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Effective Dose of Terrestrial Gamma and Gross Alpha-Gross Beta Activity Measurement in Some Drinking Water Samples at Satkhira District, Bangladesh

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Abstract: Human body exposed natural radiation by inhalation, ingestion or absorption. Excess exposure of ionizing radiation to human can cause harmful effects. Water is a source of exposed radiation to human body. In Bangladesh only a limited number of studies on internal dose assessment due to water have been performed. The main purpose of this present study is to calculate activity concentrations of natural radionuclides [^{238}U (^{226}Ra), ^{232}Th, and ^{40}K] and gross Alpha and gross Beta activity of water from different upazila of Satkhira district, Bangladesh. To measure the natural radioactivity concentration a high resolution Gamma-ray spectroscopy with an HPGe detector in a low background configuration and a Zinc Sulphide Scintillation Detector Zn(Ag)S has been carried out the analysis of gross Alpha and gross Beta activity . The findings of Gross-Alpha and Gross Beta activity mostly similar with the findings of previous studies of different countries. Some cases natural radiation dose slightly excided the previous studies of different countries. Considering this data as a baseline data further a broad line study may be happened and can be used in future to evaluate any changes due to any vulnerability.

Keywords: Natural radionuclides, Gross alpha, Gross beta, Activity concentration, Water.

1 Introduction

Man is always exposed by ionizing radiation externally and internally from natural radionuclides. Internal exposure comes from ingestion and inhalation. The main source of ingestion and inhalation of exposed radiation are air, food and drinking water. Water is essential to life as air. Natural water is not completely free of radioactive isotopes due to the presence of beta and alpha emitters from the natural decay series of uranium, thorium and actinium and other isotopes such as ^{40}K. Exposure of man to ionizing radiation can cause harmful effects. Thus, measurements of natural radioactivity in ground, surface and domestic water have been performed in many parts of the world, mostly for assessment of the doses and risk resulting from consuming water. But in Bangladesh only a limited number of studies on internal dose assessment have been performed. The main purpose of this present study is to calculate activity concentrations of natural radionuclides (^{232}Th, ^{238}U and ^{40}K) and gross alpha and gross beta activity of water from different upazila of Satkhira and provides a base line data which can be used in future to evaluate any changes. We planned to carry out the measurements of natural radioactivity by using high resolution Gamma-ray spectroscopy with an HPGe detector in a low background configuration and the analysis of gross Alpha and gross Beta activity concentration has been carried out by using a Zinc Sulphide Scintillation Detector Zn(Ag)S in Health Physics Division, Atomic Energy Center Dhaka (AECD), Bangladesh.

Although Bangladesh is not a nuclear powered country, nevertheless, it may be vulnerable to atmospheric fallout of ethnogeny radionuclides and waste disposal to the Indian Ocean by neighboring countries or by other developed countries, since no surveillance activity in this regard exists here. Besides this, Bangladesh is subjected to natural radioactivity through the draining of heavily silt-laden water by the Ganges-Brahmaputra-Meghna river system. Satkhira is an agricultural district of Bangladesh. Hence people may be exposed by radiation through the water and through their use in food preparation and processing. Water used for irrigation purposes can also be a source of radionuclides in foods. Efforts to determine levels of such radioactivity of ground and surface water in Satkhira will

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help in the development of guidelines for the protection of human beings.

Environment is quite important for human health. There are various agents, which can affect human health either directly or indirectly. Environmental radioactivity day by day is increasing in the earth crust due to various reasons e.g. nuclear explosion, use of nuclear medicine, decaying of Ozone layer etc. [1]. Humans are exposed naturally to ionizing radiation from a number of sources which include cosmic rays and natural radionuclides in air, food and drinking water [2]. Every day, we ingest/inhale nuclides in the air we breathe, in the food we eat and the water we drink. There is nowhere on the earth that one can get away from natural radioactivity [3].

Water is indispensable to human life, thus an important parameter of environmental science. The presence of radionuclides in drinking water poses a number of health hazards, especially when these radionuclides are deposited in the human body, through drinking water [4]. It is well known that water can be a source of radiation, as it contains certain amounts of naturally occurring radionuclides. Their levels in drinking water may be increased through a number of human activities such as nuclear fuel cycle and medical or other uses of radionuclides. In addition to the control of radionuclide concentrations for radiation protection, it is very important to assess the effective dose in order to predict possible biological damage to the organism [5]. Natural water is not completely free of radioactive isotopes due to the presence of beta and alpha emitters from the natural decay series of uranium, thorium and actinium and other isotopes such as ^{40}K. Thus, measurements of natural radioactivity in ground, surface and domestic water have been performed in many parts of the world, mostly for assessment of the doses and risk resulting from consuming water. Efforts to determine levels of such radioactivity will help in the development of guidelines for the protection of human beings [6].

The contribution of drinking water to total exposure is typically very small and is due largely to naturally occurring radionuclides in the uranium and thorium decay series. Radionuclides from the nuclear fuel cycle and from medical and other uses of radioactive materials may, however enter, drinking water supplies. The contributions from these sources are normally limited by regulatory control of the source or practice, and it is normally through this regulatory mechanism that remedial action should be taken in the event that such sources cause concern by contaminating drinking-water. The concentration of the radioactive isotopes in water depends on its geo-chemical history. According to the World Health Organization (WHO), about 1.1 billion people do not have potable water and the biological contamination is a serious problem for that population. It is important that the biological chemical and radiological contamination of the potable water be equal or less than the levels recommended by international health organizations like that recommended by the WHO or by national regulation [7]. In order to guarantee an exposure lower than 0.1 mSv/y WHO recommends the guideline values for drinking water 0.1 Bq/L for gross alpha activity and 1 Bq/L for gross beta activity [8].

Measurement of airborne radioactivity provides the first opportunity to identify the spectrum of radionuclides making up the contamination. Radionuclides will very rapidly appear in ground level air, and air samples can give the first indication of the nature of the contamination. Radioactive materials in the air may result in exposure to man by inhalation or ingestion of particulate matter deposited on vegetation or by ingestion of products derived from animals which were exposed to radioactive materials through inhalation or ingestion [9].

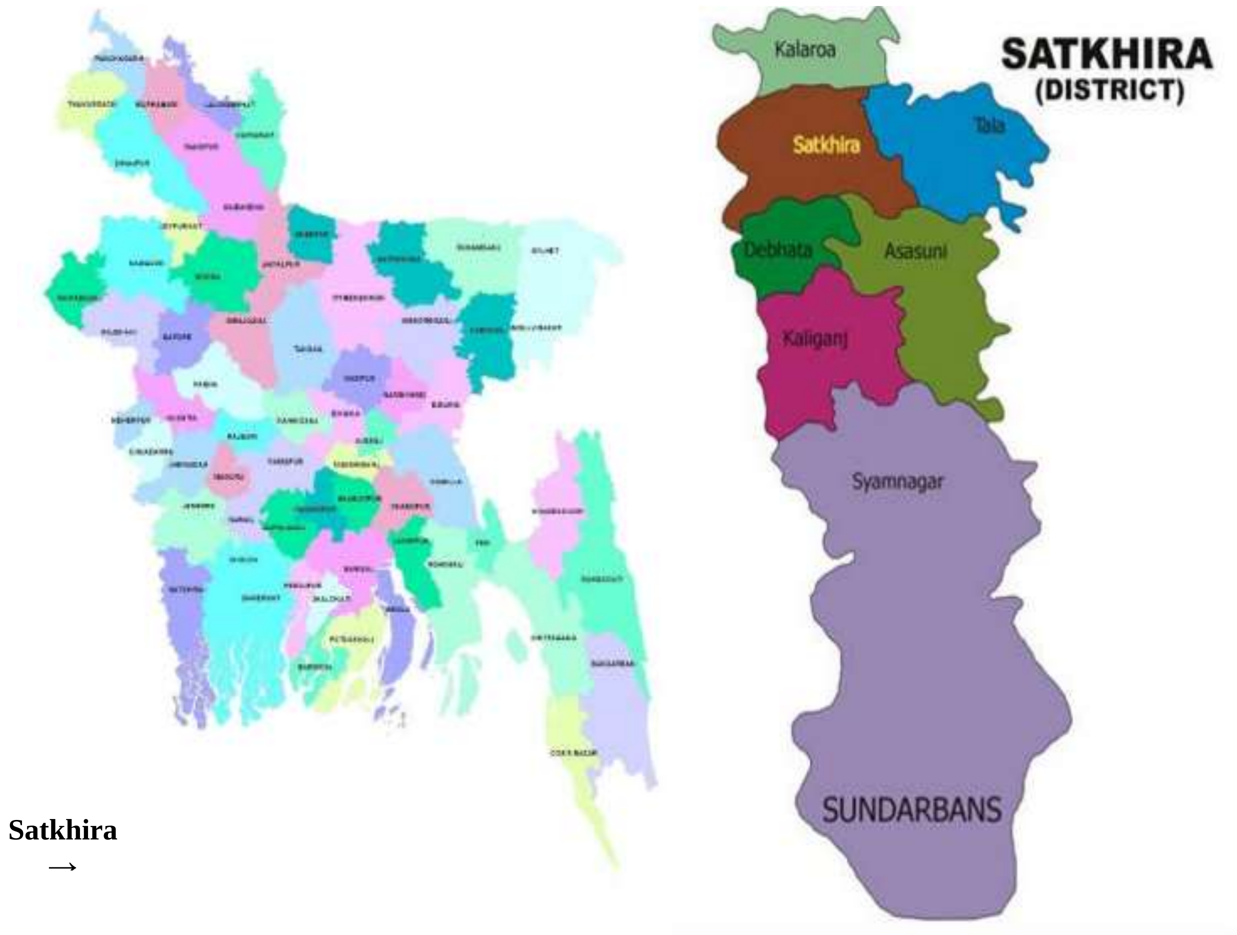
Rainwater and snow are also early indicators of radioactive contamination. In some places drinking water and rainwater can be significant pathways of short lived radionuclides, e.g. radioiodine to man or animals. Drinking water and household water are potentially important pathways, directly or through their use in food preparation and processing, although dilution, time delays and water treatment can reduce the contamination levels markedly. Water consumed by livestock and or used for irrigation purposes can also be a source of radionuclides in foods. Sea water can be a contamination source for sea foods (e.g. mussels, shellfish, fish, algae). Water from streams, lakes and ponds should also be considered as a source of contamination [9].

The effect of radiation in the environment can be dangerous and fatal to humans and animals. The damage it causes depends on the level of radiation and the resiliency of the organism. Radiation causes molecules to lose electrons thus destroying it. Killing certain enzymes in the body can simply make you sick. However, once radiation damages DNA the body may not be able to repair itself. This can increase the chances of both animals and humans developing cancer.

2 Experimental Details:

2.1 Study area:

The district Satkhira is located in between 21°36' and 22°54' north latitudes and in between 88°54' and 89°20' east longitudes, the south-west corner of Bangladesh. The area of the district is 3858.33 sq km. The district consists of seven upazilas named as Kolaroa, Satkhira Sadar, Tala, Debhata, Assasuni, Kaligonj and Syamnagar. The map of Satkhira district is shown in Fig. 1.



(a) (b)

Fig. 1: (a) Satkhira district located in Bangladesh map (b) Satkhira District with its Upazila.

2.2 Sample Collection

To measure the natural and artificial radioactivity in ground and surface water, thirteen water samples were collected randomly from different locations of Satkhira district. The samples were collected in November, when mostly the surface water being stable due to rain free weather. The samples were kept into previously cleaned 1 L capacity plastic Bottles using manual procedure. The samples were appropriately coded from 1 to 13 and transferred to Environmental Radioactivity Monitoring Laboratory of Health Physics Division at Atomic Energy Centre (AEC), Dhaka, Bangladesh. The lists of the collected soil samples are given in Table 1.

Table 1: Collection of Water Samples with Sample Number and Sample Types.

Sample Code	Sample Type	Sample Code	Sample Type
Sample-1	Tube-Well Water	Sample-8	Pond Water
Sample-2	Tube-Well Water	Sample-9	Shallow Water
Sample-3	Pond Water	Sample-10	Shallow Water
Sample-4	Pond Water	Sample-11	Shallow Water
Sample-5	Tube-Well Water	Sample-12	Shallow Water
Sample-6	Tube-Well Water	Sample-13	Tube-Well Water
Sample-7	Pond Water		

2.2 Sample preparation for gamma counting

Forty five 1 L capacity Pyrex beakers were washed with distilled water and left to dry to avoid sample contamination. About 1 L of each sample was poured into a Pyrex beaker. One milliliter concentrated HNO_3 was added to each water sample to avoid the collection of organic materials and changes in the oxidation state of the ions present in the samples. Subsequently, the water samples were slowly evaporated by water bath treatment at 105^0C and reduced upto 250 mL approximately and each of the samples was transferred to cylindrical plastic-container. The containers were approximately of equal size and shape (i.e. diameter 6.5 cm and height 7.5 cm). The containers were then labeled properly and sealed tightly, rapped with thick vinyl tapes around their screw necks for gamma detection in HPGe detector.

2.3 Sample preparation for Alpha and Beta counting

After gamma detection the water samples were slowly evaporated again by water bath treatment at 105^0C in order to reduce its volume near to dryness (5 ml approximately). During evaporation of the water sample, the pyrex beaker was covered with watch glass. Then it was transferred to a 2 inch stainless steel counting planchet and dried under an IR lamp, cooled and weighed to determine the activity. Then the sample residue was kept in a desiccator to avoid moisture.

Sample preparation on water bath

Prepared samples for gamma counting

Samples drying by Infrared (IR) lamp

Dried samples in the planchet

Dried samples in the desiccator

Fig. 2: Different stage of sample preparation.

3 Determination of the Activity Concentration

3.1 Gamma (γ) activity calculation

The number of counts under the full-energy peak areas (corrected for background peak areas), the counting time, the absolute full-energy peak efficiency for the energy of interest and the gamma-ray emission probability corresponding to the peak energy are used for the calculation of the activity concentration of a particular radionuclide in the measured samples. One problem with the direct determination of the activity of ^{238}U (^{226}Ra) and ^{232}Th is due to the low relative gamma-ray intensities following their decay. However, in a state of secular equilibrium, the activity of ^{238}U (^{226}Ra) and ^{232}Th can be estimated through several intensive gamma-ray lines of their daughter products in the decay chains. The activity concentrations of^{238}U (^{226}Ra) and ^{232}Th were determined from the average concentration of nuclides [Pb^{214} (295.2keV), Pb^{214} (351.9keV), Bi^{214} (609.3keV) and Bi^{214} (1120.2keV)] and [Pb^{212} (238.6keV), Tl^{208} (583.1keV), and Ac^{228} (911.2keV), Ac^{228} (968.9keV)] respectively. The activity concentrations of ^{40}K were determined directly by measurement of the gamma-ray transitions at 1460.8keV. The specific activity, in terms of the activity concentration, is defined as the activity per unit mass of the sample. The specific activity of individual radionuclides in water samples is given by the following equation:

$$A = \frac{N \times 100 \times 1000}{P\gamma \times \varepsilon \times W} \quad \text{……… (1)}$$

Where,

N = Net counts per second (cps) = (Sample cps) – (Background cps)

$P\gamma$ = Transition probability of gamma ray or Branching ratio

ε = Efficiency in percent

W = Weight of the sample in liter

3.2 Annual effective doses due to ingestion of water

The total annual effective doses due to ingestion of ^{226}Ra, ^{232}Th, and ^{40} K in drinking water were assessed for different age groups, according to the equation introduced by WHO 2018 [22] and the ingestion dose coefficient for relevant age group (Conversion Factors) was used from Table 2.

$$D = A \times C \times I \quad \text{……… (2)}$$

Where

D = annual dose (mSv·year−1).

A= radionuclide activity concentration in drinking-water (BqL^{-1})

C = consumption rate of drinking water for relevant age group (LY^{-1}) for a person in 1 year, which is 183L and 370L for infants and adults respectively.

I = ingestion dose coefficient for relevant age group mSvL^{-1} [22-23].

Table 2: The conversion factors (CF) of the relevant radionuclides for different age groups.

Age group	^{226}Ra ×10^{-4} (mSvL^{-1})	^{232}Th ×10^{-4} (mSvL^{-1})	^{40}K ×10^{-6} (mSvL^{-1})
Infants	9.6	4.5	5
Children	9.6–8	4.5–2.9	5
Adults	2.8	2.3	5

3.3 Lower limit of detection (LLD) Calculation

The Lower Limit of Detection is defined as the smallest amount of activity that can be detected for comparison with regulatory limits [10]. LLD values also provide a basis for predicting the least amount of radiation which can be detected by the instrument in the given counting time with the given set of calibration factors and sample variables [11]. The method we used for the LLD calculation is derived from the definition of counting sensitivity as given In The National Interim Primary Drinking Water Regulation. These equations were developed by applying probability theory to the counting statistics with pre-selected levels of reporting confidence. The equation is shown below.

$$LLD = \{1.92 + \sqrt{(3.69 + 7.68 R_b T)}\}/TE \quad \text{………. (3)}$$

Where, R_b = Background Count Rate

T = Background count time

E = Counting efficiency.

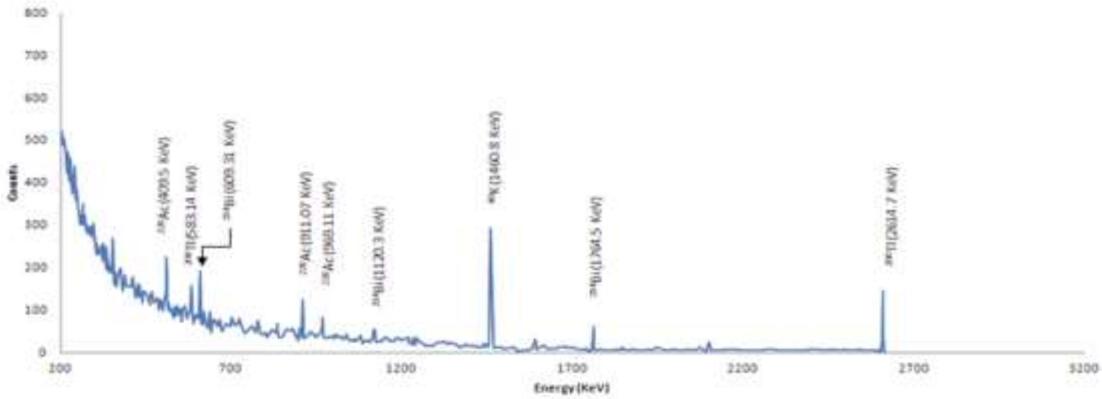


Fig. 3: Spectrum of the gamma-rays from a water sample of Satkhira.

3.4 Gross Alpha and Gross Beta Activities Calculation

For gross alpha and beta activity each sample was counted for 60 minutes. The results were displayed as count per minute (CPM), activity and standard deviation. The data were acquired for alpha and beta mode. The alpha and beta count rate as well as alpha activity and beta activity were calculated using the following formula:

$$DPM = \frac{Net\ \ CPM\ \times 100}{\varepsilon} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where, DPM= Net Alpha or Beta Disintegrations per Minute

Net CPM= Net Alpha or Beta Counts per Minute

ε = Alpha or Beta Efficiency in Percent.

Then the activity is $A = \frac{DPM}{60}$ …………….. (5)

In this work, the effective dose over one year was calculated using the following relation (IAEA 2003).

$$E_{avg}\ (\alpha/\beta) = \sum Ai(\alpha/\beta) \times DCF\ i(\alpha/\beta) \times 730 \text{ (for Adult)} \quad \text{-------- (6)}$$

$$E_{avg}\ (\alpha/\beta) = \sum Ai(\alpha/\beta) \times DCF\ i(\alpha/\beta) \times 183 \text{ (for Infant)} \quad \text{-------- (7)}$$

Where, E_{avg} (α/β) is the average gross annual alpha or beta committed effective dose in drinkable water, Ai(α/β) is the gross alpha or beta activity concentration of individual radionuclides present in water samples and DCF i(α/β) is the dose conversion factor in mSv/Bq for ingestion of the individual radionuclide. According to Gortir et al., [24] the major contributors to gross α activities is ^{226}Ra while the major contributors for β activities are ^{210}Pb and ^{228}Ra. For calculations, the dose conversion factors of 2.8×10^{-4} mSv/Bq, for ^{226}Ra and 6.9×10^{-4} mSv/ Bq for both ^{210}Po and ^{228}Ra published by the (WHO, 2004) were used.

4 Results and Discussion

4.2 Gamma activity concentration

The activity concentrations of radionuclides like ^{238}U, ^{232}Th ^{40}K and ^{137}Cs were determined in ground water samples by using HPGe gamma spectrometry. To determine the concentrations of radionuclides in the samples, Equation 1 was used. By using this equation, the data were normalized for one litter of each sample.

The activity concentrations of the daughter products of ^{238}U and ^{232}Th in the groundwater samples have been measured and are given in Table 6.1 and Table 6.2 respectively. The activity concentrations of ^{238}U and ^{232}Th are calculated from the average activity concentrations of the daughter radionuclides [^{214}pb (295keV), ^{214}Pb (351.92 keV), ^{214}Bi (609.31 keV), ^{214}Bi (1120.3 keV)] and [^{212}pb (238.6keV), ^{208}Tl (583.14 keV), ^{228}Ac (911.07 keV), ^{228}Ac (969.11 keV)] respectively. The activity concentrations of ^{40}K are determined directly by measurement of the gamma-ray transitions at 1460.8 keV.

In the present study the average activity concentration of ^{238}U is 2.95 Bq/L which is higher than the value of Iraq and Saudi Arabia. The average activity concentration of ^{238}Th in the present study is 2.43 Bq/L which is higher than the values of Iraq, Egypt and Saudi Arabia. This value is lower than the value of Iran. The average activity concentration of ^{40}K is 6.8 Bq/L which is lower than the value of Iraq. This value is higher than the value of Egypt, Iran and Saudi Arabia.

Table 3: Activity concentrations (Bq/L) of radionuclides in water samples.

Sample Code No.	Sample Type	^{238}U (226Ra) (Bq/L)	^{232}Th (Bq/L)	^{40}K (Bq/L)
Sample-1	Tube-Well Water	2.58 ±0.67	0.84± 0.01	4.67 ±0.48
Sample-2	Tube-Well Water	2.67± 0.02	1.33± 0.3	9.87 ±0.51
Sample-3	Pond Water	0.41 ±0.02	0.16± 0.14	9.87± 0.53
Sample-4	Pond Water	4.85 ±0.63	4.42 ±3.64	4.5± 0.46
Sample-5	Tube-Well Water	2.39± 0.5	2.7± 0.007	4.94 ±0.51
Sample-6	Tube-Well Water	0.43 ±0.02	2.07± 0.06	4.69 ±0.49
Sample-7	Pond Water	2.84 ±2.2	4.67 ±0.06	4.53 ±0.46
Sample-8	Pond Water	3.08± 0.57	2.07 ±0.44	4.83± 0.52
Sample-9	Shallow Water	2.46± 0.29	1 ± 1 .17	10.86± 0.57
Sample-10	Shallow Water	3.62± 3.15	0.26± 0.29	4.42 ±0.46
Sample-11	Shallow Water	5.52 ±0.45	7.08 ±0.1	5.36± 0.55
Sample-12	Shallow Water	6.28± 0.1	2.82 ±0.67	9.62± 0.52
Sample-13	Tube-Well Water	1.21±0. 78	2.12 ±0.42	5.72 ±0.6
Average		2.95±1.79	2.43±1.98	6.8±2.59

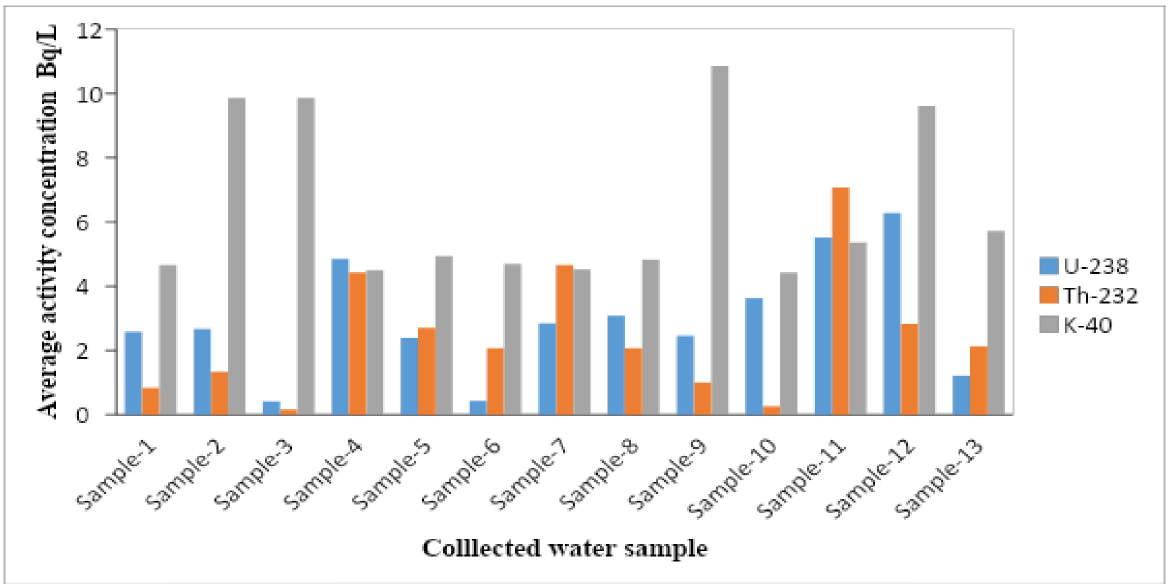


Fig. 4: The activity concentrations of ^{238}U, ^{232}Th and ^{40}K for the water samples.

Table 5: Average activity concentrations of ^{238}U, ^{232}Th and ^{40}K in water samples for different countries with that of the present work.

No	Country	^{238}U (^{226}Ra) (Bq/L)	^{232}Th (Bq/L)	^{40}K (Bq/L)	Reference
1	Iraq	0.933	0.737	24.451	[12]
2	Egypt		0.13	5.29	[13]
3	Iran		2.70	4.23	[14]
4	Saudi Arabia	0.017-0.088	0.020-0.102	0.41-1.0	[15]
5	Bangladesh	2.95	2.43	6.8	(Present study)

Table 6: Effective annual dose for natural gamma due to ingestion of water.

Sample Types	Effective dose due to ^{226}Ra ($mSvy^{-1}$)		Effective dose due to ^{232}Th ($mSvy^{-1}$)		Effective dose due to ^{40}K ($mSvy^{-1}$)		Total Effective Dose for Gamma in ($mSvy^{-1}$)	
	Infant/Children	Adult	Infant/Children	Adult	Infant/Children	Adult	Infant/Children	Adult
Tube-Well Water	0.45325	0.52735	0.06917	0.14104	0.00427	0.01705	0.52669	0.68546
Tube-Well Water	0.46907	0.54575	0.10953	0.22331	0.00903	0.03603	0.58763	0.80509
Pond Water	0.07203	0.08380	0.01318	0.02686	0.00903	0.03603	0.09424	0.14669
Pond Water	0.85205	0.99134	0.36399	0.74212	0.00442	0.01643	1.22046	1.74989
Tube-Well Water	0.41988	0.48852	0.22235	0.45333	0.00452	0.01803	0.64675	0.95988
Tube-Well Water	0.07554	0.10492	0.17046	0.34755	0.00429	0.01712	0.25029	0.46959
Pond Water	0.49893	0.58050	0.38452	0.78409	0.00415	0.01653	0.88760	1.38112
Pond Water	0.54109	0.62955	0.17046	0.34755	0.00442	0.01763	0.71597	0.99473
Shallow Water	0.43217	0.50282	0.08235	0.16790	0.00994	0.03964	0.52446	0.71036
Shallow Water	0.63596	0.73993	0.02138	0.04365	0.00404	0.01613	0.66138	0.79971
Shallow Water	0.96975	1.12829	0.58304	1.18873	0.00490	0.01956	1.55769	2.33658
Shallow Water	1.10327	1.28363	0.23223	0.47348	0.00880	0.03511	1.34430	1.79222
Tube-Well Water	0.21248	0.24732	0.17458	0.35595	0.00523	0.02088	0.39229	0.62414
Average							0.72383	1.03504

The effective annual dose for natural gamma radiation (^{226}Ra, ^{232}Th, and ^{40}K) due to ingestion of water were measured by using the equation (3). The total effective dose for natural gamma for infant/children ranges.

from 0.09424 to 1.55769 $mSvy^{-1}$, and in an average of 0.72383 $mSvy^{-1}$. The obtained dose for adult ranges from 0.14669 to 2.33658 mSvy-1, whose average is of 1.03504 $mSvy^{-1}$.

Total effective dose for natural gamma for infant/children ranges.

4.3 Concentration of Gross Alpha and Beta Activity

The measured activity concentrations of gross Alpha and Beta in water samples of different locations in Satkhira are gathered in Table 7.

Table7: The activity concentrations of gross Alpha in water samples of different locations in Satkhira.

Sample Code No.	Sample Type	Gross Alpha (Bq/L)	Gross Beta (Bq/L)
Sample-1	Tube-Well Water	0.0043	0.059
Sample-2	Tube-Well Water	0.0037	0.052
Sample-3	Pond Water [Surface]	0.0035	0.047
Sample-4	Pond Water [Depth]	0.0045	0.057
Sample-5	Tube-Well Water	0.0041	0.054
Sample-6	Tube-Well Water	0.0054	0.063
Sample-7	Pond Water [Surface]	0.0045	0.065
Sample-8	Pond Water [Depth]	0.0036	0.047
Sample-9	Shallow Water	0.0038	0.056
Sample-10	Shallow Water	0.003	0.047
Sample-11	Shallow Water	0.0027	0.042
Sample-12	Shallow Water	0.0043	0.052
Sample-13	Tube-Well Water	0.003	0.057
Average		0.0039±0.0007	0.053±0.007

The results obtained show that the measured activity concentrations of gross alpha and beta in all ground water samples are less than 0.1 Bq/L and 1.0 Bq/L resepectively, which is within the limit recommended by WHO.

The present findings of the activity concentrations of gross Alpha and gross Beta were compared with the results reported in previous studies. The activity concentrations of gross Alpha and gross Beta of water samples in the present study along with the values of other countries are presented in Table 8.

Table 8: Activity concentrations of gross Alpha and gross Beta of water samples of various countries.

Country	Gross Alpha(Bq/L)	Average	Gross Beta(Bq/L)	Average	Reference
Gombe	0.045	0.045	0.659-11.58	6.1195	[16]
Brazil	0.02-0.80	0.41	0.01-3.0	1.505	[17]
Australia	7.37	7.37	6.27	6.27	[18]
Turkey	0.09-2.59	1.34	0.25-2.61	1.43	[19]
Bangladesh (Surface water)	0.001	0.001	0.175	0.175	[20]
Bangladesh (Tap water)	0.00188-0.00816	0.00251	0.06	0.06	[21]
Bangladesh (Present study)	0.0039	0.0039	0.053	0.053	Present study

In the present study the activity concentration of gross alpha is greater than the value of surface water and tap water samples in Bangladesh and smaller than the value of Gombe, Australia and Turkey. This value is within the range of Brazil. On the other hand activity concentration of gross beta is smaller than the value of Gombeg, Australia and surface and tap water samples in Bangladesh. This value is within the range of Brazil and Turkey.

The annual effective dose for gross alpha and gross beta also calculated by using the equation (6) and the equation (7) for the adult and infant respectively. The annual effective dose due to gross alpha and gross beta are shown in Table 9.

Table 9: Annual effective dose for Gross Alpha and Gross Beta.

Sample ID	Sample Types	Effective dose due to ^{226}Ra (mSvy^{-1})		Effective dose due to ^{228}Ra (mSvy^{-1})		Total effective dose (mSvy^{-1})	
		Adult	Infant /Children	Adult	Infant /Children	Adult	Infant /Children
Sample-1	Tube-Well Water	0.00088	0.00022	0.02972	0.00743	0.03060	0.00765
Sample-2	Tube-Well Water	0.00076	0.00019	0.02619	0.00655	0.02695	0.00674
Sample-3	Pond Water	0.00072	0.00018	0.02367	0.00592	0.02439	0.00610
Sample-4	Pond Water	0.00092	0.00023	0.02871	0.00718	0.02963	0.00741
Sample-5	Tube-Well Water	0.00084	0.00021	0.02720	0.00680	0.02804	0.00701
Sample-6	Tube-Well Water	0.00104	0.00026	0.03173	0.00793	0.03277	0.00819
Sample-7	Pond Water	0.00092	0.00023	0.03274	0.00819	0.03366	0.00842
Sample-8	Pond Water	0.00074	0.00019	0.02367	0.00592	0.02441	0.00611
Sample-9	Shallow Water	0.00078	0.00020	0.02821	0.00705	0.02899	0.00725
Sample-10	Shallow Water	0.00061	0.00015	0.02367	0.00592	0.02428	0.00607
Sample-11	Shallow Water	0.00055	0.00014	0.02116	0.00529	0.02171	0.00543
Sample-12	Shallow Water	0.00088	0.00022	0.02619	0.00655	0.02707	0.00677
Sample-13	Tube-Well Water	0.00061	0.00015	0.02871	0.00718	0.02932	0.00733
Average						0.02783	0.00696

The total effective dose due to gross alpha and gross beta were measured for infant/children ranges from 0.00543 to 0.00842 mSvy^{-1}, whose average is of 0.00696 mSvy^{-1}and for adult the calculated dose ranges from 0.02171 to 0.03366 mSvy^{-1}, whose average is of 0.02783 mSvy^{-1}.

5 Conclusions

The ground water sample from Satkhira did not contain any anthropogenic radionuclide ^{137}Cs but natural radionuclides such as ^{238}U (Ra ^{232}Th ^{40}K were identified. The activities of ^{238}U in water sample varied with (0.41-6.28) Bq/L mean Concentration 2.95±1.79 Bq/L. The activities of ^{232}Th in ground water sample varied (0.16-7.08)Bq/L with mean concentration 2.43±1.98Bq/L. The activities of ^{40}K in ground water samples varied (4.42-10.86) Bq/L with mean concentration 6.8±2.59 Bq/L. No ^{137}Cs activity was detected in any of the samples.

Concentrations ranging from (0.003 to 0.0054) Bq/L with an average 0.0039±0.0007 Bq /L and from (0.0416 to 0.0.065) Bq/L with an average 0.0.053±0.007 Bq/L were observed for the gross Alpha and gross Beta activities, respectively. For ground water samples the gross Beta activities are higher than the corresponding gross Alpha activities. Both gross Alpha and gross Beta activities are respectively lower than 0.1 Bq/L and 1.0 Bq/L recommended by WHO. Since the gross Alpha activity in drinking water is lower than 0.1 Bq/L and the gross Beta activity does not exceed 1.0Bq/L. it can be assumed that the annual effective dose is less than 0.1 mSv per year. Bangladesh has no public drinking water standards for radioactivity yet. So, the above results are comparable with the guideline values of WHO for drinking water. It is found that the radionuclides concentration in water samples of Satkhira is still below the maximum suggested values. The data gathered in this study will provide base–line radiometric values of water as well as drinking water in this region that can be used to evaluate the possible changes in future. This work could help to create a public awareness about the total or gross Alpha and gross Beta activities in drinking water and the radiological impact on the Satkhira . This work will help in establishing a regulatory limit on radiation in public drinking water as well as to maintain a base data of activity of water in Bangladesh.

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