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Estimation of Natural Radionuclides in the Soil Samples from the Multivariety Belt Comprising of SAS Nagar, Rupnagar and Nawanshahr Districts of Punjab, India

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Abstract: Gamma ray spectrometry is efficient, convenient and cost effective means of estimation of radionuclides in the soil. The radioactivity concentration for naturally occurring ^{226}Ra, ^{232}Th and ^{40}K has been measured for Sahibzada Ajit Singh (SAS) Nagar, Rupnagar and Nawanshahr (SBS Nagar) districts of Punjab using Gamma ray spectroscopy. The variation in activity concentration for naturally occurring ^{226}Ra, ^{232}Th, and ^{40}K is from 20±5 Bq kg^{-1} to 49±6 Bq kg^{-1},23±6Bq kg^{-1} to 61±8Bq kg^{-1} and 292±27 Bq kg^{-1} to 627±18 Bq kg^{-1} with average values of 33±6Bqkg^{-1}, 39±7 Bq kg^{-1} and 399.7±16 Bq kg^{-1} respectively. After the analysis of these samples, radium equivalent activity is calculated to assess the radiation hazards which ranges between 92 Bq kg^{-1} to 163 Bq kg^{-1} with an average value of 117 Bq kg^{-1} which is lower than the safe limit of 370 Bq kg^{-1}. The absorbed dose ranges from 9 nGyh^{-1} to 23 nGyh^{-1}, 14 nGyh^{-1}to 38 nGyh^{-1} and 12 nGyh^{-1} to 26 nGyh^{-1} for ^{226}Ra, ^{232}Th, and ^{40}K respectively. The total absorbed dose in these districts of Punjab varies from 43 nGyh^{-1} to 79 nGyh^{-1}. The variation of hazard indices for outdoor and indoor is from 0.25 to 0.45 and 0.31 to 0.54 for H_{ex} and H_{in} respectively. As the radiation indices is less than 1, so the soil of studied area may not pose any health hazard to the residents of the area.

Keywords: Gamma ray spectrometry, Ra_{eq}activity, Annual effective doses, Internal and External Hazard Indices.

1 Introduction

Today the attention of the world is focused on the nuclear radiations because of their serious ill-effects which prolong for decades, and centuries. If some piece of land gets contaminated then such contaminations may lead to chain reactions. This results into contamination of water and crops which directly affect their consumers. Since nuclear radiations can occur at far off places from the point of leakage so continuous monitoring and checks are essential on such contamination. As such risk due to genetic defects and cancer etc cannot be under estimated [1]. Some nuclear elements may deposit in the bones and remain there for very long period leading to tumors. It is therefore very important to understand the ways in which different echo systems are affected by nuclear contaminations. The multivariety belt of Sahibzada Ajit Singh Nagar, Rupnagar and Nawanshahr, comprises of thermal plant, polluting industries and commercial units liable to contribute to radioactivity. Earlier meagre work on radioactivity has been done in this area.

These factors have motivated the selection of this area for this research. Main objective of this study is to estimate the level of natural radionuclides in the soil samples of this area.

1.1 Geography of the Selected Area

SAS Nagar is situated in Punjab between the North latitude 30.69º and East longitude 76.72º. It is mostly plain of alluvial type. The major soil is solonized tropical arid brown having saltpeter. Many large and small scale industrial units have been setup around Kurali and Derabassi towns of this district. Soil of Derabassi block is sandy and sandyloam. Zirakpur town of this district is developing very fast and number of commercial units are coming up there. People from adjoining areas are also populating this district because of its nearness to Chandigarh. Main species of plants in district are Eucalyptus, Shisham, Kikar and Poplar. District has about 60 large industrial units comprising of chemicals, textile, pharmaceutical, paper, steel, autoparts, semi-conductors, bottling plants, tools etc.

Nawanshahr district is located between North latitude 31º07′ and East longitude 76º08′ on the right bank of river Satluj. It falls in hot subhumid dry ecoregion. 40% of total land is fine loamy and the rest is coarse. 10% of area is

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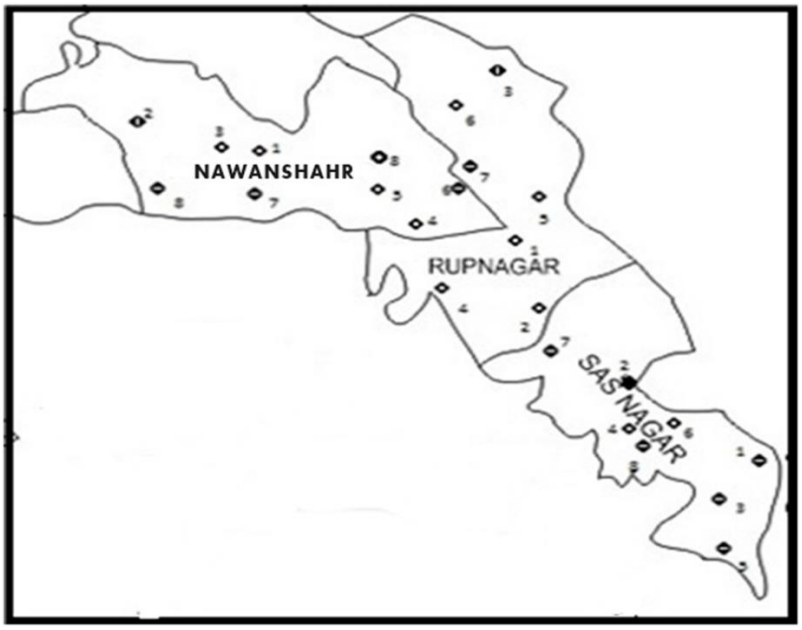

Figure 1. Nawanshahr, Rupnagar and SAS Nagar Districts of Punjab

canal irrigated. Major soil type is tropical arid brown and weakly solonized. Rupnagar district is located between North latitude 30º32′ and East longitude 76º18′.It is situated on a high ancient mound overlayed by Shivalik. Sutluj River passes close to Nangal, Rupnagar and Anandpur Sahib Towns of the district. Soil texture of the district is sandy area. Soil is generally sodic and undulating. This district has a thermal plant near Ghanuli having total generating capacity of 1260 MW using coal from more than 50 sources.

2 Experimental Section

2.1 Sample Collection

The soil samples were obtained from various locations of SAS Nagar, Rupnagar and Nawanshahr districts of Punjab at random to measure the activity of ^{226}Ra, ^{232}Th and ^{40}K .

The samples were dug from more than 75cm from the surface of ground to get the natural soil. The organic material, small stones and other unwanted materials present in the soil samples were taken out from sample by hand. Soil samples thus obtained were compressed into fine dust. Samples were then dried in an oven and were passed through a fine sieve. To get radioactive equilibrium, each dried sample was sealed in an airtight plastic box and kept separated for about 28 days so as to ensure radioactive equilibrium.

2.2 Methodology

Gamma ray spectrometer was used to measure the activity concentration of natural radionuclides in soil samples. These samples were kept in a protected gamma ray spectrometer for about 3 hours to have error free results. The measurement of ^{226} Ra, ^{232}Th and ^{40}K in these samples was carried out by using Nal(TI) Gamma Radiation Detector having dimensions 63 mm x 63 mm with a multichannel analyzer.

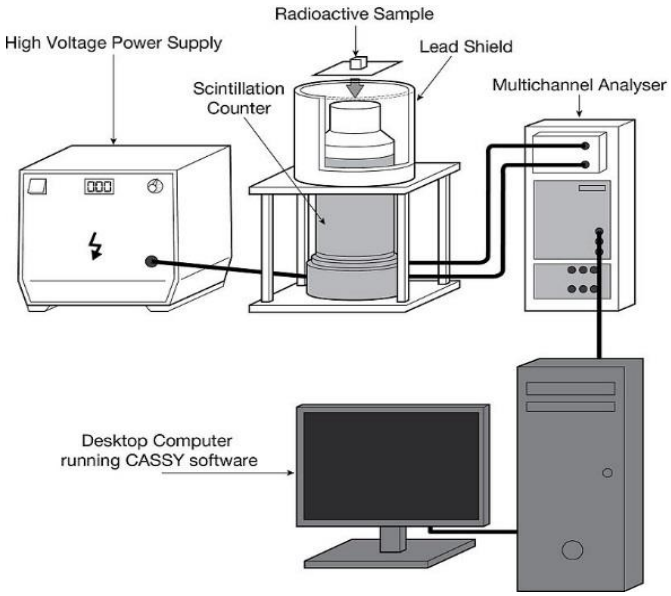

Figure 2. Experimental Setup

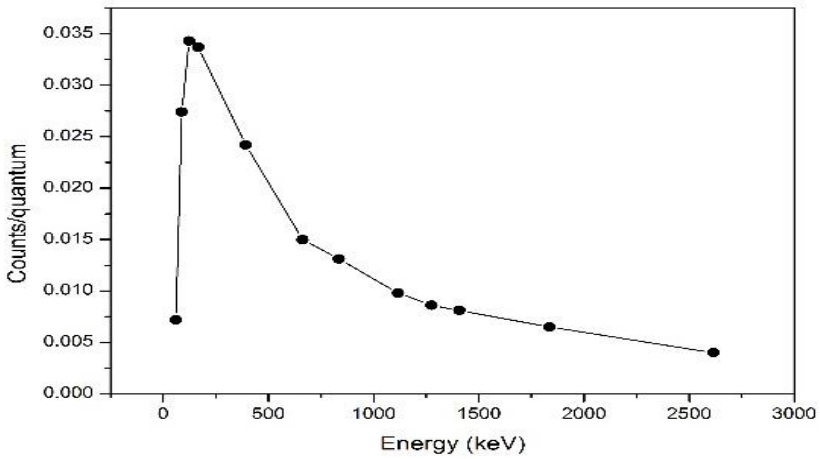

Figure 3. Counts per quantum

Table 1. Concentration of Th, K and Ra Equivalent Activity in soil samples

Place of Sample	Ra concentration C_{Ra}(Bqkg^{-1})	Th concentration C_{Th} (Bqkg^{-1})	K concentration C_k (Bqkg^{-1})	Ra Equivalent activity Ra_{eq} (Bqkg^{-1})
SAS Nagar distt.				
1. Zirakpur	24 ± 7	32 ± 10	312 ± 33	92
2. Mohali	32 ± 5	61 ± 8	625 ± 25	163
3. Dera Bassi	24 ± 6	38 ± 7	627 ± 18	122
4. Landran	20 ± 5	40 ± 8	296 ± 22	98
5. Lalru	22 ± 4	44 ± 8	408 ± 26	113
6. Kharar	32 ± 4	31 ± 10	358 ± 31	101
7. Sukhgar	20 ± 5	40 ± 10	373 ± 29	103
8. Banur	25 ± 5	35 ± 8	352 ± 21	101
Rupnagar distt.				
1. Ghanauli	38 ± 9	37 ± 8	364 ± 20	116
2. Rupnagar	36 ± 10	35 ± 5	345 ± 22	110
3. Anandpur Sahib	34 ± 7	44 ± 8	321 ± 26	119
4. Khurali	32 ± 5	42 ± 4	332 ± 26	115
5. Pojewal	44 ± 7	37 ± 7	325 ± 25	120
6. Nurpur	36 ± 6	33 ± 7	432 ± 32	113
7. Chamkaur	37 ± 7	38 ± 6.5	519 ± 27	134
Nawanshahr distt.				
1. Nawanshehar	40 ± 9	32 ± 7	314 ± 33	108
2. Banga	38 ± 8	49 ± 7	292 ± 27	129
3. Kriha	36 ± 8	47 ± 5	302 ± 29	124
4. Asro	49 ± 6	41 ± 7	325 ± 17	130
5. Jadala	36 ± 8	43 ± 8	498 ± 31	132
6. Balachaur	46 ± 4	38 ± 6	501 ± 22	135
7. Rahan	38 ± 7	23 ± 6	507 ± 19	99
8. Suhana	33 ± 6	49 ± 6	489 ± 23	132

The above data is used to plot the graphs for ready reference. The same are displayed as under

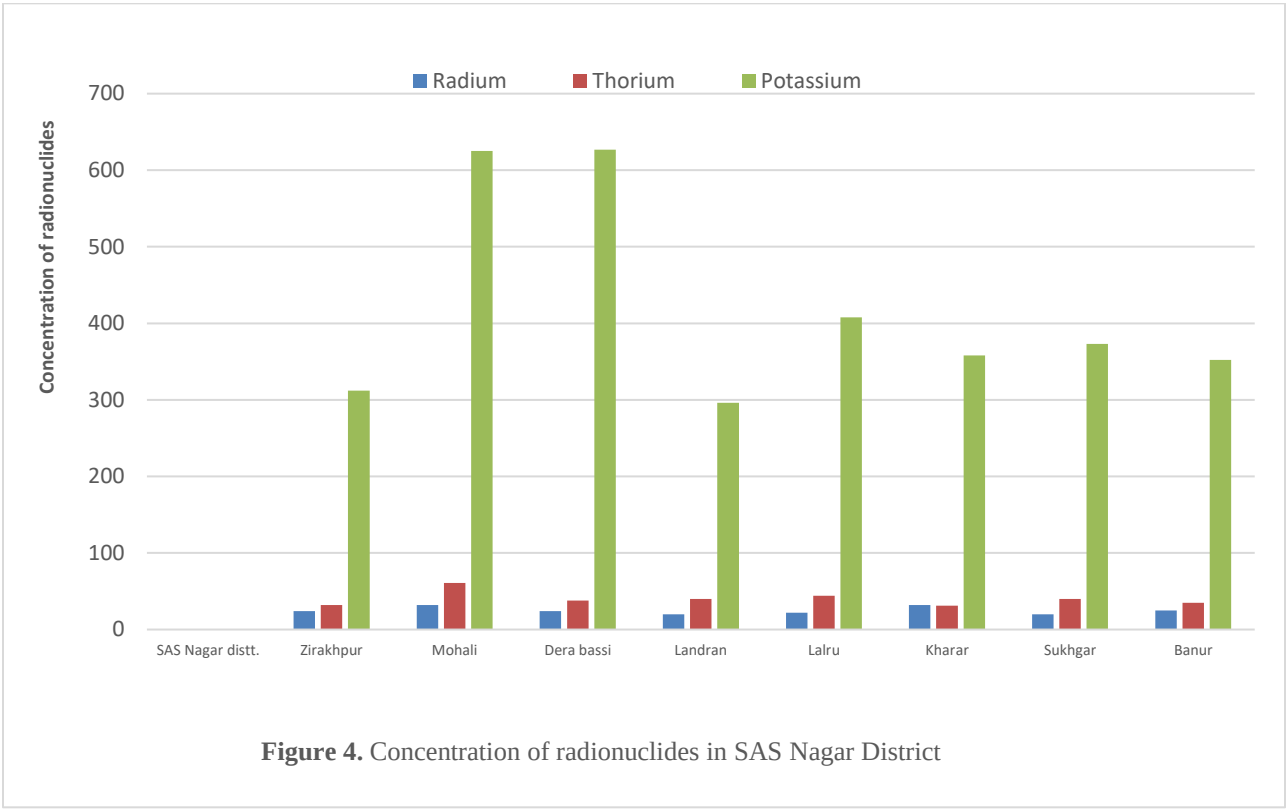

Figure 4. Concentration of radionuclides in SAS Nagar District

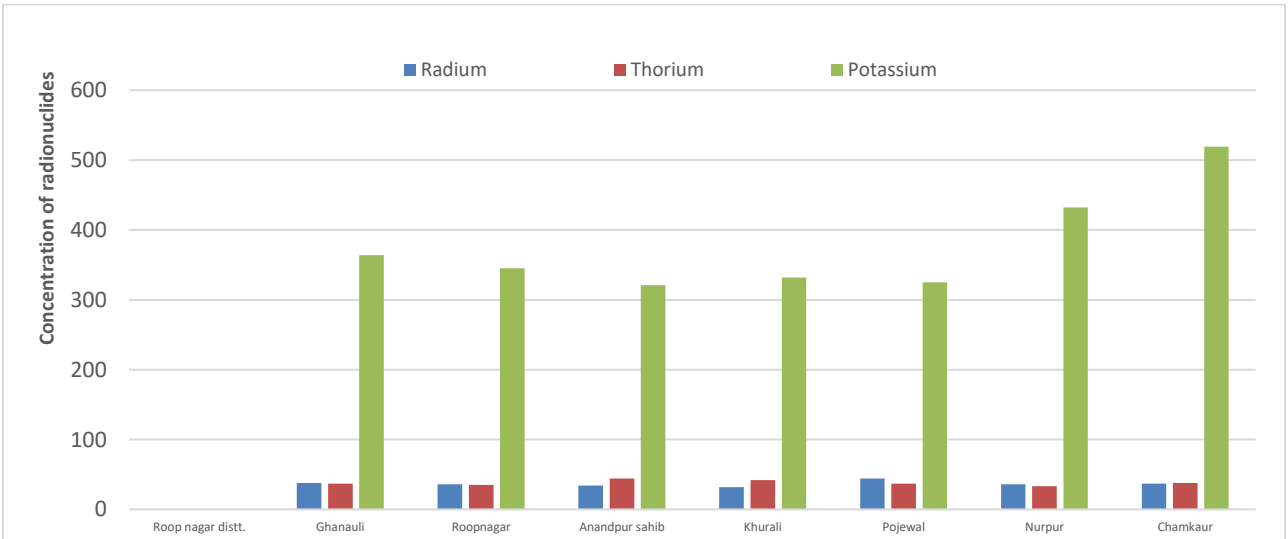

Figure 5. Concentration of radionuclides in Rupnagar District

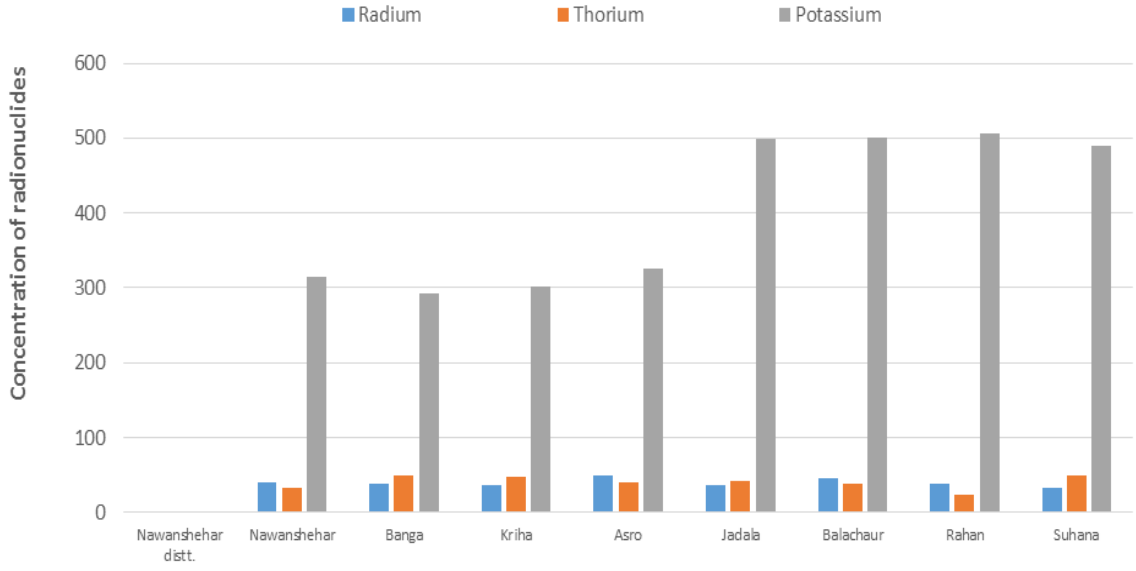

Figure 6. Concentration of radionuclides in Nawanshahr District

The activity of ^{226} Ra was determined from the 1764 keV gamma line of ^{214} Bi, the activity of ^{232}Th from the 2610 keV gamma line of ^{208} TI and that of ^{40} K from 1461 keV photo maximum. This spectral analysis was done with the help of software SPTR-ATC (AT-1315).

The energy and efficiency calibration of the gamma spectrometer was done as per reference standard source material. The efficiency calibration curve for the NaI (Tl) detector was obtained from the efficiency calculated for ^{40}K, ^{238}U and ^{232}Th.

The activity of the samples was worked out using the net area under the photo maxima using equation.

$$\text{Ac} = \frac{Cn}{P\gamma\, M\varepsilon} \quad (1)$$

Where Ac is the activity concentration of the radionuclide Cn is the net count rate under the corresponding peak, $P\gamma$ is the absolute transition probability of the specific γ-ray, M is the mass of the sample (kg) and ε is the detector efficiency at the specific γ-ray energy [3].

Concentrations were found out from the intensity of the spectrum keeping the mass, the dimensions of the samples, the counting time and detector efficiency in view.

Since natural radionuclides ^{226} Ra, ^{232}Th and ^{40} K are non-uniformly distributed in soil so the concentration of ^{226} Ra, ^{232}Th and ^{40} K is considered as per of Radium Equivalent Activity Ra_{eq} in Bqkg^{-1}. It is assumed that 370Bqkg^{-1} of ^{226}Ra or 259 Bqkg^{-1} of ^{232}Th or 4810 Bqkg^{-1} of ^{40}K produce the same dose rate. For calculating Radium equivalent activity the following relation is used.

$$\text{Ra}_{\text{eq}} = C_{Ra} + 1.43C_{Th} + 0.07C_k \quad (2)$$

WhereC_{Ra}, C_{Th} and C_k are activity concentrations of ^{226}Ra, ^{226}Th and ^{40}K in Bqkg^{-1} respectively [4].

For calculating air-absorbed dose rate the following relation is used for uniform distribution of ^{226}Ra, ^{226}Th and ^{40}K at a height of 1 m above the surface of ground using conversion factors as indicated below.

$$\text{D}\left(\frac{\text{nGy}}{\text{h}}\right) = 0.461C_{Ra} + 0.623C_{Th} + 0.0414C_k \quad (3)$$

WhereC_{Ra}, C_{Th} and C_k are activity concentrations of Radium, Thorium and Potassium respectively in the sample [5]. The absorbed dose rate in air per unit activity concentration is calculated in Bqkg^{-1}.

For calculating of **annual effective dose rate** the following relations are used by using conversion factors with indoor occupancy of 80% and outdoor occupancy of 20% [6].

Indoor (mSv) = *(Absorbed Dose) nGyh^{-1} x 8760 x 0.8x0.7 Sv/Gy x10^{-6}* (4)

Outdoor (mSv) = *(Absorbed Dose) nGyh^{-1} x 8760 x 0.2x0.7 Sv/Gy x10^{-6}* (5)

For calculating **external and internal hazard index** (Hex and Hin) for the local soil used in the construction of the houses contributing gamma dose rate following relations are used.

Table 2. Results of Absorbed Dose, Annual Effective Dose and Hazard Indices

Place of Sample	Absorbed dose ($nGyh^{-1}$)				Annual effective dose (mSv)		Hazard indices	
	^{226}Ra	^{232}Th	^{40}K	Total	indoor	outdoor	Hex	Hin
SAS Nagar distt.								
1.Zirakpur	11	20	12	43	0.21	0.05	0.25	0.31
2.Mohali	15	38	26	79	0.38	0.09	0.45	0.54
3.Dera bassi	11	24	26	61	0.29	0.07	0.34	0.4
4.Landran	9	25	12	46	0.22	0.05	0.27	0.32
5.Lalru	10	27	17	54	0.26	0.06	0.31	0.37
6.Kharar	15	19	15	49	0.24	0.06	0.28	0.36
7.Sukhgar	9	25	15	49	0.24	0.06	0.28	0.34
8.Banur	12	22	15	49	0.24	0.06	0.27	0.34
Rupnagar distt.								
1.Ghanauli	18	23	15	56	0.27	0.06	0.32	0.42
2.Rupnagar	17	22	14	53	0.25	0.06	0.3	0.4
3.Anandpur sahib	16	27	13	56	0.27	0.06	0.32	0.42
4.Khurali	15	26	14	55	0.26	0.06	0.31	0.4
5.Pojewal	20	23	13	56	0.26	0.06	0.32	0.44
6.Nurpur	17	20	18	55	0.26	0.06	0.31	0.41
7.Chamkaur	19	25	22	66	0.32	0.08	0.37	0.47
Nawanshahr distt.								
1.Nawanshahr	19	20	13	52	0.25	0.06	0.29	0.4
2.Banga	18	31	12	61	0.29	0.07	0.35	0.45
3.Kriha	17	29	12	58	0.28	0.07	0.34	0.43
4.Asro	23	26	13	62	0.3	0.07	0.35	0.49
5.Jadala	17	27	21	65	0.31	0.07	0.36	0.46
6.Balachaur	21	24	21	66	0.32	0.08	0.37	0.49
7.Rahan	14	14	21	49	0.24	0.06	0.27	0.36
8.Suhana	13	31	20	64	0.31	0.07	0.36	0.44

$$\text{Hex} = C_{Ra}/370 + C_{Th}/259 + C_k/4810 \quad (6)$$

$$\text{Hin} = C_{Ra}/185 + C_{Th}/259 + C_k/4810 \quad (7)$$

WhereC_{Ra}, C_{Th} and C_k are activity concentrations of ^{226} Ra, ^{232}Th and ^{40}K in Bq kg $^{-1}$ respectively [7] & [8].

The maximum value of external hazard index H_{ex} should be equal to unity and safe value of internal hazard index H_{in} should be less than unity for safe use of soil.

The radioactivity concentration for naturally occurring ^{226}Ra, ^{232}Th, and ^{40}K, has been measured for the soil samples obtained from SAS Nagar, Rupnagar and Nawanshahr districts of Punjab with the help of Gamma Ray Spectrometer. Results of Radium, Thorium and Potassium concentration in soil as well as Radium Equivalent activity are shown in Table -1.

The results of Absorbed Doses, Annual Effective Dose and Hazard Indices in the case of collected soil samples are shown in Table – 2.

3 Results and Discussion

Table -I shows the measured values of the natural radioactivity concentration in soil of ^{226}Ra, ^{232}Th and ^{40}K in different locations of SAS Nagar, Rupnagar and Nawanshahr districts of Punjab. Last column of Table–I shows radium equivalent activity calculated

From these measured values. It is observed that activity of ^{226}Ra, ^{232}Th and ^{40}K varies from 20±5 $Bqkg^{-1}$ to 49±6 $Bqkg^{-1}$, 23±6 $Bqkg^{-1}$ to 61±8 $Bqkg^{-1}$and 292±27 $Bqkg^{-1}$to 627±18 $Bqkg^{-1}$ respectively with mean values of 33±6 $Bqkg^{-1}$,39±7 $Bqkg^{-1}$and 399.7±16 $Bqkg^{-1}$for naturally occurring ^{226}Ra, ^{232}Th and ^{40}K respectively.

Bar graphs showing the activity of ^{226}Ra, ^{232}Th and ^{40}K and radium equivalent are drawn for SAS Nagar, Rupnagar and Nawanshahr districts (figure 4, 5 and 6 respectively).

The worldwide average activity concentration of ^{226}Ra, ^{232}Th and ^{40}K reported by UNSCEAR are 35 $Bqkg^{-1}$,30 $Bqkg^{-1}$and 400 $Bqkg^{-1}$ respectively [5]. Activity concentration of ^{226}Ra is slightly less than worldwide average activity concentration. Average activity concentration for^{232}Th is slightly higher than worldwide average activity concentration which may be because of presence of thermal plants and polluting industries in the study area. Average activity concentration for ^{40}K in the study area is same as given by worldwide average activity concentration.

Table 3 gives the comparison of activity of^{226}Ra, ^{232}Th and ^{40}K from various places in northern India.

From Table 3, it is observed that,

- ^{226}Ra concentration in the present location is at par with that of Malwa region of Punjab, Faridkot & Mansa as well as Sirsa district of Haryana where as value is much lower for Marwar region of Rajasthan and much higher for Uttrakhand, Rajasthan, & some areas of Punjab and Himachal Pradesh .
- ^{232}Th concentration is lower than other locations.

- ^{40}K concentration is higher than concentration found for Malwa region of Punjab, Rajasthan, Faridkot , Mansa, & some areas of Punjab, Himachal Pradesh and Sirsa districts of Haryana, Himachal Pradesh where as it is lower than that found in Uttrakhand and Marwar regions of Rajasthan.

The variation of Radium equivalent activity calculated from standard formula is from 92 $Bqkg^{-1}$ to 163 $Bqkg^{-1}$with an average value of 117 $Bqkg^{-1}$ which is lower than the safe limit 370 $Bqkg^{-1}$recommended by the OECD [16]. The absorbed mean rate got from standard formula is given in Table 3.

The absorbed dose rate ranges from 9 $nGyh^{-1}$to 23 $nGyh^{-1}$, 14 $nGyh^{-1}$to 38 $nGyh^{-1}$and 12 $nGyh^{-1}$to 26 $nGyh^{-1}$for ^{226}Ra, ^{232}Th and ^{40}K respectively. The total absorbed dose in these districts of Punjab varies from 43 $nGyh^{-1}$to 79 $nGyh^{-1}$which is lower than the International and Indian mean values of 86 $nGyh^{-1}$ and 90 $nGyh^{-1}$respectively as reported by UNSCEAR [5].

The yearly effective indoor as well as outdoor gamma dose rates worked out in the districts of Punjab range from 0.21 mSv to 0.38 mSv and 0.05 mSv to 0.09 mSv respectively which is much less than worldwide average annual effective dose rate which is approximately 0.5 mSv.

4 Conclusions

To assess outer and internal radiation exposure health hazard indices were calculated from measured activity concentration of ^{226}Ra, ^{232}Th and ^{40}K. The variation of hazard indices of outdoor and indoor is from 0.25 to 0.45 and 0.31 to 0.54 for H_{ex} and H_{in} respectively. As figures are less than 1, so as per radiation protection 112 of European commission [17], it is arrived at that soil from these areas can be safely used for the construction purposes without any radiological risk to the inhabitants.

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