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# Natural radioactivity in the soil samples in and around Kudankulam nuclear power plant site

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The terrestrial gamma-radiation in soil and sand samples collected around Kudankulam nuclear power plant site, i.e., in Radhapuram Taluk of Tirunelveli District has been measured using NaI(Tl) gamma-ray spectrometer. In the soil samples total dose due to three primordial radionuclides lies in the range of 13.1–168.2 nGy/h with a geometric mean of 137.2 nGy/h, which yields an annual effective dose of 0.17 mSv/y. In the sand samples the total dose due to three primordial radionuclides has been found to be in the range of 38.1–1964.4 nGy/h with a geometric mean of 300.8 nGy/h, which gives an annual effective dose of 0.37 mSv/y which is well below the permissible limit (1 mSv).

## Introduction

Unquestionably, power plays a fundamental role in the economic development process. All countries seek to ensure a supply of electricity that is affordable, reliable, and secure in order to sustain modern ways of living. In developing countries like India the demand for electricity is increasing abnormally and to sustain their economics, long-term planning is needed. India ranks sixth in the world in total energy consumption and needs to accelerate the production of electricity to meet its growth aspirations.[1] The energy consumption is increased from 4.1 quadrillion Btu (British Thermal Units = $2.94 \cdot 10^{-4}$ kW/h) in 1982 to 12.8 quadrillion Btu in 2001 which is due to the increasing population, rapid urbanization and industrial growth.

In India hydro-power and coal based thermal power have been the main sources of generating electricity and nuclear power is at slower pace. Thermal power stations in India, where poor quality of coal is used create a lot of environmental degradation problems through gaseous emissions, particulate matter, fly ash and bottom ash. Proponents of nuclear power point out that the nuclear power plants emit virtually no airborne pollutants, and overall far less waste material than fossil fuel based power plants. Even though the waste produced from the nuclear power plant is very less, it is in the form of highly radioactive and the risk to the pubic is high.

Indian Government with the help from the Russian Federation is now constructing a 2000 MWe nuclear power plant in the southern tip (Kudankulam) of the Indian sub-continent. Construction site, i.e., Kudankulam is situated in the Radhapuram Taluk of Tirunelveli District, Tamilnadu. To create a base line for data regarding the natural background radiation for the upcoming Kudankulam nuclear power plant, a systematic investigation has been carried out in the soil and sand samples in the entire Radhapuram Taluk. In the terrestrial radiation determination the measurement of natural radioactivity in soil is very important to determine the amount of changes in the natural background activity with time as a result of any radioactivity release.

Pre-operational surveys around nuclear installations have been carried out in a large number of countries worldwide. CANCIO et al.[2] carried out pre-operational study in the vicinity of Atucha nuclear power station in Argentina by measuring the natural radioactivity in air, milk and in other food items. Similar pre-operational studies were carried out in the vicinity of site of Embalse nuclear power station in the province of Cordoba, Argentina.[3] Measurements of radiation level in the environment of the two nuclear power stations in The Netherlands have been carried out to convince the public from the influence of the reactors on the environment and to check the pre-operational values.[4]

In India, the radioactivity content in environmental matrices has been analyzed for different power project site, Siddappa of Mangalore university has done a detailed survey of the natural radioactivity distribution around the Kaiga nuclear power plant site and the activities of $^{238}U$, $^{232}Th$ and $^{40}K$ in soil samples were estimated to be 30.8, 50.4 and 591 Bq/kg, respectively. IYENGAR et al.[5] have discovered the new monazite area in the beach sand of Kalpakkam nuclear power plant site during the pre-operational survey and reported gamma dose rate in air ranging from 8 to 400 μR/h.[5] BHAT et al.[6] have undertaken studies of dietary intake, gross alpha and gross beta measurements and fallout activities for Tarapur nuclear power plant.[6]

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## Study area

Figure 1 shows the map of the study area. The taluk is located between latitude 8°8′ and 9°23′ and longitude 77°09′ and 77°54′. It has a 30 km long seashore. In India, each taluk is divided in to village panchayats and every panchayats may have minimum 2 villages. Radhapuram Taluk has 45 village panchayats and 3 town panchayats. From these 48 panchayats, 129 soil and 16 sand samples have been collected. Radhapuram Taluk is one of the taluks in India which has "Red garnet sands" and "teri structures". Red garnet sands are located in huge quantity in the Uvari, K. Navaladi, and Kuttam Panchayats and the portion of garnet in sand is 45–75 percent. "teri" structures are located in Tisayanvillai, K. Pudur and Urumankulam Panchayats. Local concentration of limenite sands are noticed near Vijaypathi and Kuttankuli Panchayats.

## Experimental

A detailed ambient gamma-dose measurement has been performed in Radhapuram Taluk, using an environmental survey meter, which has a NaI(Tl) crystal coupled with a photomultiplier tube (Model SM141D; ECIL). Survey meter readings are recorded at 1 m above ground level. Five readings are taken at each spot and the average is recorded. From the ambient gamma-dose measurement, the sampling locations in each panchayats have been decided, which is an uncultivated and undisturbed area, sufficiently away from the public road and buildings. At each site, samples are collected from five pits of 30 cm×30 cm×15 cm, within an area of one to four square meters. The dug out samples are uniformly mixed after removing top layer of vegetation and roots and about two kilograms of samples are packed in polythene bags and their locations are labeled. Collected samples are dried in an oven at 110 °C till constant dry weight is obtained. The dried samples are crushed and allowed to pass through micro sieves to maintain the uniform grain size. These samples are packed in plastic containers of 250 ml and sealed hermetically and externally so that the pressure produced inside by the $^{222}$Rn from $^{226}$Ra decay would not result in leakage of gas. These samples have been kept for a period of one month so that the daughter products of $^{226}$Ra up to $^{210}$Pb and of $^{228}$Th up to $^{208}$Pb achieve secular equilibrium with their respective parent radionuclides.[7] The soil and sand samples have been analyzed by using 3"×3" NaI(Tl) detector employed with adequate lead shielding which reduces the background radiation. NaI(Tl) detector have been chosen for this study because of its high detection efficiency and working at room temperature.[8] The concentrations of primordial radionuclides $^{40}$K, $^{238}$U and $^{232}$Th have been determined using the peak at 1.46 MeV ($^{40}$K), 1.764 MeV ($^{214}$Bi) and 2.614 MeV ($^{208}$Tl). Activity calculations have been carried out using the procedure given by LALIT and RAMACHANDRA.[9] Gamma-dose rates owing to primordial radionuclides present in the samples have been calculated by using the conversion factor published by UNSCEAR.[10]

## Results and discussion

*Soil samples: Ambient gamma-dose*

Table 1 shows the ambient gamma-dose values of 48 sampling sites situated throughout the Radhapuram Taluk. The exposure rate in μR/h measured from the survey meter is converted into absorbed dose rate in nGy/h using the conversion factor given by UNSCEAR.[10] The ambient gamma dose rate varies from 45 to 810 nGy/h. The highest value recorded as 810 nGy/h in one of the samples of Vijayapathi Panchayat (No. 46). From the geological survey, local concentrations of lime stone with "teri" structure has been identified in this panchayat and also this Vijayapathi Panchayat has a long sea shore, due to the continuous monazite depositions from the sea, background radiation is enhanced naturally.


*Fig. 1.* Study area map

*Table 1.* Activity concentration of $^{40}K$, $^{238}U$ and $^{232}Th$ in soil samples of Radhapuram Taluk

| Site | Number of samples | Dose rate, nGy/h (survey meter reading) | Activity concentration, Bq·kg$^{-1}$ | | |
|---|---|---|---|---|---|
| | | | $^{40}K$ | $^{238}U$ | $^{232}Th$ |
| A. Thirumalapuram | 2 | 135–144 | 1055.9 | 24.8 | 207.9 |
| Achambadu | 3 | 90–115 | 97.0 | 17.8 | 332.6 |
| Adangar kulam | 5 | 90–225 | 627.7 | 20.2 | 205.1 |
| Anaikudi | 1 | 150–225 | BDL | 63.2 | 415.56 |
| Anaikulam | 3 | 90–100 | 174.1 | 17.1 | 83.8 |
| Anakarai | 2 | 135–150 | 603.3 | 18.7 | 149.8 |
| Appuvillai | 1 | 150–180 | 81.42 | 43.2 | 274.9 |
| Avaraikulam | 1 | 150–180 | 318.8 | 34.1 | 275.7 |
| Chettikulam | 3 | 67–157 | 412.4 | 13.9 | 146.0 |
| Chidambarapuram | 1 | 90–110 | 325.7 | 13.3 | 116.6 |
| Erukkan thurai | 4 | 90–135 | 804.8 | 30.0 | 167.5 |
| Idayankudi | 1 | 175–225 | BDL | 61.5 | 332.3 |
| K. Navaladi | 5 | 45–65 | BDL | 98.5 | 633.9 |
| K. Ovari | 1 | 225–270 | BDL | 53.5 | 282.9 |
| Kanna nallur | 1 | 110–135 | 753.2 | BDL | 54.6 |
| Karasuthupudur | 4 | 135–405 | 217.0 | 81.7 | 446.0 |
| Kasthurirengapuram | 5 | 135–180 | 257.3 | 27.9 | 264.0 |
| Kaval kinaru | 4 | 90–115 | 1118.4 | 24.7 | 276.5 |
| Koodankulam | 2 | 135–315 | 315.6 | 51.2 | 368.3 |
| Kottai karunkulam | 5 | 115–135 | 358.8 | 28.8 | 167.9 |
| Kovan kulam | 3 | 144–180 | 747.8 | 29.9 | 153.5 |
| Kumarapuram | 5 | 90–135 | 142.9 | 51.1 | 145.0 |
| Kumbi kulam | 4 | 90–180 | 229.6 | 22.4 | 129.3 |
| Kuthankuli | 0 | – | – | – | – |
| Kuttam | 3 | 90–225 | 59.0 | 31.7 | 128.0 |
| Levengi puram | 3 | 45–90 | 403.7 | 9.9 | 83.2 |
| Mahadevankulam | 3 | 90–144 | 645.1 | 38.0 | 163.4 |
| Muthu mothanmozhi | 2 | 130–135 | 11.3 | 45.9 | 216.3 |
| Palavoor | 1 | 90–95 | 583.6 | BDL | 85.3 |
| Panakudi (T) | 1 | 135–140 | 697.3 | 10.2 | 211.7 |
| Parameswarapuram | 3 | 90–135 | 208.2 | 30.0 | 196.3 |
| Radhapuram | 7 | 90–110 | 290.1 | 20.0 | 144.6 |
| Samugarengapuram | 1 | 90–135 | 336.5 | 25.0 | 109.6 |
| Soundara Pandiyapuram | 3 | 65–135 | 235.1 | 15.4 | 129.9 |
| T. Kallikulam | 2 | 90–110 | 213.8 | 10.3 | 98.4 |
| T. Karunkulam | 2 | 65–90 | 564.4 | 14.1 | 85.1 |
| T. Vallioor | 1 | 110–130 | 75.5 | 55.1 | 296.5 |
| Tisayanvillai (T) | 1 | 60–75 | BDL | 229.1 | 650.5 |
| Thanakar kulam | 7 | 90–144 | 376.8 | 20.9 | 176.6 |
| Thiruvambalapuram | 2 | 90–110 | 41.9 | 22.2 | 100.1 |
| Urumankulam | 5 | 90–135 | 524.1 | 20.3 | 141.0 |
| Uthayathoor | 4 | 90–110 | 247.0 | 25.4 | 144.6 |
| Uvari | 1 | 90–100 | 468.3 | BDL | 21.0 |
| Vadakkan kulam | 2 | 135–155 | 643.5 | 28.5 | 208.1 |
| Vallioor (T) | 1 | 90–130 | 420.7 | 16.3 | 122.4 |
| Veppilan kulam | 4 | 110–135 | 394.6 | 35.2 | 384.1 |
| Vijayapathi | 3 | 90–810 | 216.0 | 180.5 | 836.1 |
| Yacobpuram | 1 | 135–140 | 472.3 | 12.0 | 212.6 |

(T): Town Panchayat.

*Gamma-spectrometry results*

The activity concentrations of $^{232}$Th, $^{238}$U and $^{40}$K radionuclides in soil samples of Radhapuram Taluk are given in Table 1. The activity concentration of $^{40}$K varies from 11.3 to 1713.1 Bq·kg$^{-1}$ with a geometric mean of 293.2 Bq·kg$^{-1}$. Highest value of $^{40}$K has been found in one of the sample "Parivillai" from Erukkandurai Panchayat and the value is 1713.1 Bq·kg$^{-1}$. This high value of $^{40}$K is due to the cultivation work being carried out throughout the year and leaching of potassium fertilizers from the cultivation lands may influence in the increase of $^{40}$K activity.[11] Activity concentration of $^{238}$U varies from BDL (<8.5 Bq·kg$^{-1}$) – 453.7 Bq·kg$^{-1}$ with a geometric mean of 29.3 Bq·kg$^{-1}$. Activity concentration of $^{232}$Th varies from 21.0 Bq·kg$^{-1}$ to 2181.6 Bq·kg$^{-1}$ with a geometric mean of 182.1 Bq·kg$^{-1}$. Highest value of uranium and thorium has been found in the "Thilaivanam Thoppu" of Vijayapathi Panchayat. Usually teri structured soil has opaque minerals zircon, monazite, tourmaline, apatite, rutile in different composition.[12] From the gamma-spectrometry results in the teri soil, it has been identified this "Thilaivanam Thoppu" teri has the highest concentration of monazite than the other teri soil samples found in Tisayanvillai and K. Pudur Panchayats. The total dose due to three primordial radionuclides lying in the range of 13.1–168.2 nGy/h with a geometric mean of 137.2 nGy/h, which yields a annual effective dose of 0.17 mSv/y. An attempt has been made to compare the dose rate as measured by survey meter and the calculated values using UNSCEAR conversion factor with the activity values obtained from the gamma-ray spectra and correlation coefficient $R = 0.81$ (Fig. 2) has been obtained. The difference between these two readings may be due to (1) soil samples were analyzed after removal of pebbles and stones,[13] (2) natural radionuclides may not be distributed uniformly in soil,[13] (3) soil moisture may affect the dose rate significantly.[14] Figure 3 gives the correlation between the activity of $^{232}$Th and the total dose rate due to the primordial radionuclide. It is seen from the figure that there is a good correlation between the thorium activity and the total dose, where as no such correlation existed for uranium and potassium. This is due to the fact that major portion of the dose is contributed due to thorium content in soil with a small but uniform background provided by $^{238}$U and $^{40}$K.

*Sand samples: Ambient gamma-dose*

In sand samples, the survey meter value has been found to be in the range of 65–765 nGy/h with a geometric mean of 229.8 nGy/h. This shows the sea shore area of the Radhapuram Taluk is one of the high background radiation areas.

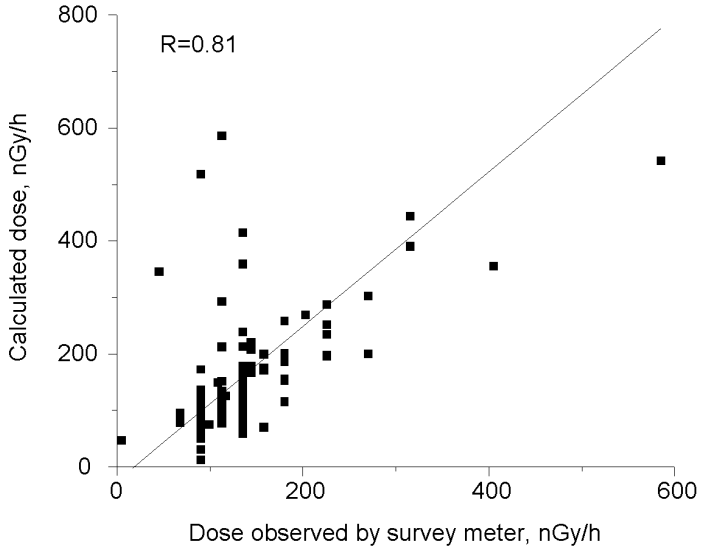


*Fig. 2.* Correlation graph between observed and measured gamma-dose

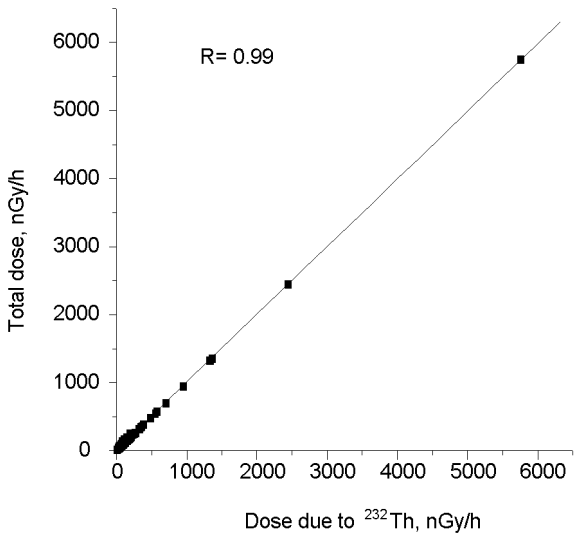


*Fig. 3.* Correlation graph between total dose and dose due to $^{232}$Th

*Gamma-spectrometry results*

Table 2 shows the activity concentration of $^{232}$Th, $^{238}$U and $^{40}$K from the sand samples of Radhapuram Taluk. Out of 16 samples, activity concentration of $^{40}$K has been found to be BDL (<13.25 Bq·kg$^{-1}$) in 9 samples. In high background radiation area (monazite area) due to the high activity of $^{232}$Th in sand, the gamma-emission energy of $^{228}$Ac, daughter product of $^{232}$Th is 1459.2 keV and for $^{40}$K the emission energy is 1460 keV is not distinguishable by NaI(Tl) gamma-ray spectrometer. Gamma-spectroscopy results of sand samples collected from the monazite rich areas have already reported that potassium activity is BDL (<13.25 Bq·kg$^{-1}$).[15] The highest value of thorium has been observed in Kuthankuli-II and the value is 9230.68 Bq·kg$^{-1}$. Kuthankuli-II is situated very near to the Bay of Bengal. Totally 2 samples have been collected in Kuthakuli at different distance from the sea. I and II samples have been collected at 120, 30 m, respectively. Sample II has the highest activity, so the deposition of monazites from the sea is the sole reason for the higher value in the sand. It has been observed from the table that thorium is present in all the samples. This may be due to the existence of igneous and granite nature of rock in the area under study. The geological survey has already proved the existence of rich deposits of red garnet sands in the beds of Uvari River which is flowing across the study area. Local concentration of Ilmenite sands may also influence in higher concentration of primordial radionuclides.[16,17] Total dose due to three primordial radionuclides have been found to be in the range of 38.1–1964.4 nGy/h with a geometric mean value of 300.8 nGy/h, which gives an annual effective dose of 0.37 mSv/y.

*Table 2.* Activity concentration of $^{40}$K, $^{238}$U and $^{232}$Th in sand samples of Radhapuram Taluk

| Site | Dose rate, nGy/h (survey meter reading) | Activity concentration, Bq·kg$^{-1}$ | | |
|---|---|---|---|---|
| | | $^{40}$K | $^{238}$U | $^{232}$Th |
| Kuduthalai | 270 | BDL | 138.38 | 575.16 |
| Nadar Ovari-I | 90 | 404.30 | 22.20 | 136.47 |
| Nadar Ovari-II | 180 | 198.89 | 21.95 | 178.11 |
| Keela Ovari | 315 | BDL | 57.68 | 332.18 |
| Karikovil | 450 | BDL | 109.98 | 618.37 |
| Kundal | 315 | 37.00 | 12.08 | 49.83 |
| Kuthankuli-I | 765 | BDL | 176.82 | 3022.60 |
| Kuthankuli-II | 225 | BDL | 105.79 | 9230.08 |
| Aaudaiyalpuram-I | 135 | BDL | 149.42 | 2130.10 |
| Aaudaiyalpuram-II | 135 | 68.28 | BDL | 20.19 |
| Aaudaiyalpuram-III | 315 | BDL | 90.26 | 614.16 |
| Thomaiyapuram | 315 | BDL | BDL | 1528.71 |
| Idindhakarai | 67.5 | 787.45 | 39.71 | 95.12 |
| Perumanal-I | 112.5 | 46.46 | 23.16 | 153.19 |
| Perumanal-II | 450 | BDL | 83.12 | 919.38 |
| Perumanal-III | 292.5 | 69.61 | 30.93 | 384.32 |

BDL: Below the detection limit.

## Conclusions

The activity concentration of $^{232}$Th, $^{238}$U and $^{40}$K in Radhapuram Taluk have been evaluated from the soil samples collected at various locations. The activity concentration of $^{232}$Th in soil has been found to be 6 times higher than the world average (30 Bq·kg$^{-1}$)[10] and the activity concentration of $^{40}$K has been found to be 0.7 times less than the world average (400 Bq·kg$^{-1}$).[10] In sand samples activity concentration of $^{232}$Th is found to be 41 times higher than the world average which shows the abnormal levels of natural radiation in the sea shores. The annual effective dose due to the three primordial radionuclides in the study area in both sand and in soil has found to be 0.37 mSv/y and 0.17 mSv/y, respectively, and it is well below the permissible limit (1 mSv).[18]

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