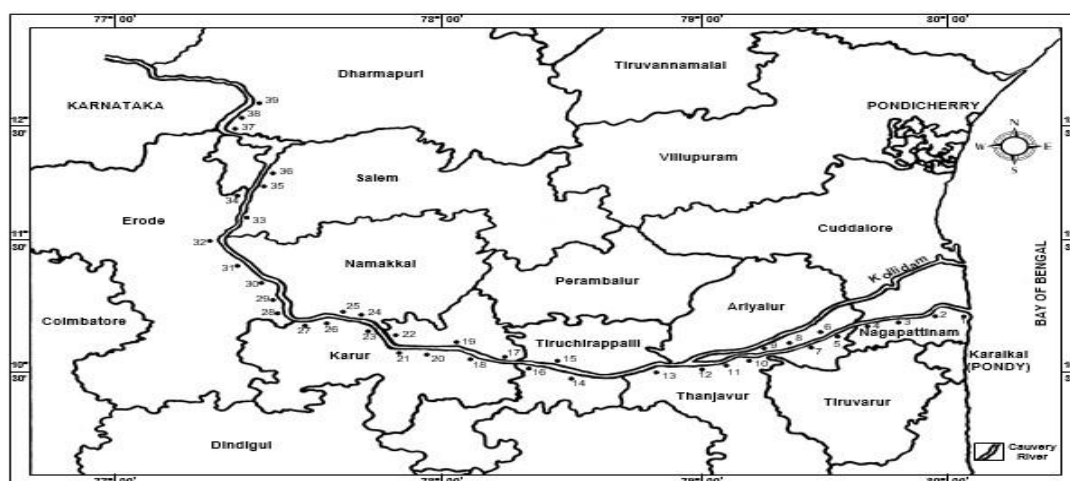


Fig 2.1: Location of Cauvery River

Table 2. 1: Latitude and Longitudinal Coordinates of Cauvery

S.No.	Location	Lattitude	Longitude
1	Poombhuhar	13°06'00N	80°12'60E
2	N.N. Chavady	12°42'60N	80°05'00E
3	Mayiladuthurai	11°05'60N	79°40'00E
4	kuttalam	11°03'60N	79°34'00E
5	Aduthurai	11°01'60N	79°28'60E
6	Thirubhuvanam	10°59'00N	79°25'60E
7	Kumbakonam	10°58'00N	79°22'60E
8	Swamimalai	10°57'60N	79°18'60E
9	Pappanasam	10°55'60N	79°16'00E
10	Kabisthalam	10°54'60N	79°10'00E
11	Tiruvaiyar	10°52'60N	79°05'00E
12	Thirukkattupalli	10°50'60N	78°58'00E
13	Kallanai	10°51'00N	78°47'60E
14	Trichy	10°51'60N	78°43'60E
15	Srirangam	10°52'00N	78°40'60E
16	Mukkombur	10°53'60N	78°32'60E
17	Gunaseelam	10°54'60N	78°28'60E
18	Kulithalai	10°55'60N	78°25'00E
19	Thottiyam	10°55'00N	78°20'60E
20	Krishnarayapuram	10°55'00N	78°16'60E
21	Mayanoor	10°55'60N	78°13'60E
22	Kattuputhur	10°47'60N	78°06'60E
23	Puliyur	10°37'60N	78°02'60E
24	Vangal	10°45'60N	77°58'60E
25	Velayuthampalayam	10°48'60N	77°56'00E
26	Pothanoor	10°52'60N	77°55'60E
27	Noyyal	11°04'60N	77°54'60E
28	Kodumudi	11°09'60N	77°52'60E
29	Solasiranmani	11°20'60N	77°48'00E
30	Valajapettai	11°26'60N	77°46'60E
31	Erode	11°20'60N	77°43'60E
32	Bavani	11°26'60N	77°40'60E
33	Kalvadangam	11°32'60N	77°42'60E
34	Ammapettai	11°37'60N	77°45'00E
35	Thekkanoor	11°42'00N	77°46'60E
36	Mettur	11°48'00N	77°47'60E
37	Kulathur	11°56'60N	77°52'60E
38	Kaveripuram	11°56'60N	77°53'00E
39	Hoggenakal	12°34'00N	77°58'00E



Fig 2. 1 Sampling location of the site number 12 (Thirukkatupalli)



Fig 2.2 Sampling location of the site number 20 (Krishnarayapuram)



Fig 2. 3 Sampling location of the site number 27 (Noyyal)



Fig 2.4 Sampling location of the site number 39 (Hoggenakal)



Fig 2. 5 Sampling location of the site number 23 (Puliyur)

CHAPTER 3

REVIEW OF LITERATURE

References for the measurement of radioactive hazards in Palar river sediments through grain size and magnetic separation has been taken in order to familiarise the radioactive exposure of natural materials. In order to know the recent work on this field of study, some of the references are reviewed are as follows.

According to **Kaliprasad C et al (2017)**, systematic measurements of ^{40}K , ^{226}Ra , and ^{232}Th active concentrations furthermore as radon exhalation rates were worn out soil samples from the Cauvery River environment during this study. Using an HPGe gamma spectrometer, the activity in the soil samples was measured, and the mean values of ^{226}Ra , ^{40}K and ^{232}Th were determined to be 1824, 342, and 191 Bq kg⁻¹, respectively.

Hameed et al. (1997) investigated the natural distribution of radioactivity in the Cauvery River's water, sediments, and biota (plankton, weeds, snails, bivalves, shrimp, and fish). The ecosystem is 95 kilometres long. It is explored the importance of ^{226}Ra activity in the abiotic and biotic components of the Cauvery River.

The comprehensive research of gamma dose rates, breathed radon, soil and sediment radium content, and water radon concentrations within the Hemavathi River environment is discussed by **Shivanandappa KC et al (2018)**. Within the study region, within the air, no particulate radiation rates ranged has a median of 145 nGy h⁻¹ and a range of 98 to 202 nGy h⁻¹. In soil and sediment, the average radon concentration is 373.90 Bqm⁻³ and 334.90 Bq m⁻³ respectively.

In this **Srinivasa E et al (2019)** take a look at, using an emanometry technique, in 31 drinking water samples obtained from various places in Chikmagalur city, Karnataka state, India, radon concentrations were measured. Radon concentrations recorded varied from 0.51 0.1 Bqkg⁻¹ to 151.98 3.5% Bqkg⁻¹, with a median price of 22.72 1.1 Bqkg⁻¹. From this observe, it became clear that 61 percentage of ingesting samples in water had degrees of radon above EPA-advocated eleven Bqkg⁻¹ most contaminant level. The expected overall annual powerful dose on the three web sites with inside the design at location changed into determined to be above the secure restriction of 0.1 mSvy⁻¹ as advocated with the help of using WHO and therefore the Council of the EU Union.

Radenkovic, M et al (2009) have studied radionuclides in the beach sands of some famous coastlines and rivers. Radiation from beaches has been identified, as well as the dangers posed by humans. Standard The quantities of various radionuclides were determined using gamma spectrometry in the sand samples. Three distinct radiation risk indices were used to calculate the corresponding radiation hazards associated with the usage of sand as a building material.

M Radenkovic and colleagues (2009) investigated radionuclides in the sands of certain well-known coasts and rivers. The hazards caused by individuals, as well as the radiation emitted by beaches, have been established. The Standard quantities of various radionuclides were determined using gamma spectrometry in the sand samples. The corresponding radiation dangers associated with the use of sand as a building material were calculated using three different radiation risk indices.

In this context, **Malik F et al (2011)** said the presence of radioactivity in the environment is a natural occurrence. Natural radioactivity in sand and other building materials exposes the general public both inside and externally. As a result, determining how much naturally occurring radionuclides, such as ^{232}Th , ^{226}Ra , and ^{40}K , are present in sand, bricks, and cement, which are often used as construction materials in Pakistan, is critical. Sand samples were collected from 18 different locations throughout 1000 km² in northern Pakistan, along the banks of the rivers Indus (Ghazi to Jabba) and Kabul (Nowshera to Kund), while bricks and cement samples were obtained from local sellers in the examined region. The activity in these samples was measured using a P-type coaxial sensor.

The average specific activities of the ^{238}U and ^{232}Th are but half of the international averages of 33 Bqkg⁻¹ and 45 Bqkg⁻¹, In keeping with **Munyao, L. N et al (2020)**. Nonetheless, The typical ^{40}K unique activity is noteworthy because it grows thrice the general mean over a complete of 420 Bqkg⁻¹. Sands calculated absorbed radiation dose rates starting from 46.8 nGyh⁻¹ to 94.2 nGyh⁻¹, with a mean of 68.5 nGyh⁻¹ and a customary deviation of 13.3 nGyh⁻¹ and a typical deviation of 13.3 nGyh⁻¹ and a typical deviation of 13.3 nGyh⁻¹ and a typical deviation of 13.3 nGyh⁻¹ and a typical deviation of 13.3 nGyh⁻¹ and therefore the highest values are 0.29 and 0.52 mSvy⁻¹, both of which are significantly below the 4,444 recommended radiation exposure limits for the final public.

Masok, F et al (2018) is results showed that the typical radioactive ^{238}U , ^{232}Th , ^{226}Ra , and ^{40}K concentrations in soil samples taken round the area containing rock

phosphates were 28.26 ± 11.40 , 29.64 ± 11.50 , 32.18 ± 11.50 and 146.77 ± 63.30 BqKg⁻¹. Additionally, all radiation hazard parameters (eg: The observed levels of ²³⁸U, ²³²Th, ²²⁶Ra and ⁴⁰K). The movement convergences gamma spectrometry and a Na light identifier (TI) The levels of ⁴⁰K, ²²⁶Ra, and ²³²Th in soil samples obtained from the two local government in Ondo State, Nigeria, were studied using a 5 cm thick lead tube, cover to keep the climate under control. The findings show that the ⁴⁰K, ²²⁶Ra, and ²³²Th deliberate dynamic centralizations have a reach (and a comparative mean) of 430.

According to **Matiullah et al. (2014)**, it is a frequent radiation encourages both inside and outward openness to society. A high virtue germanium P-type coaxial gamma spectrometer was used to quantify the different workouts in these instances. The mean of the purposeful workouts of ²²⁶Ra, ²³²Th, and ⁴⁰K, respectively, were 45.63, 74.73 and 339.83 Bqkg-1, resulting in a normal retained portion rate of 83.54 nGy h⁻¹. The population's exposure to natural radioactivity, danger indicators, and compelling portions is all below safe levels.

CHAPTER 4

EXPERIMENTAL TECHNIQUE

4.1 INTRODUCTION:

The experimental procedure employed here is done using the Thallium activated Sodium Iodide detector. This instrument is uses the principle of scintillation. This experimental technique also includes the sampling process and the procedure which is followed in NaI(Tl) detector.

4.1.1 SAMPLE PREPARATION:

The samples were collected and dried in the open air at room temperature. The collected samples are blended and dried in an oven at 100 degrees Celsius for 24 hours. After that, the samples are packaged and sealed in an impermeable air tight PVC container with a capacity of 250 mL (9 cm 96.5 cm: height 9 diameter). During the sampling process, 500 g samples were taken and used for the measurements, around 450–500 g of samples are taken. A period of approximately 4 weeks is required before measurements to bring the ^{238}U , ^{232}Th and their decay products into equilibrium with each other and the surrounding environment before measurements can be taken. Before counting the samples, the net weight of the samples is established. The figure mentioned below is Gamma Ray spectrometer.

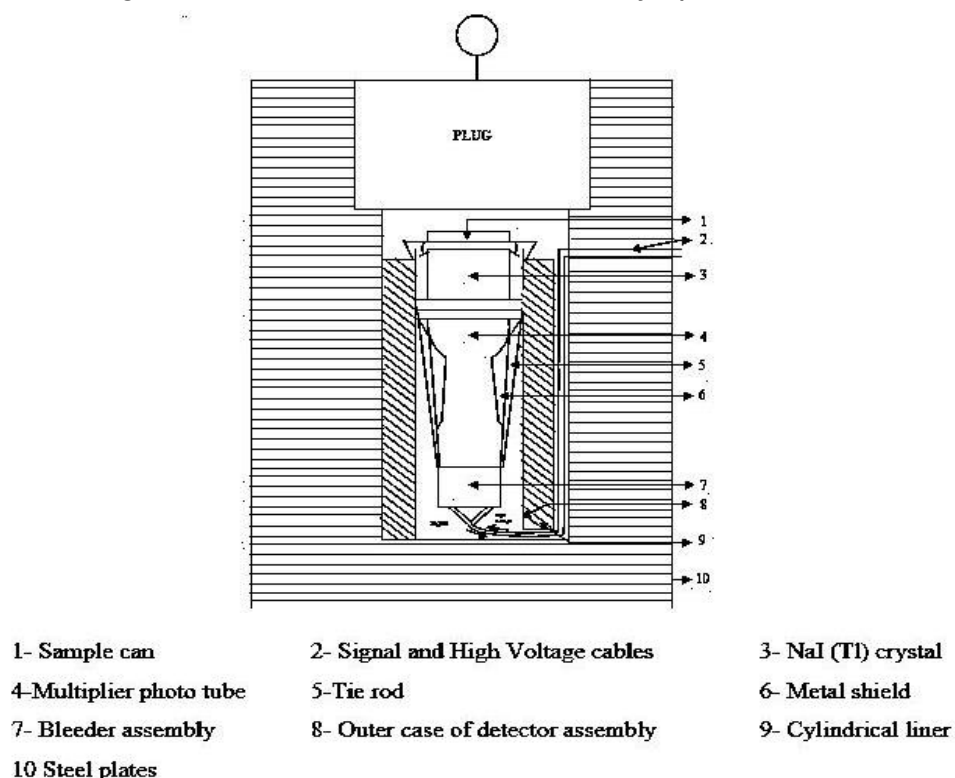


Fig 4.1: Sketch of Gamma Ray Spectrometer

4.1.2 PROCEDURE:

The measurements of radionuclides in the samples were carried out using a thallium activated sodium iodide [NaI (TI)] gamma ray spectrometer. The process of gamma ray spectroscopy, which is used to detect radioactive decay. In the photomultiplier tube, gamma rays from a sand sample strike the NaI (TI) crystal, resulting in photons being emitted from the photocathode, which are multiplied by the photomultiplier tube. A preamplifier connected to the detector collects the charges generated by the photomultiplier tube and generates a voltage that is proportionate to the charge applied to the detector (pulses). The voltage pulses are shaped and their sizes are increased by the amplifier. The voltage pulse is digitally represented by the multichannel analyzer.

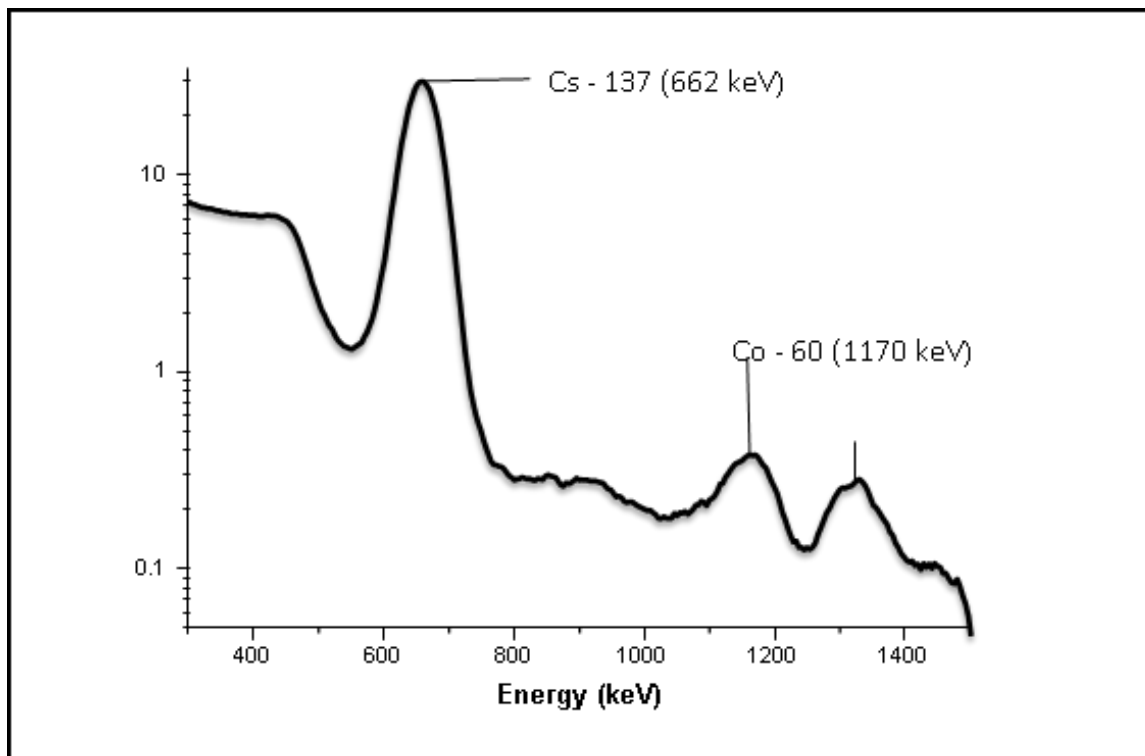


Fig 4.2: Energy calibration graph

The following is the energy calibration of the NaI (TI) spectrometer:

In nuclear energy, energy calibration is the process of correcting a detector's output to be consistent with the standard IAEA radionuclides. This is done in order to obtain the relationship between peak positions and the related nuclear energy. To account for variations in weather, vibrations, and the heating up of the detector, this was done at the beginning of each measurement. It was accomplished through the measurement of gamma ray emission peaks from sources with precisely known energy and the comparison of the measured peak position with the known energy. Cobalt-60 was utilized to calibrate the photo peak at 662 keV, while cesium-137 and cobalt-60 were used to calibrate the photo peak at 1170 keV and 1330 keV, respectively.

The calibration equation of the polynomial fit is given in the form of equation (Debertin and Helmer, 1988):

$$E = Y_0 + C_1B + C_2B^2$$

Where E is the photon energy, B is the channel number and (Y_0 , C_1 and C_2) are fit Parameters.

Table 4.1: Energy calibration parameter

Parameter	Fitted value
Y_0	13.9 ± 0.7
C_1	3.5 ± 0.2
C_2	0.10 ± 0.0001

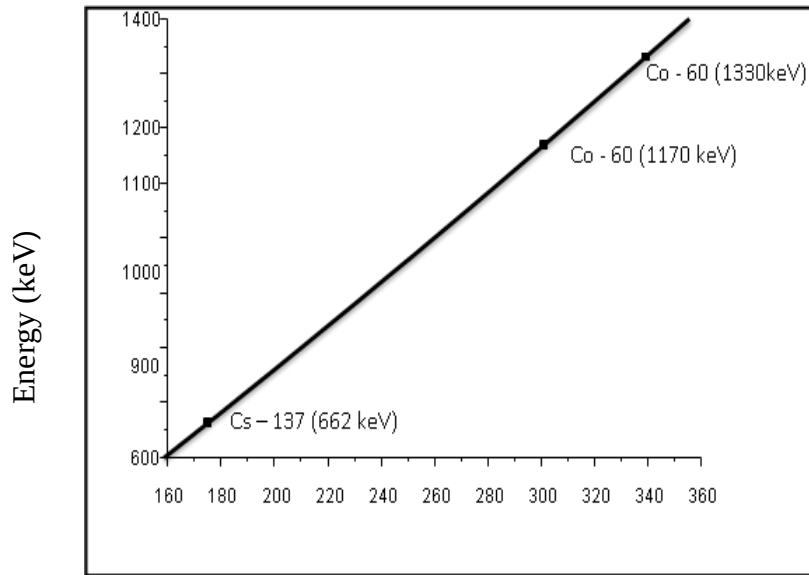


Fig 4.3: Energy calibration graph

For the energy calibration, the fit parameters of the polynomial equation were utilized to fit the connection between photon energy and channel number as a function of channel number.

4.1.3 Energy resolution of the detector:

This is the ability of a detector to differentiate the photon energies of two or more closely lying radionuclides. The energy resolution of the detector was determined by fitting a Gaussian model to the measured cesium – 137 photo peak. The result of the fitting is shown. The Gaussian model equation used to plot figure is shown in equation:

$$Y = Y_0 + \frac{A/A}{w\sqrt{\frac{\pi}{2}}} \exp\{-2(x - x_c)w\}^2$$

Y_0 is the baseline offset, A is the area under the curve, x_c is the center of the peak and w is width of the curve at half height.

CHAPTER 5

RESULT AND DISCUSSION

5.1 Formula for Radiological Dose and Radiological Hazardous Parameters:

River Sand refers to the loose, scattered, and naturally-occurring sand consisting of extremely microscopic particles of decayed shells, corals, or boulders. Sand is not only an essential component of the river, but it also plays a significant role in the building sector as well. Current usage and utilization are widespread and extensive all over the world, where it is used to provide bulk, strength, and other properties to building materials such as concrete and asphalt. It is one of the most commonly used and utilized materials in the construction process. It is widely used and utilized all over the world. River sand is often employed in the construction of buildings in Tamil Nadu and neighboring states. It is not uniform in each river when it comes to the distribution of uranium, thorium, and potassium isotopes in different environmental compartments. The research area does not have appropriate statistical data for cancer, the average lifespan of humans, typical health conditions, or any other issue relevant to the study. Instead than relying on average radioactivity, the maximum radiation should be taken into consideration instead. In order to assess radioactive hazard of river sediments, it is useful to calculate different radioactive indices using the following formulas.

5.1.1 Radiological Dose Parameters:

The calculation and correlation of radiological dose parameters such as indoor (AD_{in}) and outdoor (AD_{out}) absorbed dose, Internal (E_{in}) and External (E_{ex}) Annual Effective Dose Equivalent are used to limit radiation exposure to living things while river sand is used as a building material.

5.1.1.1 Absorbed Dose Rate (AD):

The absorbed dose rate which are tabulated to provide a characteristics of external terrestrial gamma radiation are shown. Absorbed gamma dose rate is the amount of energy from ionizing radiation that is absorbed per unit mass per unit time of matter, in Gray. The absorption dosage is used to calculate the probability of biochemical changes occurring in certain tissues. The addition of natural

radionuclides add to the absorbed dose rate (DR)which depends on how much ^{238}U , ^{232}Th , and ^{40}K are present in the environment. The majority of the gamma radiation comes from radionuclides which are found in earth's surface. The absorbed dose rate (D_{in} nGy h^{-1}) is calculated using the following equation **Anima Upadhyay et al.**

$$D_{\text{in}} = (0.92 C_U + 1.1 C_{\text{Th}} + 0.081 C_K)$$

$$D_{\text{out}} = (0.427 C_U + 0.662 C_{\text{Th}} + 0.043 C_K)$$

Where C_U , C_{Th} and C_K are the activity concentrations of ^{236}U , ^{232}Th and ^{40}K , respectively.

5.1.1.2. Annual Dose Effective equivalent (AEDE):

In order to identify how much radiation one is exposed to each year, one has to take into account, the conversion coefficient from the absorbed dose in air to how much radiation is absorbed. The possibility of a harmful effect from radiation exposure is dependent on which part(s) of the body is exposed and amount of radiation is exposed. Some organs are more vulnerable to radiation than others, while some are more sensitive than others. This is taken into consideration via the application of a tissue weighting factor (WT). A dose to an organ is calculated by multiplying the equivalent dosage to that organ by the tissue weighting factor for that organ. The result is the effective dose to that organ. The Sievert is the metric unit of effective dosage (Sv). If more than one organ is exposed, the effective dosage, denoted by the letter E, is the total of the effective doses received by all of the organs that were exposed.

Table 5.1: Annual Effective Dose received by Human Organs

Tissue	Tissue weighting factor W_T	Sum of Tissue weighting factors
Bone-marrow (red), colon, lung, stomach, breast, remaining tissues(*)	0.12	0.72
Gonads	0.08	0.08
Bladder, oesophagus, liver, thyroid	0.04	0.16
Bone surface, brain, salivary glands, skin	0.01	0.04
	Total	1.00

The annual effective dose rates (nGy h⁻¹) for indoor and outdoor in units of mSvy⁻¹ were calculated using the following formula:

$$\text{AEDE Outdoor} = ((D_{\text{out}} \times 24 \times 365 \times 0.8 \times 0.7) / 1000000) \text{ mSvy}^{-1}$$

$$\text{AEDE Indoor} = ((D_{\text{in}} \times 24 \times 365 \times 0.8 \times 0.7) / 1000000) \text{ mSvy}^{-1}$$

Where D is the dose rate.

Total Annual Effective Dose (E_{tot}):

The total annual effective dose E_{tot} is given by the following

$$E_{\text{tot}} = E_{\text{out}} + E_{\text{in}}$$

5.1.2 Radiological Hazardous Parameters:

The calculations and correlations of several radiological hazardous indices, such as the Excessive Lifetime Cancer Risk (ELCR), H_{in} and H_{ex} indices, the Alpha Index (I_{α}), the Gamma Index (I_{γ}), the Activity Utilization Index (AUI), Radium equivalent, Radioactive heat production (RHP) are analysed.

5.1.2.1 Excessive Lifetime Cancer Risk (ELCR):

Potential carcinogenic effects are quantified by predicting the probability of cancer incidence over a certain lifespan in a population of individuals using estimated intakes (and exposures) and chemical-specific dose–response data (i.e., slope factors). The added or increased risk of acquiring cancer is caused by an individual's lifelong exposure to a harmful substance. The outdoor, indoor and total ELCR were calculated according to the estimated values of the annual effective doses and is given by (Ramasamy et al. 2009):

$$\text{ELCR (outdoor)} = E_{\text{out}} \times DL \times RF$$

$$\text{ELCR (indoor)} = E_{\text{in}} \times DL \times RF$$

$$\text{ELCR}_{\text{tot}} = \text{ELCR}_{\text{out}} + \text{ELCR}_{\text{in}}$$

5.1.2.2. Internal Hazard Index (H_{in}):

Internal hazard index is defined as the radiation that happens when a person consumes anything that releases radiation. The internal hazard index is used to figure

out how much radon and its compounds are in one's body (H_{in}). The radiation then enters and radiates directly into the human body, resulting in radiological dangers.

$$H_{in} = (C_U / 185 + C_{Th} / 259 + C_K / 4810) \leq 1$$

5.1.2.3. External Hazard Index (H_{ex}):

The external hazard (H_{ex}) index is another radiation hazard index to measure the indoor radiation dose rate related to the external exposure to gamma radiation from natural radionuclides in building materials. The external hazard index measures the risk caused by natural gamma radiation. This index is used to determine a material's radiological compatibility. This index's primary goal is to keep radiation doses below the permissible dose equivalent limit of $1 \text{ mSv} \cdot \text{y}^{-1}$. In order to limit the radiation hazard to a minimum, H_{ex} must be less than unity. If $H_{ex} < 1$ indicates that materials-related activities are safe and do not result in excessive amounts of radiation exposure.

$$H_{ex} = (C_U / 370 + C_{Th} / 259 + C_K / 4810) \leq 1$$

5.1.2.4 Radium Equivalent Activity (Ra_{equ}):

The Ra_{equ} is a widely used index for describing the gamma output of different combination of uranium, thorium, and potassium in sediments which are collected from various places. Radium equivalent activity yields gamma index gives from the combination of ^{226}Ra or ^{238}U , ^{232}Th and ^{40}K in the sample, Where A (1.43), B (0.077) are constants.

$$Ra_{equ} = (C_U + A \cdot C_{Th} + B \cdot C_K)$$

5.1.2.5 Activity Utilization Index (AUI):

To estimate the air dose rates from various fusions of the above-mentioned fundamental radionuclides in sand and soils. By inserting the appropriate conversion factors, this AUI is calculated.

$$AUI = \left(\frac{C_U}{50 \text{ Bqkg}^{-1}} \right) f_U + \left(\frac{C_{Th}}{50 \text{ Bqkg}^{-1}} \right) f_{Th} + \left(\frac{C_K}{500 \text{ Bqkg}^{-1}} \right) f_K$$

where C_U , C_{Th} , and C_K are the actual values of the activities per unit mass (Bq kg⁻¹) of ²³⁸U, ²³²Th, and ⁴⁰K in the building materials considered; and f_U , f_{Th} , and f_K are the fragmentary contributions due to gamma radiation from the above environmental radioactive nuclides, which are 0.462, 0.604, and 0.041, respectively.

5.1.2.6 Alpha Index and Gamma Index (I_α and I_γ):

In order to check out whether the safety requirements for building materials are being fulfilled, a activity concentration index or external hazard, I_α is used to calculate alpha index whereas I_γ is calculated as gamma index as proposed by the European Commission.

$$I_\alpha = \frac{C_U}{200 \text{ Bqkg}^{-1}} \leq 1$$

$$I_\gamma = \frac{C_U}{300 \text{ Bqkg}^{-1}} + \frac{C_{Th}}{200 \text{ Bqkg}^{-1}} + \frac{C_K}{3000 \text{ Bqkg}^{-1}} \leq 1$$

5.1.2.7 Radioactive Heat Production (RHP):

The rate of radioactive heat generation determines the lithosphere's thermal evaluation, and the above mentioned environmental radioactive isotopes contributed significantly to this terrestrial heat flow. These fundamental radioactive elements (²³⁸U, ²³²Th, and ⁴⁰K) become critical in determining the composition of the earth's mantle and crust, as well as their heat-generating capability.

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

Where RHP in μWm^{-3} , ρ - sample density in Kgm^{-3} , C_U and C_{Th} – uranium and thorium concentration in ppm and C_K - potassium concentration in %.

5.2 Radiological doses and hazardous parameters for sediments greater than 125 micro size:

Radioactivity concentration of ^{238}U , ^{232}Th and ^{40}K in Cauvery River Sediment Samples Measured by NaI (TI), the gamma ray detector is shown in Table 5.2. The measured activity is 1.09 to 8.39 Bq kg⁻¹ for ^{238}U , 1.06 to 51.17 Bq kg⁻¹ for ^{232}Th . 50.58 to 447.58 Bq kg⁻¹ for ^{40}K . Measured activity of Radionuclides vary from site to site. Apart from the natural processes like weathering and leaching, human activities are also known to contribute in changes. This variation occurs due to local features by chemical sorting process which differs from place to place. This can also be due to the drainage pattern of the field (E.g. Erode Dyeing units discharging effluents into Cauvery). The average radioactivity of ^{238}U , ^{232}Th and ^{40}K is 2.58, 8.06 and 248.26 Bq kg⁻¹ are respectively, the activity concentrations are in the following order: The concentration of ^{40}K , ^{232}Th , ^{238}U and ^{238}U , ^{232}Th and ^{40}K are much lower than the world average.

Across all the sites, the mean concentration of ^{238}U and ^{40}K is lower and average concentration of ^{232}Th slightly lower than the world average (^{238}U , ^{232}Th and ^{40}K are 35, 30 and 400 Bqkg⁻¹, respectively). Average concentration of ^{238}U and ^{232}Th and ^{40}K concentrations are lower when compared with the Indian mean values (14.8 Bqkg⁻¹, 64 Bqkg⁻¹ and 400 Bqkg⁻¹ for ^{238}U , ^{232}Th and ^{40}K respectively). The main purpose of radioactive measurement is to estimate exposure of radiation to the public.

From Table 5.3, the maximum absorbed dose rate of >125 µm for indoor ($\text{AD}_{\text{in}} = 82.48$) is slightly less than world average (84nGy/h) and the outdoor absorbed dose rate ($\text{AD}_{\text{out}} = 45.27\text{nGy/h}$) is also less than world average of (59nGy/h). Those two maximum is noted in C31 and it has high exposure which may cause metabolic changes inside the human body. The AD_{in} and AD_{out} values vary from 7.76 to 82.48 nGy/h and 4.12 to 45.27 nGy/h with the mean values 31.35 nGy/h and 16.80 nGy/h. The calculated AEDE_{in} values ranged from 38.04 to 406.64 µSvy⁻¹ with a mean value of 153.8 µSvy⁻¹, which is lesser than the world average indoor value of 450 µSvy⁻¹. The AEDE Outdoor calculated values ranged from 5.05 to 55.52 µSvy⁻¹ with a mean value of 20.6 µSvy⁻¹, which is lesser than the world average outdoor value of 70 µSvy⁻¹.

Table 5.2: Radioactivity Concentration of ^{238}U , ^{232}Th and ^{40}K

S.No.	^{238}U (Bqkg ⁻¹)	^{232}Th (Bqkg ⁻¹)	^{40}K (Bqkg ⁻¹)	S.No.	^{238}U (Bqkg ⁻¹)	^{232}Th (Bqkg ⁻¹)	^{40}K (Bqkg ⁻¹)
1	1.62	2.11	341.13	22	2.03	13.17	282.6
2	1.34	4.89	281.13	23	3.16	7.4	288.72
3	2.13	3.76	348.95	24	1.4	4.13	183.78
4	1.24	5.11	258.26	25	1.12	2.44	209.53
5	1.57	3.12	319.44	26	1.16	1.06	205.83
6	3.06	4.92	299.66	27	1.09	2.28	191.51
7	2.34	3.95	350.51	28	3.95	4.5	163.42
8	1.82	2.63	399.98	29	4.88	8.93	111.18
9	2.54	3.15	401.54	30	7.62	29.62	212.16
10	1.82	3.82	327.68	31	8.39	51.17	228.14
11	2.39	7.89	242.67	32	2.08	2.79	200.01
12	1.98	5.44	227.27	33	1.24	3.15	229.71
13	2.32	13.2	334.94	34	5.15	6.68	111.28
14	1.38	10.73	263.52	35	6.17	7.13	447.58
15	1.56	3.87	215.05	36	1.31	2.23	50.58
16	1.14	6.82	204.22	37	2.53	8.32	110.52
17	1.32	4.62	211.02	38	4.73	8.6	180.4
18	1.47	4.29	205.25	39	6.01	17.66	199.12
19	1.16	9.32	279.56	Max	8.39	51.17	447.58
20	1.28	10.75	327.42	Min	1.09	1.06	50.58
21	1.15	18.73	237.11	Mean	2.58	8.06	248.26

**Table 5.3: Radiological dose parameters for sediments greater than 125
microns in size**

S.No.	AD _{in} nGyh ⁻¹	AD _{out} nGyh ⁻¹	AEDE _{in} mSvy ⁻¹	AEDE _{out} mSvy ⁻¹	S.No.	AD _{in} nGyh ⁻¹	AD _{out} nGyh ⁻¹	AEDE _{in} mSvy ⁻¹	AEDE _{out} mSvy ⁻¹
1	31.44	16.67	0.15	0.02	22	39.25	21.22	0.19	0.03
2	29.38	15.71	0.14	0.02	23	34.43	18.37	0.17	0.02
3	34.36	18.26	0.17	0.02	24	20.72	11.07	0.10	0.01
4	27.68	14.82	0.14	0.02	25	20.69	11.01	0.10	0.01
5	30.75	16.35	0.15	0.02	26	18.91	10.01	0.09	0.01
6	32.50	17.26	0.16	0.02	27	19.02	10.12	0.09	0.01
7	34.89	18.53	0.17	0.02	28	21.82	11.52	0.11	0.01
8	36.97	19.61	0.18	0.02	29	23.32	12.43	0.11	0.02
9	38.33	20.31	0.19	0.02	30	56.78	30.83	0.28	0.04
10	32.42	17.25	0.16	0.02	31	82.49	45.27	0.40	0.06
11	30.53	16.37	0.15	0.02	32	21.18	11.23	0.10	0.01
12	26.21	14.01	0.13	0.02	33	23.21	12.37	0.11	0.02
13	43.78	23.62	0.21	0.03	34	21.10	11.15	0.10	0.01
14	34.42	18.61	0.17	0.02	35	49.77	26.32	0.24	0.03
15	23.11	12.32	0.11	0.02	36	7.76	4.12	0.04	0.01
16	25.09	13.52	0.12	0.02	37	20.43	11.02	0.10	0.01
17	23.39	12.52	0.11	0.02	38	28.42	15.13	0.14	0.02
18	22.70	12.13	0.11	0.01	39	41.08	22.13	0.20	0.03
19	33.96	18.32	0.17	0.02	Max	82.49	45.27	0.40	0.06
20	39.52	21.32	0.19	0.03	Min	7.76	4.12	0.04	0.01
21	40.87	22.36	0.20	0.03	Mean	31.35	16.80	0.15	0.02

Since the external hazardous index (H_{ex}) measures the radiological compatibility, From Table.5.4 the index values varies from 0.02 to 0.31 $Bqkg^{-1}$ with the mean value of 0.09 $Bqkg^{-1}$ and internal index measures the presence of radon and its compounds in a human body, whose values are 0.02 to 0.34 $Bqkg^{-1}$ with the mean value of 0.10 $Bqkg^{-1}$. Both external and internal indices are less than the world average and those sites are safe for construction purpose. Here the radium equivalent values varies from 6.50 to 116.03 Bq/kg with the mean value of 33.22 Bq/kg , in which the sites of Cauvery River is less than the world average values and the sediments can be used for construction purpose. Along with these values the ELCR outdoor, indoor value and total varies from 0.02 to 0.18, 0.13 to 1.34 and 0.15 to 1.61 with their mean values 0.07, 0.51 and 0.61 respectively. The site C31 in $ELCR_{tot}$ is greater than the world average which has high cancer risk when compared to other sites. The heat production rate varies from 0.04 to 0.89 μWm^{-3} with the mean value 0.20 μWm^{-3} . The RHP rate is minimal (below 1 μWm^{-3}) along the locations of Cauvery River. The internal hazardous and external values, radium equivalent activity along with the ELCR indoor and total values have world average values such as $H_{ex} = 0.5 Bqkg^{-1}$, $H_{in} = 0.5 Bqkg^{-1}$, Radium equivalent activity $Ra_{equ} = 129.7 Bq/kg$, $ELCR_{out} = 0.290 \times 10^{-3}$, $ELCR_{tot} = 1.45 \times 10^{-3}$ and the radioactive heat rate is 1.00 μWm^{-3} .

From Table 5.5, The Activity Utilization index values varies from 0.03 to 0.73 with the mean value 0.14. The mean value indicate that AUI is <2 and the sediments can be used for construction purpose. Along with this, alpha and gamma activity concentration index value varies from 0.03 to 0.43 and 0.01 to 0.04 with the average values 0.03 and 0.01 respectively.

Table 5.4 Radiological Hazardous parameters for sediments greater than 125 micron in size

S.No	ELCRx10 ⁻³			Ra _{equ} (Bq/Kg)	RHP μWm ⁻³	H _{in} Bq/kg	H _{ex} Bq/kg	S.No	ELCR x10 ⁻³			H _{in} Bq/kg	H _{ex} Bq/kg	RHP μWm ⁻³	Ra _{equ} (Bq/Kg)
	in	out	tot						in	out	tot				
1	0.54	0.07	0.61	30.90	0.12	0.09	0.08	22	0.67	0.09	0.76	0.12	0.12	0.25	42.62
2	0.50	0.06	0.57	29.98	0.12	0.08	0.08	23	0.59	0.07	0.67	0.11	0.10	0.19	35.97
3	0.59	0.07	0.67	34.38	0.13	0.10	0.09	24	0.36	0.04	0.40	0.06	0.06	0.10	21.46
4	0.48	0.06	0.54	28.43	0.12	0.08	0.08	25	0.36	0.04	0.40	0.06	0.06	0.09	20.74
5	0.53	0.07	0.60	30.63	0.12	0.09	0.08	26	0.32	0.04	0.37	0.05	0.05	0.07	18.52
6	0.56	0.07	0.63	33.17	0.15	0.10	0.09	27	0.33	0.04	0.37	0.05	0.05	0.09	19.10
7	0.60	0.08	0.68	34.98	0.14	0.10	0.09	28	0.37	0.05	0.42	0.07	0.06	0.14	22.97
8	0.63	0.08	0.72	36.38	0.13	0.10	0.10	29	0.40	0.05	0.45	0.08	0.07	0.20	26.21
9	0.66	0.08	0.75	37.96	0.15	0.11	0.10	30	0.97	0.12	1.11	0.20	0.18	0.49	66.31
10	0.56	0.07	0.63	32.51	0.13	0.09	0.09	31	1.42	0.18	1.61	0.29	0.27	0.76	99.13
11	0.52	0.07	0.59	32.36	0.17	0.09	0.09	32	0.36	0.05	0.41	0.06	0.06	0.12	21.47
12	0.45	0.06	0.51	27.26	0.14	0.08	0.07	33	0.40	0.05	0.45	0.07	0.06	0.11	23.43
13	0.75	0.10	0.85	46.99	0.25	0.13	0.13	34	0.36	0.05	0.41	0.08	0.06	0.19	23.27
14	0.59	0.08	0.67	37.01	0.19	0.10	0.10	35	0.85	0.11	0.97	0.15	0.14	0.27	50.83
15	0.40	0.05	0.45	23.65	0.11	0.07	0.06	36	0.13	0.02	0.15	0.03	0.02	0.06	8.39
16	0.43	0.05	0.49	26.62	0.13	0.07	0.07	37	0.35	0.04	0.40	0.07	0.06	0.16	22.94
17	0.40	0.05	0.46	24.18	0.11	0.07	0.07	38	0.49	0.06	0.55	0.10	0.08	0.19	30.92
18	0.39	0.05	0.44	23.41	0.11	0.07	0.06	39	0.71	0.09	0.80	0.14	0.13	0.36	46.60
19	0.58	0.07	0.66	36.01	0.19	0.10	0.10	Max	1.42	0.18	1.61	0.34	0.31	0.87	116.03
20	0.68	0.09	0.77	41.86	0.22	0.12	0.11	Min	0.13	0.02	0.15	0.02	0.02	0.04	6.50
21	0.70	0.09	0.80	46.19	0.30	0.13	0.12	Mean	0.54	0.07	0.61	0.10	0.09	0.20	33.22

**Table 5.5: Activity Utilization Index, Alpha and Gamma Index for sediments greater than
125 microns in size**

S.No.	AUI	Gamma (I_γ)	Alpha (I_α)	S.No.	AUI	Gamma (I_γ)	Alpha (I_α)
1	0.07	0.13	0.01	22	0.20	0.17	0.01
2	0.09	0.12	0.01	23	0.14	0.14	0.02
3	0.09	0.14	0.01	24	0.08	0.09	0.01
4	0.09	0.12	0.01	25	0.06	0.09	0.01
5	0.08	0.13	0.01	26	0.04	0.08	0.01
6	0.11	0.13	0.02	27	0.05	0.08	0.01
7	0.10	0.14	0.01	28	0.10	0.09	0.02
8	0.08	0.15	0.01	29	0.16	0.10	0.02
9	0.09	0.16	0.01	30	0.45	0.24	0.04
10	0.09	0.13	0.01	31	0.71	0.36	0.04
11	0.14	0.13	0.01	32	0.07	0.09	0.01
12	0.10	0.11	0.01	33	0.07	0.10	0.01
13	0.21	0.19	0.01	34	0.14	0.09	0.03
14	0.16	0.15	0.01	35	0.18	0.21	0.03
15	0.08	0.10	0.01	36	0.04	0.03	0.01
16	0.11	0.11	0.01	37	0.13	0.09	0.01
17	0.09	0.10	0.01	38	0.16	0.12	0.02
18	0.08	0.09	0.01	39	0.29	0.17	0.03
19	0.15	0.14	0.01	Max	0.73	0.43	0.04
20	0.17	0.17	0.01	Min	0.03	0.03	0.01
21	0.26	0.18	0.01	Mean	0.14	0.13	0.01

5.3 Radiological doses and hazardous parameters for nonmagnetic sand samples:

An electromagnet is used to separate the nonmagnetic sediment samples from the magnetic substances present in the sediments. The radiation doses and parameters are then determined using the nonmagnetic sediment samples that have been isolated earlier.

From Table 5.6 Radioactivity concentration of ^{238}U , ^{232}Th and ^{40}K in Cauvery River Sediment Samples Measured by (NaI (TI)), the gamma ray detector is shown in Table 4. The measured activity is 1.01 to 10.12 Bq kg⁻¹ for ^{238}U , 2.92 to 54.70 Bq kg⁻¹ for ^{232}Th . and 90.88 to 387.76 Bq kg⁻¹ for ^{40}K . Measured activity of Radionuclides varies from site to site. Apart from the natural processes like weathering and leaching, human activities are also known to contribute in changes. This variation occurs due to local features by chemical sorting process which differs from place to place. This can also be due to the drainage pattern of the field (Eg. Erode -Dyeing units discharging effluents into Cauvery). The average radioactivity of ^{238}U , ^{232}Th , ^{40}K is 2.71, 11.63 and 170.25Bq kg⁻¹ are respectively, the activity concentrations are in the following order: The concentration of ^{40}K , ^{232}Th , ^{238}U and ^{238}U much lower than ^{232}Th and ^{40}K .

From Table 5.7, The maximum value of absorbed dose rate for less nonmagnetic grain size (indoor) is slightly less than world indoor average dose rate of 87 nGy/h (calculated value (AD_{in} is 87.04nGy/h) and outdoor values (AD_{out} = 47.72nGy/h) are also found to be less than world outdoor average dose rate of 59nGy/h. The site C31 has the highest absorbed dose rate for indoor, which is higher than the world average and it has high exposure which may cause metabolic changes which occur inside the human body. The AD_{in} and AD_{out} values vary from 15.45 to 87.04 nGy/h and 8.21 to 47.72 nGy/h with the mean value of 29.08 nGy/h and 15.72 nGy/h. The calculated AEDE_{in} values are ranged from 75.8 to 427 μSvy⁻¹ with a mean value of 142.6 μSvy⁻¹, which is lesser than the world average indoor value of 450 μSvy⁻¹. Outdoor calculated values are ranges from 10.1 to 58.5 μSvy⁻¹ with a mean value of 19.3 μSvy⁻¹, which is lesser than the world average outdoor value of 70 μSvy⁻¹.

Table 5.6 Radioactivity Concentration of ^{238}U , ^{232}Th and ^{40}K

S.No	$^{238}\text{U}(\text{Bqkg}^{-1})$	$^{232}\text{Th}(\text{Bqkg}^{-1})$	$^{40}\text{K}(\text{Bqkg}^{-1})$	S.No	$^{238}\text{U}(\text{Bqkg}^{-1})$	$^{232}\text{Th}(\text{Bqkg}^{-1})$	$^{40}\text{K}(\text{Bqkg}^{-1})$
1	4.23	8.43	123.11	22	1.03	16.47	226.96
2	1.45	7.21	151.72	23	4.66	16.31	214.34
3	2.81	7.13	165.12	24	1.89	13.24	103.74
4	1.23	4.12	215.88	25	1.12	7.21	156.94
5	1.12	8.94	135.26	26	1.12	5.62	177.93
6	1.62	8.78	130.78	27	1.12	7.14	154.11
7	1.13	10.67	127.57	28	2.51	7.31	156.79
8	2.18	9.73	142.54	29	3.09	12.21	125.32
9	1.32	13.79	151.15	30	8.45	32.12	203.71
10	2.33	8.62	144.26	31	10.12	54.70	216.74
11	3.21	7.42	158.73	32	3.46	6.24	169.92
12	1.47	6.24	156.27	33	1.25	4.21	241.12
13	1.12	12.08	212.14	34	7.61	8.01	90.88
14	2.13	9.23	137.63	35	6.76	12.31	387.76
15	1.06	5.85	181.89	36	1.81	2.92	130.56
16	1.12	8.12	177.52	37	2.51	9.61	100.21
17	1.52	7.13	175.72	38	4.98	18.31	126.32
18	1.58	6.49	163.15	39	6.42	24.06	152.93
19	1.16	6.32	213.76	Max	10.12	54.70	387.76
20	1.08	16.35	208.51	Min	1.01	2.92	90.88
21	1.01	22.93	230.61	Mean	2.71	11.63	170.25

Table 5.7 Radiological dose parameters for nonmagnetic sediment samples

S.No.	AD _{in} nGyh ⁻¹	AD _{out} nGyh ⁻¹	AEDE _{in} mSvy ⁻¹	AEDE _{OUT} mSvy ⁻¹	S.No.	AD _{in} nGyh ⁻¹	AD _{out} nGyh ⁻¹	AEDE _{in} mSvy ⁻¹	AEDE _{OUT} mSvy ⁻¹
1	23.14	12.35	0.114	0.02	22	37.45	20.46	0.184	0.03
2	21.55	11.63	0.106	0.01	23	39.59	21.37	0.194	0.03
3	23.80	12.74	0.117	0.02	24	24.71	13.52	0.121	0.02
4	23.15	12.37	0.114	0.02	25	21.67	11.72	0.106	0.01
5	21.82	11.86	0.107	0.01	26	21.62	11.63	0.106	0.01
6	21.74	11.79	0.107	0.01	27	21.37	11.55	0.105	0.01
7	23.11	12.62	0.113	0.02	28	23.05	12.37	0.113	0.02
8	24.25	13.12	0.119	0.02	29	26.42	14.32	0.130	0.02
9	28.63	15.65	0.140	0.02	30	59.61	32.38	0.292	0.04
10	23.31	12.57	0.114	0.02	31	87.04	47.72	0.427	0.06
11	23.97	12.82	0.118	0.02	32	23.81	12.67	0.117	0.02
12	20.87	11.23	0.102	0.01	33	25.31	13.52	0.124	0.02
13	31.50	17.13	0.155	0.02	34	23.17	12.15	0.114	0.01
14	23.26	12.58	0.114	0.02	35	51.17	27.23	0.251	0.03
15	22.14	11.92	0.109	0.01	36	15.45	8.21	0.076	0.01
16	24.34	13.17	0.119	0.02	37	21.00	11.37	0.103	0.01
17	23.47	12.65	0.115	0.02	38	34.95	18.97	0.171	0.02
18	21.81	11.73	0.107	0.01	39	44.76	24.31	0.220	0.03
19	25.33	13.62	0.124	0.02	Max	87.04	47.72	0.430	0.06
20	35.87	19.61	0.176	0.02	Min	15.45	8.21	0.080	0.01
21	44.83	24.63	0.220	0.03	Mean	29.08	15.72	0.140	0.02

Since the external hazardous index measures the radiological compatibility, from Table 5.8 the index values varies from 0.03 to 0.32 Bqkg⁻¹ with the mean value of 0.09 Bqkg⁻¹ and internal index measures the presence of radon and its compounds in a human body, whose values are found to be 0.04 to 0.35 Bqkg⁻¹ with the mean value of 0.10 Bqkg⁻¹. Both external and internal indices are less than the world average and those sites are said to be safe for construction purposes. The radium equivalent activity calculated values varies from 12.18 to 118.20 Bq/kg with the mean value of 32.45 Bq/kg, and the sites of this river has values less than the world average values and the sediments from these sites can be used as for construction purpose. Along with these values the ELCR outdoor, indoor value and total varies from 0.03 to 0.19, 0.25 to 1.41 and 0.30 to 1.69 with their mean values 0.03, 0.25 and 0.56 respectively. The site C31 of ELCR_{tot} is greater than the world average which will be high having cancer risk when compared to other sites. The radioactive heat production rate varies from 0.40 to 0.53 μWm^{-3} with the average value of radioactive heat production rate is 0.43 μWm^{-3} . The world average world values for parameters such as internal hazardous and external values, radium equivalent activity along with the ELCR indoor and outdoor values are as follows, $H_{\text{ex}} = 0.5 \text{ Bqkg}^{-1}$, $H_{\text{in}} = 0.5 \text{ Bqkg}^{-1}$, Radium equivalent activity $Ra_{\text{equ}} = 129.7 \text{ Bq/kg}$, the $\text{ELCR}_{\text{out}} = 0.290 \times 10^{-3}$, $\text{ELCR}_{\text{tot}} = 1.45 \times 10^{-3}$ and the radioactive heat rate is $1.00 \mu\text{Wm}^{-3}$.

From Table 5.8: The Activity Utilization index values vary from 0.05 to 0.79 with the mean value 0.18. The mean value indicates that $\text{AUI} < 2$ and the sediments can be used as safest construction materials. Along with this alpha and gamma activity concentration index value varies from 0.05 to 0.44 and 0.01 to 0.05 with the average values 0.12 and 0.01.

Table 5.8 Radiological hazardous parameters for nonmagnetic samples

S.No.	ELCR $\times 10^{-3}$			H _{in}	H _{ex}	RHP μWm^{-3}	Ra _{equ} (Bq/Kg)	S.No.	ELCR _{in} $\times 10^{-3}$			H _{ex}	H _{in}	RHP μWm^{-3}	Ra _{equ} (Bq/Kg)
	in	Out	tot						in	out	tot				
1	0.40	0.05	0.45	0.08	0.07	0.18	25.76	22	0.64	0.08	0.73	0.11	0.12	0.42	42.06
2	0.37	0.05	0.42	0.07	0.06	0.13	23.44	23	0.68	0.09	0.77	0.12	0.13	0.46	44.49
3	0.41	0.05	0.46	0.08	0.07	0.14	25.72	24	0.42	0.05	0.48	0.08	0.08	0.40	28.81
4	0.40	0.05	0.45	0.07	0.06	0.10	23.74	25	0.37	0.05	0.42	0.06	0.07	0.40	23.51
5	0.37	0.05	0.43	0.07	0.07	0.14	24.32	26	0.37	0.05	0.42	0.06	0.06	0.35	22.86
6	0.37	0.05	0.42	0.07	0.07	0.36	24.25	27	0.37	0.05	0.42	0.06	0.07	0.46	23.20
7	0.40	0.05	0.45	0.07	0.07	0.36	26.21	28	0.40	0.05	0.45	0.07	0.07	0.43	25.04
8	0.42	0.05	0.47	0.08	0.07	0.38	27.07	29	0.45	0.06	0.52	0.08	0.09	0.44	30.20
9	0.49	0.06	0.56	0.09	0.09	0.39	32.68	30	1.02	0.13	1.16	0.19	0.21	0.49	70.07
10	0.40	0.05	0.45	0.08	0.07	0.40	25.76	31	1.49	0.19	1.70	0.28	0.31	0.53	105.03
11	0.41	0.05	0.47	0.08	0.07	0.42	26.04	32	0.41	0.05	0.46	0.07	0.08	0.54	25.47
12	0.36	0.05	0.41	0.06	0.06	0.43	22.43	33	0.43	0.05	0.49	0.07	0.07	0.45	25.84
13	0.54	0.07	0.61	0.10	0.09	0.39	34.73	34	0.40	0.05	0.45	0.07	0.09	0.55	26.06
14	0.40	0.05	0.45	0.08	0.07	0.39	25.93	35	0.88	0.11	1.00	0.15	0.16	0.50	54.22
15	0.38	0.05	0.43	0.07	0.06	0.38	23.43	36	0.27	0.03	0.30	0.04	0.05	0.48	16.04
16	0.42	0.05	0.47	0.07	0.07	0.37	26.40	37	0.36	0.05	0.41	0.06	0.07	0.42	23.97
17	0.40	0.05	0.46	0.07	0.07	0.39	25.25	38	0.60	0.08	0.68	0.11	0.12	0.41	40.89
18	0.37	0.05	0.42	0.07	0.06	0.41	23.42	39	0.77	0.10	0.87	0.14	0.16	0.54	52.60
19	0.43	0.06	0.49	0.08	0.07	0.41	26.66	Max	1.49	0.19	1.70	0.32	0.35	0.53	118.20
20	0.62	0.08	0.70	0.11	0.11	0.42	40.52	Min	0.27	0.03	0.30	0.03	0.04	0.40	12.18
21	0.77	0.10	0.88	0.14	0.14	0.46	51.56	Mean	0.50	0.06	0.57	0.09	0.09	0.43	32.45

Table: 5.9 Activity Utilization Index, Alpha and Gamma Index for nonmagnetic sediment samples

S.No.	AUI	Gamma (I_γ)	Alpha (I_α)	S.No.	AUI	Gamma (I_γ)	Alpha (I_α)
1	0.15	0.10	0.02	22	0.23	0.16	0.01
2	0.11	0.09	0.01	23	0.26	0.17	0.02
3	0.13	0.10	0.01	24	0.19	0.11	0.01
4	0.08	0.10	0.01	25	0.11	0.09	0.01
5	0.13	0.09	0.01	26	0.09	0.09	0.01
6	0.13	0.09	0.01	27	0.11	0.09	0.01
7	0.15	0.10	0.01	28	0.12	0.10	0.01
8	0.15	0.10	0.01	29	0.19	0.11	0.02
9	0.19	0.12	0.01	30	0.48	0.26	0.04
10	0.14	0.10	0.01	31	0.77	0.38	0.05
11	0.13	0.10	0.02	32	0.12	0.10	0.02
12	0.10	0.09	0.01	33	0.08	0.11	0.01
13	0.17	0.13	0.01	34	0.17	0.10	0.04
14	0.14	0.10	0.01	35	0.24	0.21	0.03
15	0.10	0.09	0.01	36	0.06	0.06	0.01
16	0.12	0.10	0.01	37	0.15	0.09	0.01
17	0.11	0.10	0.01	38	0.28	0.15	0.02
18	0.11	0.09	0.01	39	0.36	0.19	0.03
19	0.10	0.11	0.01	Max	0.79	0.44	0.05
20	0.22	0.15	0.01	Min	0.05	0.05	0.01
21	0.31	0.19	0.01	Mean	0.18	0.12	0.01

CHAPTER 6

CONCLUSION

Systematic investigations are carried out on sand samples with a size greater than 125 μm to understand the distribution of natural radionuclide concentrations. AEDE (indoor and outdoor), ELCR, and RHP values from prior investigations are carried out on bulk samples are superior to those obtained from the current study, as seen above. This study's findings demonstrate that by eliminating particles with grain size less than 125 μm , the exposure rate to radiation is exponentially reduced, confirming the lower risk of developing cancer. This study mean Ra_{equ} , H_{ex} , and H_{in} values are all lower than the suggested international limits. The mean value of the activity concentration index and the rate of RHP are both below the internationally suggested limit as is the RHP rate. This has resulted in less impact factor when it comes to the radioactive hazards while the sediments of the Cauvery River are employed as a building material. The results of the non-magnetic sand samples demonstrate when non-magnetic components are eliminated from the sand samples. The radiation impact is reduced as a consequence. Annual effective dosage equivalent and ELCR data confirm this claim. Except for site 31, all other sites are less than the world average, allowing this location to be avoided for building development in the future. In greater than 125 μm size sediment samples the systematic studies are carried out to understand the distribution of natural radionuclide concentration. It clearly shows excellent results compared with AEDE (indoor and outdoor), ELCR, and RHP values of previous studies carried out for bulk samples. From the observed results, it shows that when removing lesser than 125- μm size particles from the sand the exposure rate of the radiation is exponentially decreased and it confirms the lesser risk rate of cancer. In this study, the mean value of Ra_{equ} , H_{ex} , and H_{in} was lower than the recommended international limit respectively. The mean value of the activity concentration index and RHP rate is also below the international recommended limit. As a result, the sediments of the Cauvery River pose a lesser impact factor as a radioactive hazard when used as a construction material. The result of non-magnetic sand samples also shows reduced radiation impact when non-magnetic materials were removed from the sand samples. It is confirmed through the results of the AEDE and ELCR. Except the site 31, all other sites are lesser than the world average so this site can be avoided for building construction.

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