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Radioactivity levels in soil of salt field area, Kelambakkam, Tamilnadu, India

R. RAVISANKAR[1*] A. RAJALAKSHMI[1] P. ESWARAN[2] V GAJENDIRAN.[3]
V. MEENAKSHISUNDRAM[3]

([1] Department of Physics, Sri Sivasubramania Nadar College of Engineering, Kalavakkam, Chennai- 603110, Tamilnadu, India;

[2] Department of Physics, SMK Fomra Institute of Technology, Thaiyur, Chennai- 603 103, Tamilnadu, India;

[3] Radiological Safety Section, Health and Safety Division, Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam- 603102, Tamilnadu, India)

Abstract Soil samples in and around salt field area have been analyzed for natural radioactivity concentration using gamma ray spectrometer. The activity concentration for ^{232}Th, ^{238}U and ^{40}K are ranged from 27.88 to 45.27 Bq/kg, from BDL to 13.30 Bq/kg, and from 135.54 to 381.28 Bq/kg, respectively. The measured activity concentrations for these radionuclides were compared with world average activity of soil. The average activity concentration of ^{232}Th in the present study is 1.19 times higher than world median value while the activity of ^{238}U and ^{40}K is found to be lower. The absorbed dose rates due to these radionuclides were calculated. The average absorbed gamma dose rate due to the presence of ^{232}Th, ^{238}U and ^{40}K in soil samples is 36.99 nGy·h^{-1}. These results indicate no radiological anomaly. The data presented in this study will serve as a base line survey for primordial radionuclides concentration in the study area.

Key words Natural radioactivity, Soil samples, Salt field, Gamma-ray spectrometer

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1 Introduction

Mankind has all along lived in natural radiation environment due to various natural sources of terrestrial and extra terrestrial origin. The extra terrestrial sources of radiation are cosmic rays and other radioactive elements produced due to the interaction of cosmic rays with the atmosphere. The sources of terrestrial radiation are radionuclide present in the earth's crust or in the atmosphere. Most of the terrestrial radionuclides originate from ^{238}U and ^{232}Th series. They also originate from the singly occurring primordial radionuclide ^{40}K. This radionuclide may enter into our food chain and cause internal exposure. The distribution of natural radionuclides is an essential prerequisite for the evaluation and control of public exposures. Gamma radiation from these radionuclides represents the main external source of radiation to the human body. Natural environmental radioactivity and the associated external exposure due to gamma radiation depend primarily on the geological and geographical conditions, and appear at different levels in the soils of each different geological region [1]. The specific levels of terrestrial environmental radiation are related to the geological composition of each lithologically separated area, and to the content of thorium, uranium and potassium in the rock from which the soil originate in each area.

Investigations on terrestrial natural radiation have received particular attention world wide and lead to extensive surveys in many countries. They mainly serve as baseline data of natural radioactivity such that man-made contaminations can be detected and quantitatively determined. They can further be used to assess

* Corresponding author. E-mail: ravissn@gmail.com, ravi@ssnce.ac.in
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public dose rates and to perform epidemiological studies. The results obtained in each country can be exploited to enrich the world's data bank which is needed for evaluating worldwide average values of radiometric and dosimetric quantities.

The gamma ray spectrometry method for the determination of naturally occurring radioactive materials (NORM) is of great interest in Earth sciences. There are a number of possible applications spanning from ore exploration to environmental radiation monitoring problems, most of them involving the determination of the U, Th and K in amount in soils, sediments and rocks [2].

Mother Nature has gifted mankind with lot of precious gifts. Common salt is one of them. In the globe, Tamilnadu is one of the ideal locations for producing salt. Kelambakkam salt field area is one of the leading producers of salt in global market. The climate, soil and availability of brine are a great asset for producing quality salts. This salt field consists of nearly 500 acres of saltpans in the town of Kelambakkam very near to the East coast of Tamilnadu and connected to the Information Technology highway [3].

Salt-field, a closed salt-production unit, is composed of a basin for the first pumping for water reserves, five-grade evaporation basins, crystallization basins and collector basin for effluent discharges. During high tide, salters let the water to the salt-field from the main sea channel through the conduit sluice gate. Here it flows from one evaporation basin to the other along little channels and through sluice gates with the aid of wind and hand pumps. Table salt begins to separate from its crystallization basins. This is the time for the salt to be harvested and stored. During low tide, salters let effluent discharges and rainwater into the channel and back into the sea through the drain sluice gate. This salt-production unit also includes the salt-pans house and the main channel for the inflow of seawater.

In the present work, the primordial radionuclides concentration in soil samples collected in and around the salt field area, Kelambakkam, Tamilnadu was measured using gamma ray spectrometer.

2 Sample collection

The soil profiles were sampled using an automatic core driller. Cores extruded and sectioned at 10 cm diameter and 25 cm depth were used to take soil samples. The soil samples were collected at six sites, each covering $1m^2$ area. After making 1m×1m area and removing the top layer of the soil, five pits were dug and from each pit the soil samples were collected, mixed and packed. This ensures uniform mixing of the soil at the particular site. The locations of the sampling sites were randomized to avoid any bias in results. The collected samples after coning, quartering and sieving were used for different analyses. These samples were weighed individually. Nearly 2 kg of the samples were air dried for 10 days and kept in an oven at 105ºC. After homogenization samples were sieved through 100-mesh sieve. These fine samples were used for the radioactivity analysis. The salt samples were also collected for analysis. Sample S_7 was collected slightly away from the salt field area and was used for reference in the analysis.

3 Materials and methods

The selected known amount of samples were packed in plastic containers and aged for four weeks to allow the parent nuclides in the samples to reach equilibrium with their respective progeny [4]. All the soil samples were subjected to gamma ray spectral analysis with a counting time of 20,000 s. A 3"×3" NaI (Tl) detector was employed with adequate lead shielding which reduced the background by a factor of about 95. The efficiency for various energies was arrived at using IAEA standard sources and required geometry. The system was calibrated both in terms of energy response and also for counting efficiency. The concentrations of various nuclides of interest are determined in Bq/kg using the count spectra. The peaks corresponding to 1.46 MeV (^{40}K), 1.76 MeV (^{214}Bi) and 2.614 MeV (^{208}Tl) were considered in arriving at the activity levels.

At each sampling spot the ambient gamma dose was measured using a digital Environmental Radiation Dosimeter (ERDM), which comprises of a Geiger Muller (G.M) counter. Before starting the survey, the ERDM was calibrated regularly using a standard source. The ERDM readings were recorded at 1 m above ground level. A total of five readings were

taken at each spot and the average was recorded. The observed dose rate is presented in Table 1.

The spectra obtained were analyzed for the concentration of radionuclides using computer curve fitting techniques. For each location the activity concentrations S_U, S_{Th} and S_K for ^{232} Th, ^{238}U, and ^{40}K respectively (in Bq/kg) were calculated.

4 Results and discussion

The distribution of natural radionuclides in soil samples and also the corresponding absorbed dose rate in air above the ground level are presented in Table 1. From the table it is seen that the activity of ^{232}Th varies from 27.88 to 45.27 Bq/kg and the arithmetic mean is 35.96 Bq/kg. The activity concentration of ^{238}U varies from BDL to 13.30 Bq/kg and the arithmetic mean of 3.81 Bq/kg. Similarly the activity concentration of ^{40}K varies from 135.54 to 381.28 Bq/kg and the arithmetic mean is 271.78 Bq/kg. The existence of wide range of variation in the activities of these radionuclides draws attention. This fact may be attributed to wide variety of lithogocial components existing in the zone under study.

Table 1 Activity concentration of ^{232}Th, ^{238}U and ^{40}K in soil samples

Sampling sites	Activity concentration / Bq·kg^{-1}			Calculated dose rate /nGy·h^{-1}	Observed dose rate /nGy·h^{-1}
	^{232}Th	^{238}U	^{40}K		
S_1	39.61 ± 6.41	BDL	135.54 ± 31.36	32.07	35.23
S_2	27.88 ± 6.33	BDL	281.47 ± 33.48	30.39	28.64
S_3	45.27 ± 7.59	9.58 ± 8.35	381.28 ± 39.81	50.27	55.48
S_4	30.52 ± 6.69	13.30 ± 7.60	274.66 ± 35.51	37.56	40.79
S_5	33.09 ± 6.87	BDL	278.02 ± 35.83	33.71	38.04
S_6	39.42 ± 7.16	BDL	279.70 ± 37.02	37.92	40.25
Mean	35.96	3.81	271.78	36.99	39.74
S_7^*	20.29 ± 5.92	9.94 ± 6.79	80.82 ± 30.29	21.17	25.17
Salt	BDL	BDL	BDL	-	-

BDL- Below Detectable Limit, * - Reference sample

The world average concentrations of ^{232}Th, ^{238}U and ^{40}K are 30, 35 and 400 Bq/kg respectively [1]. If one compares the activity of radionuclides of the present study with world average values, ^{232}Th is higher by a factor of 1.19 while the activity of ^{238}U was found to be lower by a factor of 0.10 and ^{40}K activity is lower by a factor of 0.67. The highest ^{232}Th activity found in the present study is due to the presence of heavy minerals in the study area which has been confirmed by the spectral investigations [5]. The sample collected outside of the salt field area was considered as the reference sample. The activity concentration of primordial radionuclides in the reference sample is found to be lower than other sampling sites.

Among the three radionuclides found in soil samples, the highest activity concentration of ^{40}K (381.28 Bq/kg) followed by ^{232}Th (45.27 Bq/kg) is seen at S_3 site. Thorium activity concentration was found to be higher than uranium in all the sampling sites. This may be due to low geochemical mobility of thorium [6]. Another possible reason is attributed to the different chemical behavior of Th and U resulting in the concentration differences. Thorium can enter the crystal lattice of principal minerals if the molecular space is adequate or if involved in the adsorption processes in clays. The presence of clay minerals in the study area was confirmed by the FT-IR and XRD techniques which support the above statement [5]. However the salt samples collected in salt field area value showed below detectable limit and which indicates that the salt is free from radiological hazards.

5 Dose calculation

UNSCEAR (1988) has given the dose rate for converting the activity concentration of ^{232}Th, ^{238}U and ^{40}K into doses (nGy·h^{-1} per Bq/kg) as 0.429, 0.666 and 0.042 respectively [7]. Using these factors the total absorbed dose rate in air at 1 m above the ground level is calculated as per the equation below

$$D = 0.429\ S_U + 0.666\ S_{Th} + 0.042\ S_K$$

where S_U, S_{Th} and S_K are the specific activity concentrations of uranium, thorium and potassium in soil respectively. It can be observed from Table 1 that the calculated total absorbed dose rate due to the presence of ^{232}Th, ^{238}U and ^{40}K in soil samples varied between 30.39 (S_2) and 50.27(S_3) nGy·h^{-1}. The mean absorbed dose rate 36.99 nGy·h^{-1} found in the present study is lower than the global background dose in air (59 nGy·h^{-1}) complied by UNSCEAR 2000. The absorbed dose rate of the reference sample 21.17 n Gyh^{-1} (S_7) is also much lesser than the global value. This indicates that from the environmental point of view, there is no radiation hazard in the study area as well as the area surrounding it.

6 Conclusion

This study is focussed only on the concentration of ^{232}Th, ^{238}U and ^{40}K in soil samples and the resulting radiation dose from these radionuclides. The effective dose equivalent is expected to increase if one includes the other gamma emitting radionuclides and the fallout activity. These results indicate no radiological anomaly. The data presented in this study will serve as a base line survey for primordial radionuclides concentration in the study area and also gives a base line for proper assessment of radiation exposure to the dwellers. This study reflects the fact that the salt area does not pose any radiation hazards.

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