Mudasir Ashraf, C. Anu Radha*, Shakeel Ahmad, Sajad Masood, Rayees Ahmad Dar, V. Ramasubramanian, and P. Yadagiri Reddy

Radiological health assessment due to gamma radiation levels of natural radioactivity of soil in vicinity of Nichahoma lignite belt, Kashmir Valley

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Abstract: The measurements of activity concentrations in soil of the lignite belt and soil of the villages surrounding the lignite belt have been carried out in order to present the radiological health hazards due to gamma radiation levels of the soil to general public. A low- background Pb-shielded gamma spectroscopic counting assembly utilizing NaI(Tl) detector was employed for the measurements. The activity concentration of radionuclides have been determined and compared with the international and national recommended values. A correlation analysis was also performed in order to predict the contribution of the respective nuclides towards the measured dose rate and to the find the existence of these radioactive nuclides together in the study area.

Keywords: Measured dose rate, soil of villages, radiation hazard index.

1 Introduction

It is well known fact natural environmental radioactivity is present in varying proportions in rocks and soil of different geological formations across the globe. The concentrations and associated external radiation doses to the general public in different environmental matrices depend on the geology and geographical conditions of such environmental processes, due to weathering, rainfall of a place and other environmental processes, radionuclides in different environmental matrices such as soil and rocks may accumulate in the sediments and dissolve into drinking water, air we breathe, thus lead to human exposure which in turn produce biological damage of the human tissue. The pathways of human exposure include: uptake from contaminated water through roots of the plants and trees, inhalation of soil dust, and direct exposure from primordial radionuclides in the indoor and outdoor environments, etc. Research on environmental natural radiations have received worldwide attention and lead to extensive study in many countries like Spain, Turkey, Nigeria, Malaysia, Iran, and Botswana. The absorbed dose rate in air depends mainly on the radionuclide concentration in the soil, as the largest component of the gamma radiation from the terrestrial radionuclides and the cosmic rays [1, 2]. There is a direct correlation between terrestrial gamma and radionuclide concentrations in soil as it contains small quantities of radioactive elements like Uranium and Thorium along with their progenies [3]. Radioactivity in soil depends on its characteristics such as formation and transport process that were present since the dawn of the universe [4].

Scientific research on natural radioactivity is necessary, not only because of their radiological impact on the living things, but also because they serve as excellent biochemical and geochemical tracers in the environment [5]. In the present study, the activity concentrations of terrestrial radionuclides in soil of the lignite belt and soil of the residential areas surrounding the lignite belt of Nichahoma Kupwara, Kashmir Valley, India have been measured by using a low background lead-shielded gamma spectroscopic counting assembly utilizing NaI(Tl) to determine the outdoor radiation exposure and the radiological health assessment of the lignite soil. The results of this study are of great interest in the environmental radiologi-

***Corresponding author: C. Anu Radha,** School of Advanced Sciences, VIT University, Vellore, Tamil Nadu, India, e-mail: caradhavit@gmail.com
Mudasir Ashraf: School of Advanced Sciences, VIT University, Vellore, Tamil Nadu, India; and Department of Radiological Physics and Bio-engineering, Sher-i-Kashmir Institute of Medical Sciences, Soura, Srinagar, India
Shakeel Ahmad, Sajad Masood: Department of Physics, University of Kashmir, Srinagar, India
Rayees Ahmad Dar: Division of Biostatistics, Sher-i-Kashmir Institute of Medical Sciences, Soura, Srinagar, India
V. Ramasubramanian: School of Advanced Sciences, VIT University, Vellore, Tamil Nadu, India
P. Yadagiri Reddy: Department of Physics, Osmania University, Hyderabad, India

cal protection especially for Kashmir Valley where lignite and coal is being drilled and used as fuel. To the best of our knowledge, no such study has been carried out in Kashmir Valley. The study, therefore, will serve as a baseline data for further extension of radiological research in the area under study.

2 Geology of the study area

The Kupwara region of Kashmir valley has latitude of 34.52 degrees North and longitude of 74.25 degrees East. The region has quartz veins carrying sulphides of copper and iron with some oxide, carbonates and arsenides. The presence of gold and silver in traces is indicated in the quartz veins carrying sulphides of copper and iron in association with some oxides, carbonates and arsenides in Lolab area of region. The upper Cambrian region of Kupwara in the northwest Kashmir contains several thick bands of hard and siliceous recrystallised limestone, which is currently being mined and marked as "Kupwara Marble". The estimated lignite reserves at Nichahoma to be 80 million tones. This lignite occurs in a track which is around 80 km long and 16 km wide has lignite showing rapid variation in thickness and quality. The geological survey of India proved 4.5 million tones reserves of lignite up to a depth of 36.5 m in Nichahoma area. The Indian Bureau of Mines indicated proven reserves of 7.26 million tones. The quarriable reserves in Nichahoma area were estimated to be 5.26 million tons [6].

3 Sampling and sample preparation

The ten different soil samples from the surface of the lignite belt and ten soil samples of from the villages surrounding the lignite belt are randomly collected. The collected soil samples were placed in labeled polyethane bags then transferred to the laboratory for preparation and analysis. The samples were pulverized, heated and dried in an oven at a temperature of 125 °C for 24 h so as to make them moisture free and sieved through a 2 mm mesh. 1000 g of samples was filled and sealed in leakproof, air tight PVC merinelli beakers, weighed and stored for a period of four weeks to enable the samples to attain a state of secular equilibrium, where the rate of progeny becomes equal to that of the parent (^{226}Ra and ^{232}Th) [7].

4 Radiometric analysis

The concentration of ^{226}Ra, ^{232}Th, and ^{40}K were determined using the low background lead-shielded gamma-ray spectrometer consisting of a NaI(Tl) detector (crystal size 40.0 mm × 60.0 mm) connected to 1024 channel multichannel analyser (MCA). Before measurement, the system is calibrated using ^{137}Cs and ^{60}Co radioactive sources produce γ-ray energies of 662 keV, 1173 keV and 1332 keV, respectively

The spectrum was analysed by Leybold Cassy Lab Multi-Channel Analyser model Pocket- CASSY 559901 (Germany made). The activity of ^{40}K was measured directly with 1460.7 (10.7%) keV peak of the gamma ray spectrum. To determine the activity concentration of ^{226}Ra, the average value of gamma ray lines 295.1 (19.2%) and 351.9 (37.1%) keV from ^{214}Pb to 609.3 (46.1%) and 1764.5 (15.9%) keV gamma ray from ^{214}Bi is used. The activity concentration of ^{232}Th was determined using the average value of gamma rays peaks 238.6 (43.6%) keV from ^{212}Pb, 338.4 (12%), 911.1 (29%) and 968.9 (17.4) keV from ^{228}Ac, 583.1 (86%) and 2614 keV from ^{208}Tl. Each sample was examined for 18 000 s. The Activity concentrations in the samples were calculated according to the following relation [8]:

$$A = \frac{C}{\varepsilon \times P_{\gamma} \times M_{s} \times T} \quad (1)$$

Where C is the count rate of gamma rays, ε is the detectors efficiency of the specific γ-rays, P_{γ} is the absolute transition probability of the γ-decay, M_{s} is the mass of the sample in kg, and T is the counting time in seconds obtained for the measured radionuclides are expressed in Bq Kg^{-1} per dry weight.

5 Assessment of radiological hazard parameters

The most extreme and important ambition of the measured activity concentrations in any material is to assess the radiological hazards incurred by general public either indoor or outdoor. Outdoor exposure is considered for the population working on the mining site and those living in the immediate environment, while the indoor exposure is for population due to their habitation such as cement houses made from marble rocks, mud of rural houses and the ventilation system etc. and major contribution is from indoor radon radioactive noble gas.

The radionuclides which are distributed in soil were assessed through various radiation hazard indices which include radium equivalent activity, outdoor dose rate, annual effective dose equivalent, annual gonad dose and external hazard index.

The distribution of natural radioactivity in the samples under investigation is not uniform. Therefore, a common radiological hazard index has been used to evaluate the actual activity level ^{226}Ra, ^{232}Th, and ^{40}K in the samples and the radiation hazards associated with these radionucleides. This index is usually known as radium equivalent activity [8].

$$\mathrm{Ra_{eq}} = A_{\mathrm{Ra}} + 1.43A_{\mathrm{Th}} + 0.077A_{\mathrm{K}} \quad (2)$$

Where A_{Ra}, A_{Th}, and A_{K} are the specific activities of ^{226}Ra, ^{232}Th, and ^{40}K respectively in Bq kg^{-1}. It is calculated based on the assumption that 370 Bq kg^{-1} of ^{226}Ra, 259 Bq kg^{-1} of ^{232}Th and 4810 Bq kg^{-1} of ^{40}K produce an equal gamma ray dose rate. Radium equivalent activity is directly related to the external and internal gamma dose due to radon and its progenies [9].

In order to assess any radiological hazard, the exposure to radiation arising from radionucleides present in soil can be estimated in terms of many parameters. A direct connection between radioactivity concentrations of natural radionucleides and their exposure rate is known as the absorbed dose in the air at 1 meter above the ground surface. The mean activity concentrations of ^{226}Ra (of the ^{238}U series), ^{232}Th, and ^{40}K (Bq kg^{-1}) in soil samples are used to calculate the absorbed dose rate (nano Grays per hour) given using the following formula provided by United Nations Scientific Committee 0n Effects of Atomic Radiations [10] and European Commission [11]. UNSCEAR and the European Commissions have provided the dose conversion coefficients for the standard room centers.

$$D\,(\mathrm{nGy\,h^{-1}}) = 0.462A_{\mathrm{Ra}} + 0.604A_{\mathrm{Th}} + 0.0417A_{K} \quad (3)$$

where D is the absorbed dose rate in nGy h^{-1}, A_{Ra}, A_{Th}, and A_K are the activity concentration of ^{226}Ra (^{238}U), ^{232}Th and ^{40}K, respectively. The dose coefficients in the units of nGy h^{-1}, per Bq kg^{-1} are taken from the UNSCEAR report [10].

The severity of any radiological hazard is estimated based on the annual radiation dose received by a person working or living in the radiation environment. The absorbed dose rate in air at 1 m above the ground surface does not directly provide the radiological risk to which an individual is exposed [12]. The absorbed dose can considered in terms of the Annual effective dose equivalent (AEDE) (E_{T}) from the outdoor terrestrial gamma radiation which is converted from absorbed dose by taking into account two factors, namely the conversion coefficient from the absorbed dose in air to effective dose and the occupancy factor. The AEDE (mili Siverts per year) can be estimated using the following formula [10, 11]

$$E_{\mathrm{T}}\,(\mathrm{mSv\,y^{-1}}) = D\,(\mathrm{nGy\,h^{-1}}) \times 24\,\mathrm{h} \times 365.25 \times 0.2 \times 0.7\,\mathrm{Sv\,Gy^{-1}} \times 10^{-6} \quad (4)$$

The value of those parameters used in the UNSCEAR report (2000) is 0.7 Sv Gy^{-1} for conversion coefficients from the absorbed dose in air to effective dose received by the adult and 0.2 for outdoor the occupancy factor. Effective dose exceeding the dose limit of 1 mSv y^{-1} should be taken into account in terms of radiation protection.

The gonadals, active bone marrow, and the bone surface cells are considered the organs of interest by UNSCEAR [10]. Therefore, the Annual Gonad Dose Equivalent AGDE (μSv y^{-1}) owing the specific activities of ^{226}Ra, ^{232}Th, and ^{40}K were calculated using the following formula [13, 14]:

$$\mathrm{AGDE}\,(\mu\mathrm{Sv\,y^{-1}}) = 3.09A_{\mathrm{Ra}} + 4.18A_{\mathrm{Th}} + 0.314A_{\mathrm{K}} \quad (5)$$

where A_{Ra}, A_{Th} and A_{K} are the concentration in Bq kg^{-1} of ^{226}Ra, ^{232}Th and ^{40}K respectively.

The decay of naturally occurring radionuclides in the soil produces a radiation field that penetrates the different layers of soil and soil –air interface to produce significant human exposure. The external hazard index (H_{ex}) is determined and examined with the help to following equation [15]:

$$H_{\mathrm{ex}} = \frac{A_{\mathrm{Ra}}}{370} + \frac{A_{\mathrm{Th}}}{259} + \frac{A_{\mathrm{K}}}{4810} \leq 1 \quad (6)$$

The value H_{ex} must not exceed the limit of unity so as to keep radiation hazard insignificant to the general public. The maximum permissible value of H_{ex} equal to unity corresponds to the upper limit of $\mathrm{Ra_{eq}}$ 370 Bq kg^{-1} measured dimensions and calculated densities.

6 Results and discussions

6.1 Radioactivity concentration levels

The radioactivity concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil samples of the lignite belt and in the soil of the villages surrounding the lignite belt with their mean value, standard deviation and median are summarized in the Tables 1 and 2 respectively. The ^{226}Ra is distinctly higher than

Table 1: Activity concentration of ^{226}Ra, ^{232}Th, ^{40}K, radium equivalent activity and radiological hazard indices of the soil of lignite belt.

Sample code	Activity concentration (Bq kg^{-1})			Ra_{eq} (Bq kg^{-1})	Absorbed dose rate (nGy h^{-1})	H_{ex}	E_T (mSv y^{-1})	AGDE (μSv y^{-1})
	^{226}(Ra)	^{232}Th	^{40}K					
S_1	53.6	23.4	39.8	90.1	40.6	0.2	0.05	275.9
S_2	53.9	24.0	39.8	91.3	41.1	0.3	0.05	279.4
S_3	52.7	23.4	27.8	88.3	39.6	0.2	0.05	269.4
S_4	53.2	22.5	35.8	88.1	39.7	0.2	0.05	269.7
S_5	55.2	18.3	27.8	83.5	37.7	0.2	0.05	255.8
S_6	55.4	21.3	26.2	87.9	39.6	0.2	0.05	268.5
S_7	46.0	22.1	30.1	79.9	35.9	0.2	0.04	244.0
S_8	55.6	23.0	32.3	91.0	40.9	0.3	0.05	278.1
S_9	52.3	24.0	38.7	89.6	40.3	0.2	0.05	274.1
S_{10}	51.2	23.6	31.6	87.4	39.2	0.3	0.05	266.8
Mean	52.9	22.5	33.0	87.7	39.5	0.2	0.05	268.2
Standard deviation	2.8	1.7	5.2	3.5	1.6	0.01	0.002	10.9
Median	53.4	23.2	33.0	88.3	39.7	0.24	0.05	259.5

Table 2: Activity concentration of ^{226}Ra, ^{232}Th, ^{40}K, radium equivalent activity and radiological hazard indices of the soil of villages surrounding the lignite belt.

Sample code	Activity concentration (Bq kg^{-1})			Ra_{eq}	Absorbed dose rate (nGy h^{-1})	H_{ex}	E_T (mSv y^{-1})	AGDE (μSv y^{-1})
	^{226}Ra	^{232}Th	^{40}K					
VS_1	52.0	68.9	37.4	153.4	67.2	0.4	0.08	460.4
VS_2	51.6	68.3	38.2	152.2	66.7	0.4	0.08	456.9
VS_3	55.7	73.7	46.1	164.6	72.2	0.4	0.09	494.7
VS_4	58.8	77.9	41.3	173.4	75.9	0.5	0.09	520.3
VS_5	57.2	75.8	39.8	168.7	73.9	0.5	0.09	506.1
VS_6	55.1	72.9	39.3	162.4	71.1	0.4	0.09	487.3
VS_7	61.8	81.8	38.8	181.8	79.6	0.5	0.1	545.1
VS_8	58.0	76.9	44.8	171.4	75.1	0.5	0.09	514.7
VS_9	55.5	73.5	41.7	163.8	71.8	0.4	0.09	491.8
VS_{10}	60.0	80.3	39.8	177.9	77.9	0.5	0.1	533.6
Mean	56.6	75.0	40.7	167.0	73.1	0.5	0.09	501.1
Standard deviation	3.3	4.4	2.8	9.7	4.2	0.03	0.005	28.8
Median	56.45	74.8	39.8	1.6	73.0	0.45	0.09	500.3

^{232}Th and ^{40}K with mean activity 52.9 Bq Kg^{-1} in the soil of the lignite belt. The ^{232}Th activity concentration ranges from 18.3 to 23.4 Bq Kg^{-1} with mean activity 22.5 Bq Kg^{-1} which are less than the activity concentration of ^{40}K as reported in the Table 1. The activity concentrations of the soil of the villages surrounding the lignite belt reported in the Table 2 shows higher value compared to the activity concentration of the soil of the lignite belt. The value of ^{226}Ra activity concentration ranges from 51.6 to 61.8 with mean value 56.6 Bq Kg^{-1}. The ^{232}Th and ^{40}K activity concen-

Table 3: The average value of concentrations of the natural radionucleides in soil samples $Bq\,kg^{-1}$ reported for different parts of world.

Country	Mean activity concentration ($Bq\,kg^{-1}$)			Reference
	Ra^{226}	Th^{232}	K^{40}	
Egypt	18.7	24.7	331.0	[18]
Japan	32.4	54.0	794.0	[19]
Taiwan	30.0	44.0	431.0	[19]
Ireland	37.0	26.0	350.0	[19]
Turkey	79.0	62.0	574.0	[20]
Venezuela	27.0	31.0	357.0	[21]
Bangladesh	33.0	16.0	574.0	[22]
Southern Punjab Pakistan	21.7	31.0	393.2	[23]
Indian Punjab	56.74	87.42	143.04	[15]
Lahore Pakistan	25.8	49.2	561.6	[25]
Punjab Province Pakistan	58.23	53.6	564.48	[26]
Indian average	16.0	37	100.0	[15]
World average	50.0	50.0	500.0	[10]
Soil of lignite belt	52.9	22.5	33.0	Present study
Soil of villages surrounding the lignite belt	56.6	75.0	40.7	Present study

tration have the mean values 70.0 and 40.7 $Bq\,Kg^{-1}$. The radionuclide concentrations for the two different classes of soil samples under investigation indicate and envisage the disagreement of geological formation for the area under study. Soils are considered as weathered byproducts of rock types and distribution of radioactive elements is immensely affected by processes like weathering, rainfall of a place and erosion. Soil radioactivity depends mainly on the types of rocks from which the soil originates [16]. For comparison purpose, the activity concentration of ^{226}Ra, ^{232}Th, ^{40}K has been compared with the published data reported by the different nations as is presented in the Table 3, the observed mean values of ^{226}Ra, ^{232}Th are higher than the world average. While as the average values of ^{40}K is well below the world average [10]. The Ra_{eq} activity a relevant quantity for when considering radiation risk to humans is estimated using the Equation (2) for all the soil samples and other radiological hazard indices determined are summarized in the Tables 1 and 2.

The gamma absorbed rate in air at a height of 1 m above the ground due to concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the soil of the lignite belt and soil of the villages surrounding the lignite belt is estimated by the using Equation (3) and are presented in the respective tables. The mean value of absorbed dose rate due to soil of the lignite belt and due soil of the villages surrounding the belt are 39.5 and 73.1 $nGy\,h^{-1}$ respectively. The absorbed rate estimated from soil for the Indian sub-continent is about 69 $nGy\,h^{-1}$ [17] and the world average is 51 $nGy\,h^{-1}$ [10]. In the present study the average absorbed dose rate due soil of the villages surrounding the lignite belt is higher than the global value. The annual effective dose rate ranges from 0.04 to 0.05 $mSv\,y^{-1}$ with mean value of 0.05 $mSv\,y^{-1}$ for the soil of the lignite belt and 0.08 to 0.1 $mSv\,y^{-1}$ with an average value of 0.09 $mSv\,y^{-1}$ for the soil of villages surrounding the lignite belt respectively. The mean value annual effective dose rates for the soil of the villages surrounding the lignite belt are higher than the value 0.07 $mSv\,y^{-1}$ given by UNSCEAR as the world wide representative value. The external hazard index and the annual gonad dose are also presented in the tables for both the types of the samples.

A frequency distribution was ploted to delineate the distribution of radionuclides in the study area and is provided in Figures 1 and 2 for soil of the lignite belt and the soil of villages respectively. The frequency distribution for the absorbed dose rate for both the types of soil is provided in the Figure 3. The activity and absorbed dose rate fitted to normal distribution with an asymmetric curve indicating its dominance in a particular region.

6.2 Correlation studies between the activity concentration and the measured dose rate

In order find the existence of these radioactive nuclides together at a particular place, correlation studies were performed between the ^{226}Ra and ^{232}Th and ^{40}K and ^{232}Th for the soil of the lignite belt and the soil of the villages surrounding the lignite belt as presented in Figures 4–7. A very weak correlation observed between individual activity concentrations of radionuclides for the soil of the lignite belt, which envisages that the individual results for any of radionuclides, is not a good predictor of the concentration of the other. In contrast to this a good correlation was observed for ^{226}Ra and ^{232}Th ($r \approx 1.0$) for the soil of the villages surrounding the lignite belt as shown the Figure 6.

The poor correlation observed between activity concentrations of ^{232}Th and ^{226}Ra in the soil samples of the lignite belt (Figure 4) envisages that the variation in activity concentration of ^{232}Th is not affected by the activity

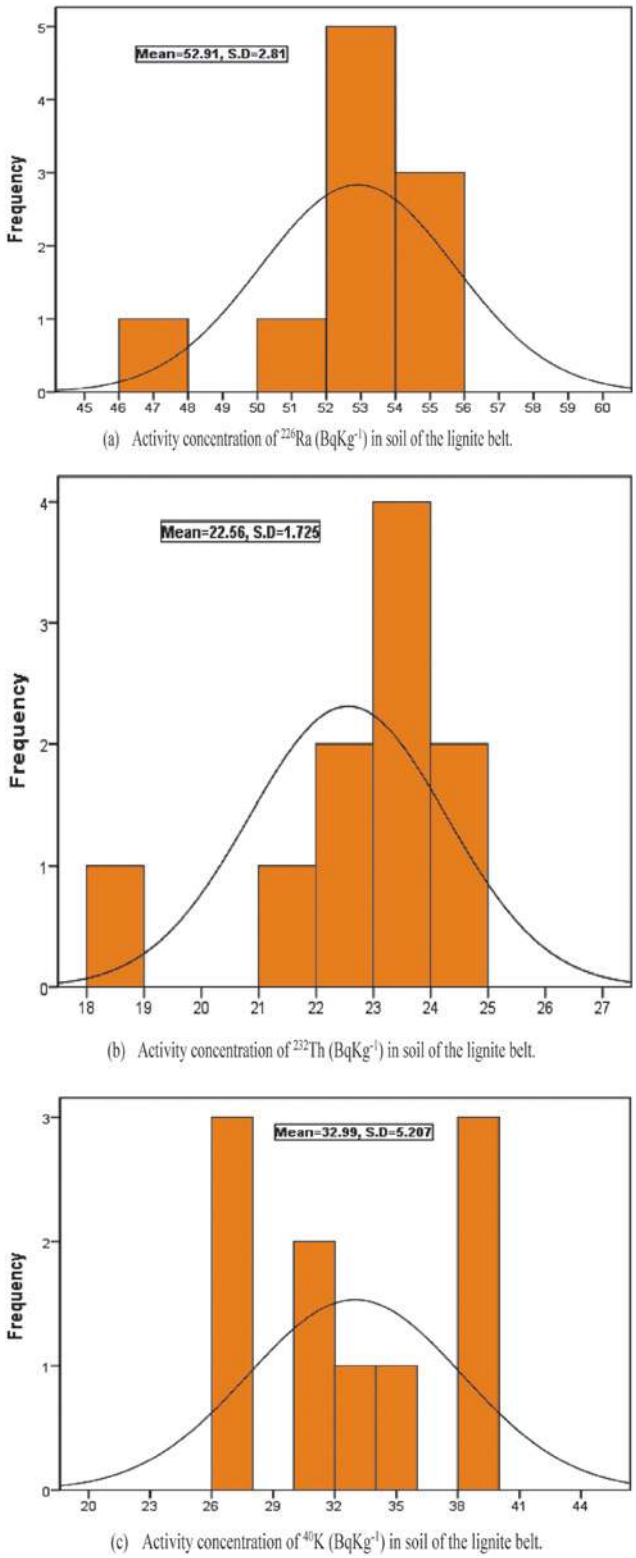


Figure 1: Frequency distribution of the ^{226}Ra, ^{232}Th and ^{40}K concentrations of the soil of lignite belt.

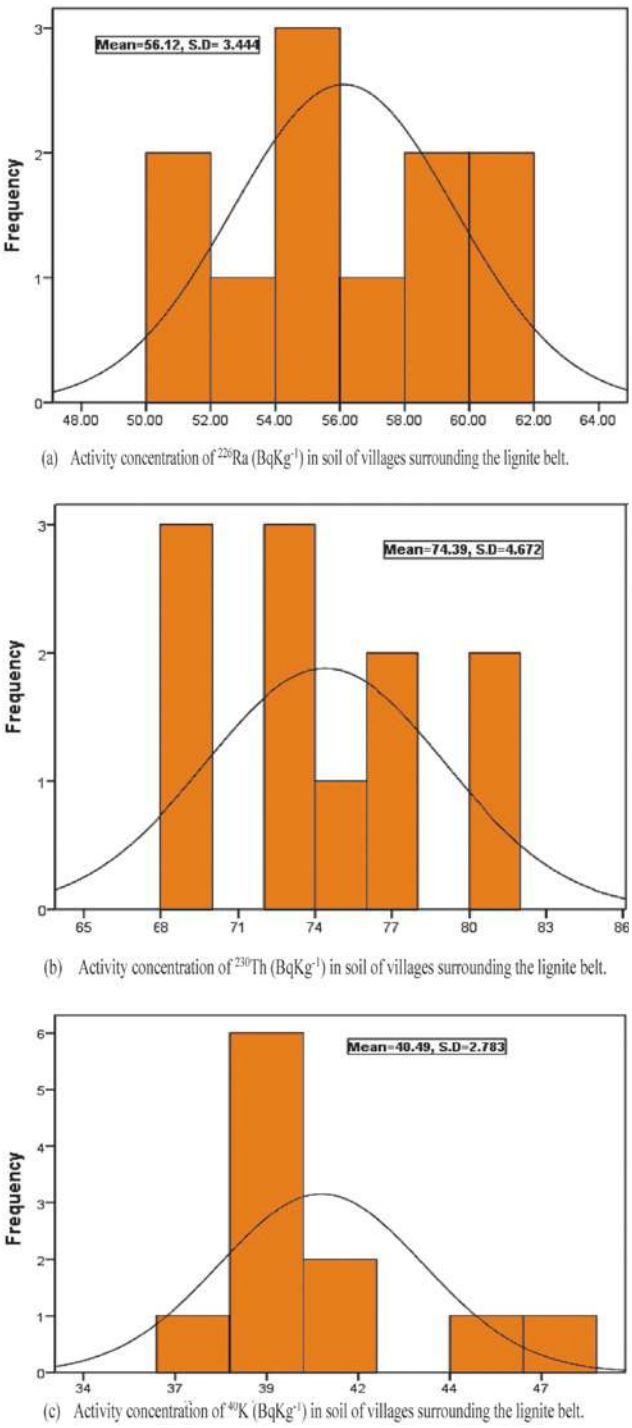
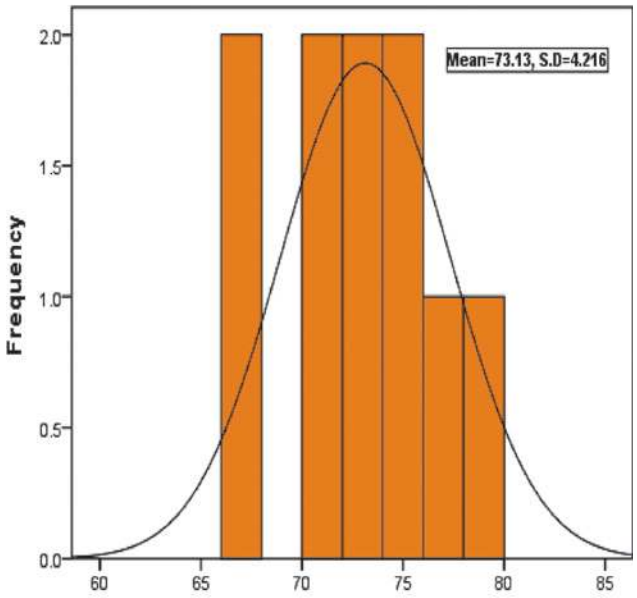
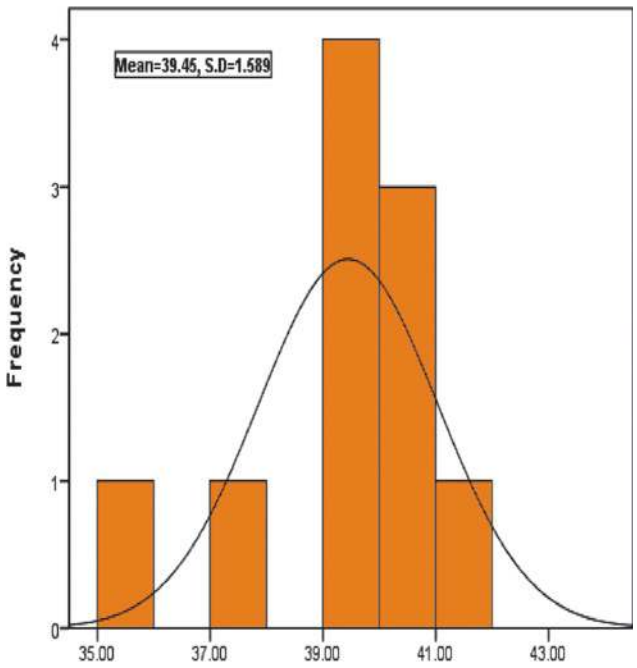


Figure 2: Frequency distribution of the ^{226}Ra, ^{232}Th and ^{40}K concentrations in soil of villages surrounding the lignite belt.

concentration of ^{40}K. The weak correlation observed (Figures 5 and 7) between the activity concentrations of ^{232}Th and ^{40}K in two different classes of the soil samples under investigation rules out the dependence of ^{40}K activity concentrations on activity concentration of ^{232}Th.



(a) Absorbed dose rate (nGyh^{-1}) due to soil of the villages surrounding the lignite belt



(b) Absorbed dose rate (nGyh^{-1}) due to soil of the lignite belt.

Figure 3: Frequency distribution of the absorbed dose.

The correlation for the measured dose rate and the activity concentrations are given in Figures 8–13. There is a good correlation between the ^{226}Ra activity and the measured dose rate and ^{232}Th activity and the measured dose rate ($r \approx 1.0$) for the soil of the villages surrounding the lignite belt as presented in the Figures 11 and 12. A very weak correlation existed between the activities concentrations and measured dose for the soil of the lignite belt.

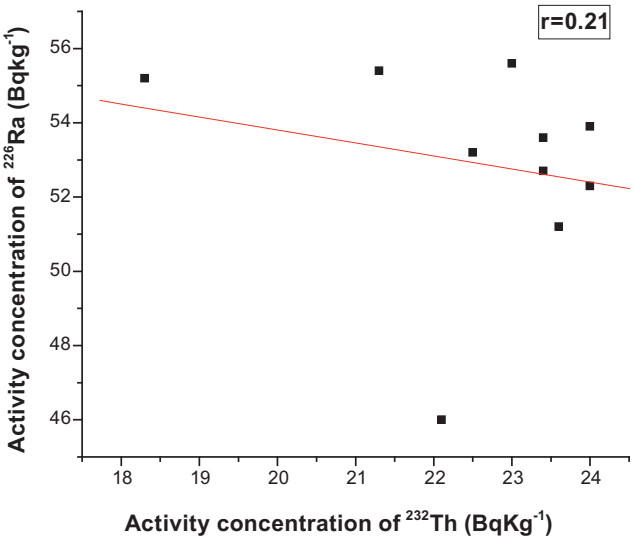


Figure 4: Correlation between activity concentrations of ^{232}Th and ^{226}Ra in soil samples of the lignite belt.

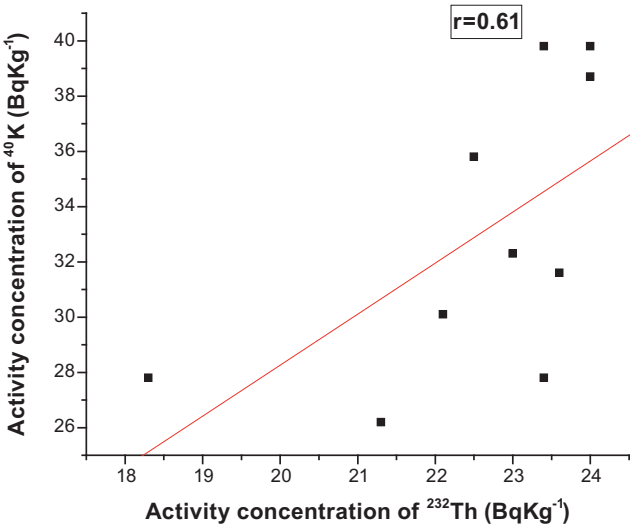


Figure 5: Correlation between activity concentrations of ^{232}Th and ^{40}K in soil samples of the lignite belt.

7 Conclusion

Measurement of activity concentrations of terrestrial radionuclides in the soil of the lignite belt and the soil of the villages surrounding the lignite belt have been carried out to ascertain the variations of activity levels of these radionuclides, to assess the associated radiological health hazards and with an intention that the radiometric analysis will serve as the baseline data for carrying out extensive research in the area under investigation. The results of measurement on activity concentrations of radionuclides and gamma radiation dose rates on comparison with the

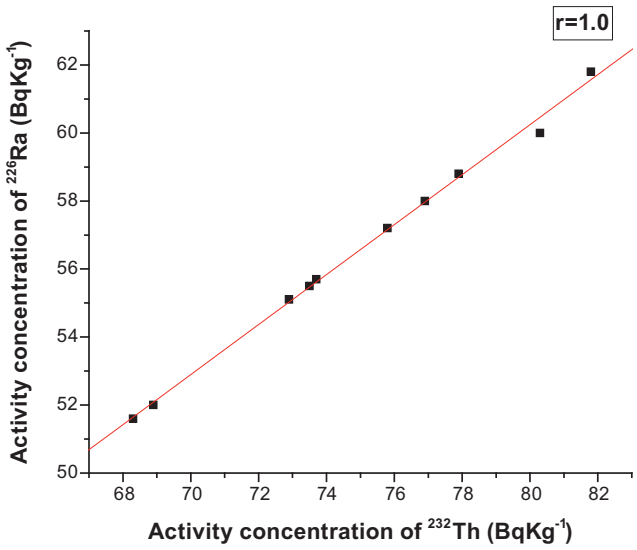


Figure 6: Correlation between activity concentrations of ^{232}Th and ^{226}Ra in soil samples of villages surrounding the lignite belt.

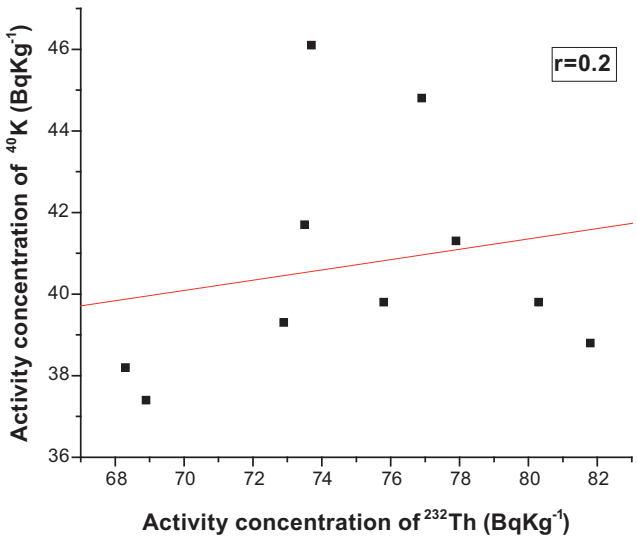


Figure 7: Correlation between activity concentrations of ^{232}Th and ^{40}K in soil samples of villages surrounding the lignite belt.

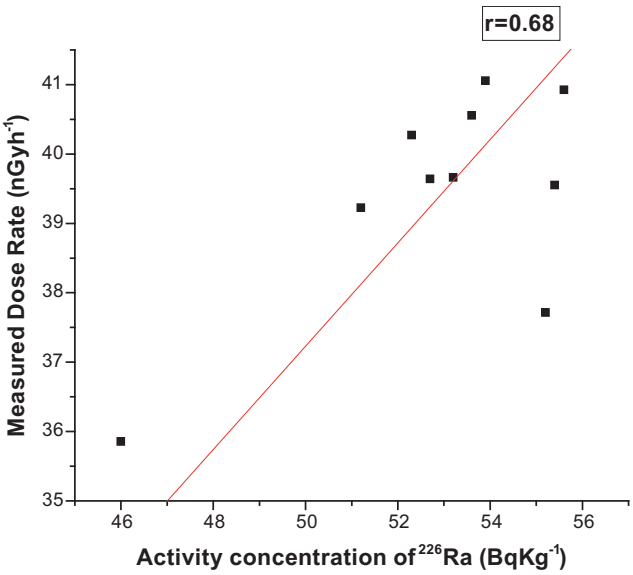


Figure 8: Correlation between the activity concentrations of ^{226}Ra and measured dose rate for soil of the lignite belt.

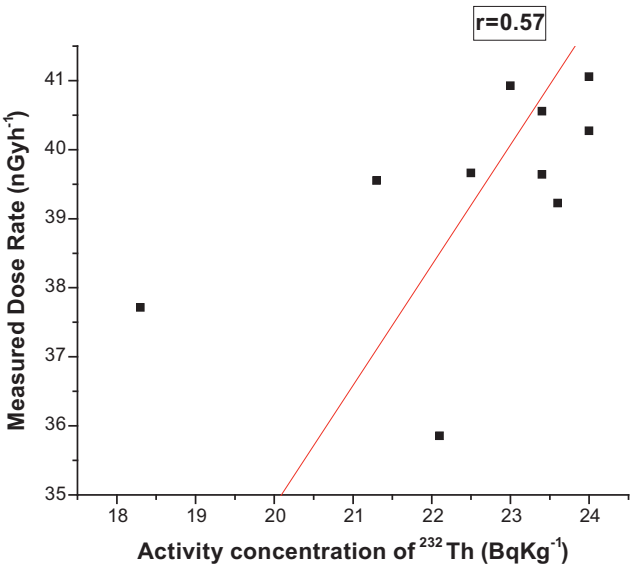


Figure 9: Correlation between the activity concentrations ^{232}Th versus measured dose rate for soil of the lignite belt.

global and the Indian average values show that the activity concentrations of ^{226}Ra are higher than world and Indian average values of 50 and 16 Bq kg^{-1}. Further the activity concentrations of ^{232}Th were found to be higher than the world average of 50 Bq kg^{-1}. Moreover, the gamma ray spectrometric analysis of the soil samples of the lignite belt and soil of the villages surrounding the lignite belt envisage the disagreement of geological formation of soil samples for the area studied. The difference in the specific radionuclide concentrations in the soil may be related to the underlying bed rock types and local geology of the study area. There is a good correlation between ^{226}Ra, ^{232}Th and the measured dose rate in the soil of the villages surrounding the lignite belt. However, the value of the external hazard index and other radiological hazard indices determined in the two different classes of soil under investigation is less than the recommended value of unity.

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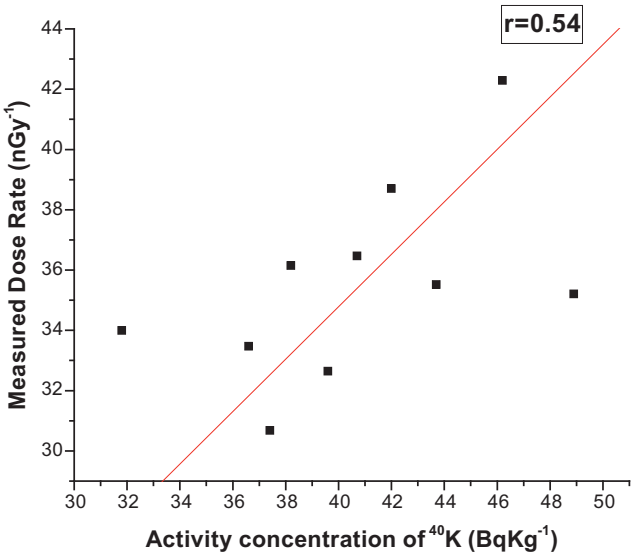

Figure 10: Correlation between the activity concentrations ^{40}K and measured dose rate for soil of the lignite belt.

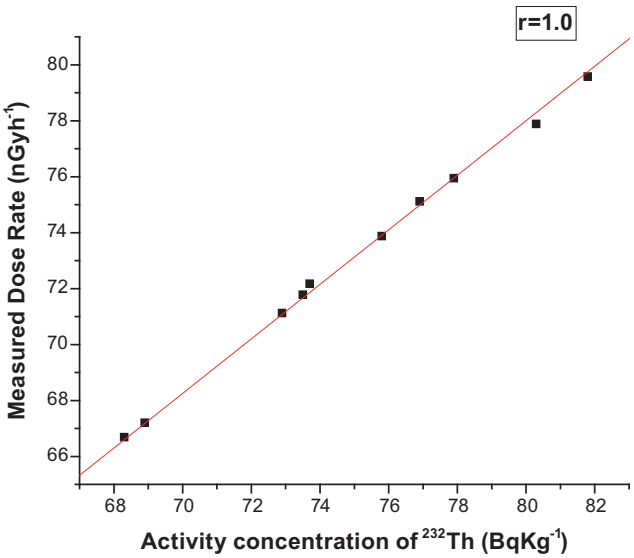

Figure 12: Correlation between the activity concentrations ^{232}Th and measured dose rate for soil of the villages surrounding lignite belt.

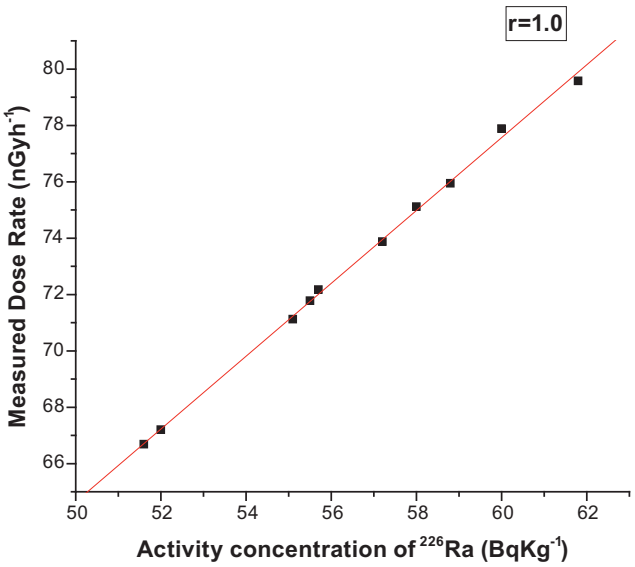

Figure 11: Correlation between the activity concentrations ^{226}Ra and measured dose rate for soil of the villages surrounding lignite belt.

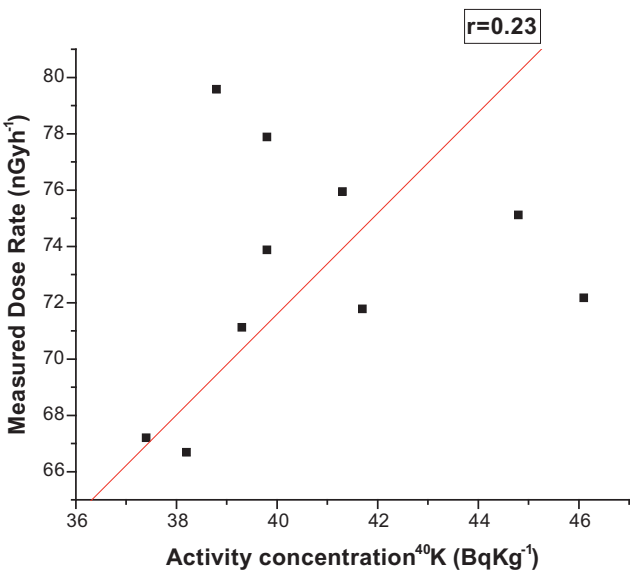

Figure 13: Correlation between the activity concentrations ^{40}K and measured dose rate for soil of the villages surrounding lignite.

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