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Measurement of Natural Radioactivity due to ^{226}Ra, ^{232}Th and ^{40}K in Soil at Chandpur District, Bangladesh

Research Article

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Abstract: Ffifteen soil samples, collected from Chandpur district, Bangladesh, have been studied and radioactivity of ^{226}Ra, ^{232}Th and ^{40}K were identified. Gamma-ray spectrometry system was employed to perform the measurements. With the help of a high purity germanium (HPGe) detector, the average radioactivities of ^{226}Ra, ^{232}Th and ^{40}K in the collected soil samples have been calculated respectively 24.81±0.040408 Bq/kg, 18.97±0.03769 Bq/kg and 398.82±0.3534962 Bq/kg.

Keywords: *Activity concentration of soil • Health hazards in Chandpur district*

I. Introduction

Radiations are omnipresent in the environment since the big bang occurred. We the people and our foods are always exposed to different types of natural radiation which can be originated from diverse sources, like cosmic, terrestrial and natural decay series of radioactive nuclides (Dinh et al., 2011). A most important source for natural radioactivity is soil and considered as one of the main source for radiation-hazard interritory. So soil's natural-radioactivity is well-thought-out as a basic indicator for radiological contamination (Rahman and Faheem, 2008). Some vital primeval radionuclides are of 238U-series (half-life, t1/2 = 4.47 × 109 yrs), 232 Th-series (t1/2 = 1.41 × 109 yrs) and 40K (t1/2 = 1.28 × 109 yrs) (UNSCEAR, 1993). ^{232}Th is the first elemental isotope of thorium with copiousness of 100% on earth. ^{40}K can be found in human, animal, soil and in the oceans with different concentrations. The copiousness of ^{40}Kon earth is around 0.012 % (Environmental Science Division, 2010).

The objective of this work is to find out the radiation level of environment in Chandpur district. Measurements of the radioactivity of the radionuclides in soils, waters, plants and air of a region can help to determine the radioactivity level. Therefore, analysis of soil has a great significance. Choosing the Chandpur district has some explicit reasons. It is a quite important district in our country. It is situated at the meeting point of three big rivers (Dakatia, Meghna and Gomoti) of the country. A huge number of national fish Hilsha was found in the rivers of this district. So, if the radioactivity of this area's soil exceed the hazardous limit (suggested by the NSRC (nuclear safety and radiation control) Rules -1997, Bangladesh), then not only the large population of this district will be in danger but also whole country will be at high health risk as vegetables, foods that are grown inside this district are frequently transported to other parts of the country.

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2. Experiment

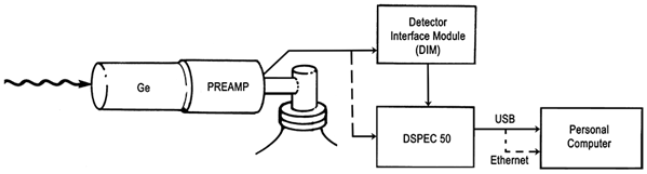

Figure 1. Block diagram of gamma spectroscopy system (HPGe detector)

In this study, spectral analysis of the fifteen soil samples has been performed in Atomic Energy Centre Dhaka (AECD) using a gamma spectrometer equipped with high purity germanium detector (HPGe). The equipment engaged in this gamma-ray spectrometry (UNSCEAR Annex, 2000a) include an energy-sensitive radiation detector named high purity germanium detector (HPGe), high voltage power supplier, multichannel analyzer, amplifiers and computer. The quantitative study of the energy spectra of gamma-ray sources is done by means of Gamma-ray spectroscopy. Some familiar sources of gamma ray are nuclear laboratory and nuclear process and other radiation measurement contexts. Most of the radioactive sources emit gamma rays with different characteristics such as energy and intensity. When gamma emissions are analyzed with a gamma-ray spectrometer, gamma energy spectra are produced. Figure 1 gives the block diagram of gamma spectroscopy whereas Figure 2 gives the pictorial view of experimental set up.

Figure 2. Photograph of laboratory setup for radioactivity measurement.

2.1 Sample Collection

All the samples were collected from Hajigonj upazilla of Chandpur district. Fifteen soil samples from different area were collected. Samples were marked by Global Positioning System (GPS) for each respective locationsTable.1 gives the positioning information of the soil samples which can be used for referencing.. Samples were then numbered and taken into the laboratory for dealing out.

2.2 Preparation of Soil Samples

If sample preparation is not done appropriately then it can be a big source of inaccuracies which must implies defect in the scientific results. Therefore deep care was taken for every sample to avoid impurity. All the samples were collected during the month of August in 2019. The collected soil samples were first dried in air for 2-3 days as august is a month of monsoon. Dried soil samples were heated up by an electric oven at 110^{o}C for twenty four hours and placed inside an electric furnace thereafter at 350 ^{o}C for 48 hours. This process transform the leftover plants to ash. All the samples were then pressed through a mesh of 2 mm in size to obtain a homogenous sample matrix (IAEA, 1989). An electronic balance was used to weigh the samples. Lastly each samples were sealed in different plastic containers for a month before gamma spectrometry.

Table 1: GPS location of the source of soil sample.

Sl	Name of locality	Sample ID	Lattitude	Longitude
01.	Badda	Soil-01	23.277847N	90.861704E
02.	Badamtali	Soil-02	23.281506N	90.873024E
03.	Bawra	Soil-03	23.285112N	90.869212E
04.	Nischintopur	Soil-04	23.285072N	90.857163E
05.	Suhilpur	Soilpur-05	23.291765N	90.834013E
06.	Kalocho	Soil-06	23.299565N	90.895421E
07.	Belghar	Soil-07	23.281841N	90.873281E
08.	Nowapara	Soil-08	23.282527N	90.873950E
09.	Sihircho	Soil-09	23.289654N	90.845655E
10.	Sarashia	Soil-10	23.281498N	90.862905E
11.	Kazirgaw	Soil-11	23.277956N	90.859744E
12.	Goureshor	Soil-12	23.312152N	90.894562E
13.	Khakbaria	Soil-13	23.275898N	90.835636E
14.	Dhadda	Soil-14	23.301256N	90.856425E
15.	Matain	Soil-15	23.265782N	90.845326E

Figure 3. Collection of samples from study area.

Figure 4. Sample prepared for measurement

2.3 Activity Calculation

Each samples were put on top of the HPGe detector and counted for 10,000 seconds. The software of the HPGe detecting system provides the respective gamma spectra for each samples. By subtracting a linear background distribution for a pulse spectra from corresponding peak energy area, net amount of the sample were obtained. Using the following equation the net counts activity of the each samples has been calculated

$$A = \frac{CPS}{E \times P\gamma \times w} \quad (2.1)$$

Where, A= activity of the soil sample in Bq/Kg, Counts per second (CPS), E stands for gamma energy counting efficiency, Pγ is the absolute gamma ray intensity and w = net weight of sample in gm.

2.4 Equivalent Activity of Radium

The distribution of ^{226}Ra, ^{232}Th and ^{40}K are not homogeneous in every location of soil. The reason of this inhomogeneous distribution is disequilibrium between 226Ra and its decay products. For uniformity in exposure, the radionuclide concentrations are defined in terms of 'Radium equivalent activity' (Raeq) in Bq/kg. According to Beretka and Mathew (Beretka and Mathew, 1985) equivalent activity of Radium (Raeq) is the specific activity of materials comprising of different amounts of 226-Ra, 232-Th and 40-K,were calculated here with the help of equation 2.2:

$$Raeq = A_{RA} + 0.077\ A_K + 1.43\ A_{Th} \quad (2.2)$$

Here A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K, respectively in Bq/kg.

2.5 Absorbed Dose Rate

The absorbed dose rate in air, which originate from radioactive sources in the soil is a measure of the effects of gamma radiation. The absorbed dose rate in air, 1 meter above the ground surface due to the radionuclides ^{238}U, ^{232}Th and ^{40}K was assessed by the help of equations in UNSCEAR 1993 (UNSCEAR Annex, 2000b).

$$D(n/Gyh) = 0.462A_{RA} + 0.042A_k + 0.604A_{Th} \quad (2.3)$$

here, A_{RA}, A_{Th} and A_k are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg.

2.6 Health Hazard Indices

Soil is also be used for housing. Thus it might contribute to the external health hazard to human being. The radiation dose rate due to the external exposure of gamma radiation in materials is termed as the external hazard index (H_{ex}) (Lu and Xiolan, 2006) and can be estimated as follows

$$H_{ex} = A_{Ra}/370 + A_K/4810 + A_{Th}/259 \quad (2.4)$$

The internal hazard index (H_{in}) gives the internal exposure to carcinogenic radon and its short-lived daughter nuclide, can be obtained with the help of equation 2.5 [69]:

$$H_{in} = A_{RA}/185 + A_{Th}/259 + A_k/4810 \quad (2.5)$$

Here A_{RA}, A_{Th} and A_k have same meanings as in equation (2.3). To keep the radiation hazard trivial, value of Hex should be lower than unity.

3. Result And Discussion

The activity concentrations of different radioactive nuclides have been measured using gamma spectrum. Measured activity concentration of ^{238}U, ^{226}Ra, ^{232}Th from their progeny nuclides which consist of daughter nuclides [^{214}Pb (295.2 keV), ^{214}Pb (351.9 keV), ^{214}Bi (609.3 keV), ^{214}Bi (1120.2 keV)] and [^{212}Pb (238.6 keV), ^{208}Tl (583.1 keV), ^{228}Ac (911.2 keV), ^{228}Ac (968.9 keV)] respectively.

3.1 Activity Concentration of Radionuclides in fifteen samples

The following table shows the activity concentration of radionuclides (using equation 2.1) in each samples.

Table 2. Activity Concentration of radio-nuclides.

Sample ID	226-Ra $Bqkg^{-1}$	Th-232 $Bqkg^{-1}$	K-40 $Bqkg^{-1}$
1	26.62	24.54	350.70
2	22.91	15.10	261.99
3	18.85	15.59	400.00
4	29.58	13.77	398.00
5	21.30	26.57	259.64
6	31.05	20.83	665.07
7	32.82	15.90	133.95
8	29.73	21.44	401.76
9	27.17	21.75	539.07
10	22.13	12.03	155.75
11	26.18	19.42	328.04
12	21.56	15.26	224.48
13	20.66	26.54	635.88
14	25.39	16.90	808.71
15	16.21	19.00	419.31
Average	24.81	18.97	398.82

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the soil samples were varied from 16.21Bq/kg to 32.82 Bq/kg,13.77 Bq/kg to26.54 Bq/kg and 155.75 Bq/kg to Bq/kg respectively. n soil sample for world, the average value of ^{226}Ra, ^{232}Th and ^{40}K are 32Bq/kg, 45Bq/kg and 420Bq/kg respectively (Debertin and Helmer, 1988). Figure 5 shows a graphical view of activity concentrations of radionuclides in samples.

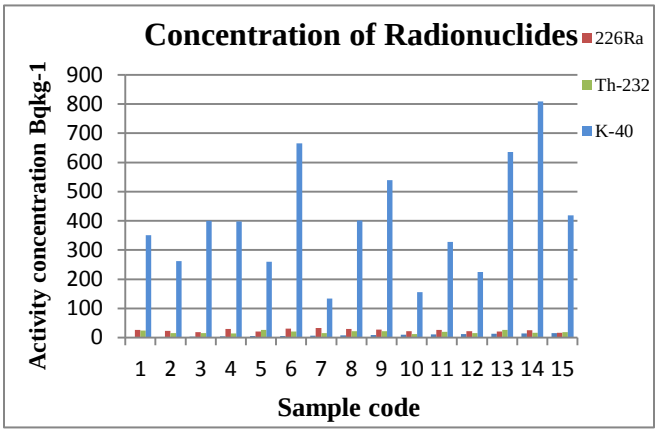

Figure 5. Graphical Representation of activity concentration of natural radionuclides.

3.2: Radium Equivalent Activity (Ra_{eq})

The following Table 3 shows the calculated value for Radium Equivalent Activity (equation 2.2) and absorbed dose rate in air (equation 2.3).

Table 3. Radium Equivalent Activity and Absorbed dose rate for all samples.

Sample number	Radium equivalent activity (Ra_{eq}) Bq/kg	Absorbed dose rate (D) $nGyh^{-1}$
1	88.723173	41.74777
2	64.680113	30.63148
3	71.9497	34.80783
4	79.93082	38.58575
5	79.305609	36.72393
6	112.0574921	54.66447
7	65.887528	30.35924
8	91.3385764	43.44462
9	99.786967	48.17157
10	51.337118	23.99016
11	79.21683	37.50713
12	60.682424	28.54543
13	107.588789	52.09742
14	111.844964	55.66865
15	75.665869	36.4497
Min	51.337118	23.99016
Max	112.0574921	55.66865
Average	82.66682	39.5599

The minimum and maximum absorbed dose in the air are 23.99106 and 55.66865 $nGyh^{-1}$ respectively and average value is 39.5599$nGyh^{-1}$, whereas the population weighted average of absorbed dose in air is 59 $nGyh^{-1}$.The minimum and maximum values of Radium equivalent activity are 51.337118 and 112.0574921 Bq/kg and the average value of Radium equivalent activity is 82.66682 Bqkg-1 whereas average value for the world is 370 Bq/kg as recommended by IAEA (UNSCEAR Annex, 200c).

Graphical representations of radium equivalent activity and absorbed dose rate in air have been shown in Figure 6 and 7 respectively:

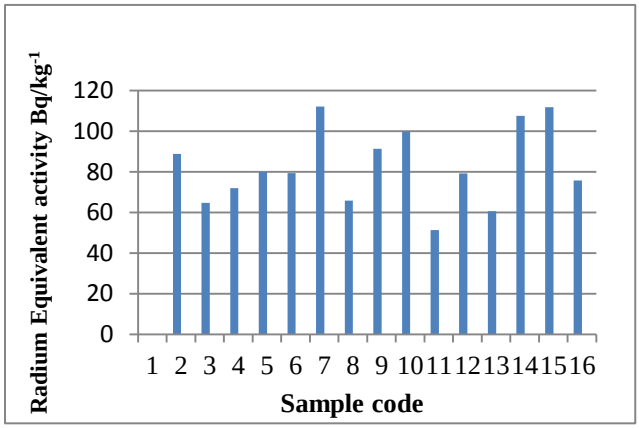

Figure 6. Graphical representation of radium equivalent activity in all samples.

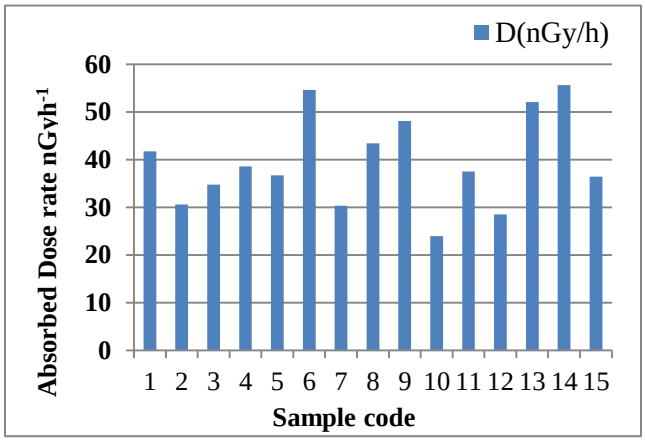

Figure 7. Graphical representation of Absorbed Dose rate in all samples.

3.3 Hazard Index

Table 4 shows data for External hazard index (obtained by using equation 2.4) and Internal hazard index (obtained by using equation 2.5):

Table 4. Data for External and Internal hazard index.

Sample code	External hazard index(H_{ex})nGyh^{-1}	Internal hazard index(H_{in})nGyh^{-1}
1	0.23962	0.311571
2	0.174698	0.236617
3	0.194315	0.245277
4	0.215893	0.295861
5	0.214183	0.271775
6	0.302639	0.386583
7	0.177985	0.266696
8	0.246695	0.327068
9	0.269498	0.342947
10	0.13867	0.198503
11	0.21395	0.284713
12	0.163901	0.222186
13	0.290546	0.346402
14	0.30205	0.370697
15	0.204342	0.248153
Min	0.13867	0.198503
Max	0.302639	0.386583
Average	0.223268	0.290339

The indexed value of external and internal hazard should be less than unity in order to keep the radiation hazard insignificant .Here the average values of hazard index in all samples are lower than the safety margin .The obtained average value of internal and external hazard index are 0.29 and 0.223 nGyh^{-1} respectively which are less than unity which indicate non-hazardous for human being and environment. The graphical representation of external and internal hazard index have been shown in Figures 8 and 9 respectively.

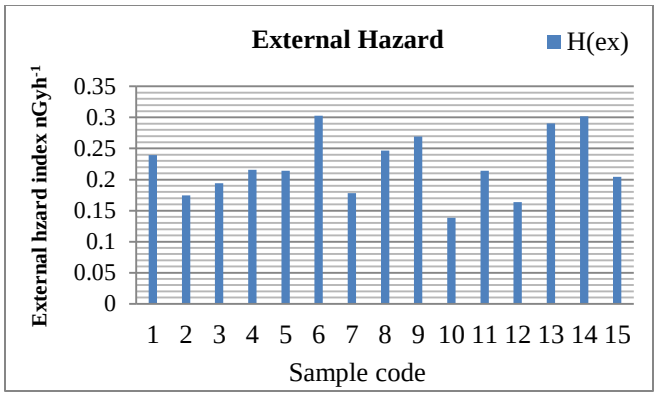

Figure 8. Graphical representation of external hazard.

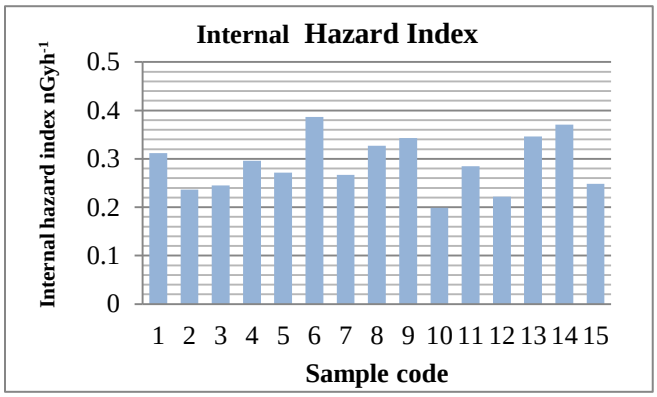

Figure 9. Graphical representation of internal hazard index in all samples

3.4 Comparison with previous works

A comparative study has been done for activity concentrations in soil sample with other studies performed in Bangladesh and abroad, as shown in Table 5. This comparison shows that the radioactivity level in soil in other parts of Bangladesh and around the world is comparable with present study.

Table 5. Comparison with previous works in other regions.

Country/Region	Radioactivity concentration (Bqkg^{-1})			References
	Radionuclides			
	^{226}Ra	^{232}Th	^{40}K	
Chandpur, BD	24.81±0.040408	18.97±0.03769	398.82±0.35349	Present
Satkhira, BD	35.71 ± 3.92	54.06 ± 3.45	= 580.6 ± 71.63	(Hossen and Ferdous, 2015)
Savar, Dhaka, BD	23.31	42.24	733.19	(Foisal et al. 2014)
Dinajpur, BD	36.7±1	59.7±1.7	282.5±2.3	(Rahman et al., 2013)
Rooppur, BD	30.85 ± 3.42	40.88 ±5.17	521.65± 28.35	(Ferdous et al., 2013)
Rainforest Sites in Western Ghats, BD	26.26 ± 9.1	53.61 ± 10.4	204.08 ± 30.4	(Manigandan and Natrrajan, 2014)
West Bank, Palestine	41.4	19.5	113.3	(Samreh et al., 2014)
Chakwal, Pakistan	34.27 ± 1.28	51.59 ± 2.73	606.42 ± 21.23	(Rahman et al., 2018)
Kirkuk-IRAQ	27.4 to 57	11.0 to 25.4	207.4 to 516.0	(Taqi and Sarker, 2028)
Kuala Krai district, Malaysia	40.2-264.0	49.2-312.9	491.1-1184.2	(Hamzah et al., 2011)
Tamil Nadu, India	42.9± 9.4	14.7± 1.7	149.5±3.1	(Senthilkumor et al., 2010)
Nigeria	12.90±0.02	45.56±0.01	250.00±0.02	(Felix et al., 2016)
South Konkan , Maharashtra , India	44.97± 1.22	59.70± 2.17	217.51± 8.75	(Joel et al., 2014)
north Jeddah west, Saudi Arabia	44.87	54.59,	2652.30	(Dhawal et al., 2014)
Kisii Region, Kenya	38.6 to 271.7	431to 360	245 to 1780	(Safia, 2014)

4. Conclusion

Activity concentrations of radionuclides were investigated in this study. The maximum values of activity concentrations of ^{232}Th, ^{226}Ra, and ^{40}K were found to be 13.77 $Bqkg^{-1}$ to26.54 $Bqkg^{-1}$, 16.21$Bqkg^{-1}$ to 32.82 $Bqkg^{-1}$ and 155.75 $Bqkg^{-1}$ to 808.71 $Bqkg^{-1}$ respectively. The mean values are 24.81±0.040408 Bq.kg-1, for ^{226}Ra, 18.97±0.03769 Bq.kg-1 for ^{232}Th and 398.82±0.3534962 Bq.kg-1 for ^{40}K respectively.

The Radium equivalent activity (Ra_{eq}) of soil samples for Chandpur district is varied from 51.337118$Bqkg^{-1}$ to 112.0574921 $Bqkg^{-1}$ and the average value of Radium equivalent activity (Ra_{eq}) is 82.66682 $Bqkg^{-1}$. The minimum and maximum absorbed dose in the air are 23.99106 $nGyh^{-1}$ and 55.66865 $nGyh^{-1}$ respectively and average value is 39.5599$nGyh^{-1}$. The values of external hazard (H_{ex}) in these samples ranged from 0.13867 $nGyh^{-1}$ to 0.302639$nGyh^{-1}$ with a mean value 0.223268$nGyh^{-1}$. The values of internal hazard (H_{in}) in the samples ranged from 0.198503$nGyh^{-1}$ to 0.386583$nGyh^{-1}$ with a mean value 0.290339$nGyh^{-1}$.Here both internal and external hazard index are not more than the unity for soil samples. t is matter of relaxation that there were no artificial radionuclides .As the obtained values are within the limits suggested by NSRC -1997 rules of Bangladesh and International Atomic Energy Agency (IAEA) so it is clear that the radiation level in soil of Chandpur district does not pose any health risk currently.

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