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Study of Gross Alpha and Gross Beta Radioactivities in Environmental Samples

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Abstract

The main objective of this study is to determine the Gross alpha and gross beta radioactivity in environmental sample. Thirty samples of soil, water and vegetable were randomly collected from the different locations of Bheramara and Ishwardi near the proposed Rooppur Nuclear Power Plant area, Kushtia and Pabna, Bangladesh. The Gross Alpha activity under investigation ranges from 1.13 to 5.66 Bq kg^{-1} with an average of 2.78±0.16 Bq kg^{-1} for soil sample, 0.45 to 1.36 mBq L^{-1} with an average of 0.91± 0.18 mBq L^{-1} for water sample, and 0.23 to 1.81 Bq kg^{-1} with an average of 1.0 ±0.11 Bq kg^{-1} for vegetable sample. The Gross Beta activity under investigation ranges from 30.74 to 132 Bq kg^{-1} with an average of 71.85±1.99 Bq kg^{-1} for soil sample, 61.49 to 279 mBq L^{-1} with an average of 175 ±4.02 mBq L^{-1} for water sample, and 305 to 1676 Bq kg^{-1} with an average of 930 ±3.27 Bq kg^{-1} for vegetable sample. This study will help to prepare baseline data for gross alpha and gross beta radioactivity in environmental sample which will be used as finger print for the comparison of radioactivity level.

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Keywords: Gross alpha and gross beta radioactivity; Environmental samples; Zinc sulfide scintillation detector; Zones (Ag).

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1. Introduction

Radionuclides are found in air, water, soil and plant. Every day, we ingest/inhale nuclides in the air we breathe, in the food we eat and the water we drink. Radioactivity is common in the rocks and soil that makes up our planet, in the water and oceans, and even in our building materials and homes. It is just everywhere. There is no where on earth that one can get away from natural radioactivity [1]. Soil acts as a source of transfers of radionuclides through the food chain depending on their chemical properties and the

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uptake process by the roots to plants and animals [2]; hence, it is the basic indicator of the radiological status of the environment. These radionuclides take part in several biogeochemical processes that determine their mobility and availability for biological update [3]. The major potential hazard from the natural radiation is from external exposure either by direct exposure to soil or as they enter in many building materials. Vegetables may be subjected to direct and indirect contamination of uranium series radionuclides. Use of fertilizers lead to elevation of uranium series nuclides in vegetable. Naturally occurring radio nuclides of thorium and uranium are the significant contributors of ingestion dose and are present in the biotic system of plants, animal, soil, water, air and thus in food [4]. Water contains a number of both alpha (such as ^{238}U, ^{226}Ra and ^{210}Po) and beta emitters (such as ^{40}K, ^{228}Ra and ^{210}Pb). Natural radioisotopes as ^{40}K and the nuclides from the ^{238}U and ^{232}Th series are the greatest source of internal and external exposure in human beings. External radiation is originated from cosmic rays and terrestrial radiation, while the ingestion and inhalation of natural radionuclides lead to the doses for internal radiation. Among the radionuclides of terrestrial origin, ^{40}K and the constituents of the ^{238}U and ^{232}Th series enter the human body largely by food and water ingestion, being the total exposure per person 0.29 mSv, of which 0.17 mSv due to the ^{40}K and 0.12 mSv due to the radionuclides of the ^{238}U and ^{232}Th series [5]. The ^{238}U represents 99.28% of the natural uranium found in the earth's crust in form of uranium ores [5]. The main emitters of alpha that can be present in soil, water and vegetable are the ^{238}U, ^{234}U, ^{232}Th, ^{226}Ra and ^{210}Po and beta ^{40}K, ^{228}Ra and ^{210}Pb in different concentrations. The gross alpha activity is defined as the total activity of all the alpha emitters (including ^{226}Ra) once the radon has been eliminated. The gross beta activity is the activity of all beta emitters excluding ^{3}H, ^{14}C and other weak beta emitters [6]. The identification and concentration of each radionuclide present in the soil, water and vegetable requires expensive time-consuming analyses. In general, gross alpha and beta analysis, one of the simplest radio analytical procedures, is used as the first step of a screening method, for being a very fast, safe and low cost method [5]. This present study will help to prepare baseline data for gross alpha and gross beta radioactivity in environmental sample, which will be used as fingerprint for the comparison of radioactivity level.

2. Experimental

2.1. *Collection and preparation of samples*

In order to measure gross alpha and gross beta activity in environmental samples, thirty samples of soil, water and vegetable were randomly collected from different locations of Beamer and Shard near the proposed Roper Nuclear Power Plant area, Cushier and Pane, Bangladesh. The nuclear power plant site is located on the east bank of the Ganges River at the village Roper, in the district of Pane and approximately 170 km northwest of the city Dhaka, the capital of Bangladesh which is shown in Fig. 1A-C. The coordinates of the sites are: latitude 24º4.35" North and longitude 89º2.80" East. Soil samples were collected from different locations around the proposed site of the Plant. All the samples were collected at a depth of 0-5 cm from the soil-surface, surface water, vegetable. Each of the sample weight/volume was 1kg for soil, 1L for water and 1.5 to 2.0 kg for vegetable. The samples were carried in dried acetone-cleaned polyethylene bags with sample codes and transferred to the laboratory. The samples were appropriately coded from Soil -1 to Soil-10 for soil, Water-01 to Water-10 for water and Vegetable by name. The collected environmental samples were transferred to the laboratory for gross alpha and gross beta radioactivity analyses.

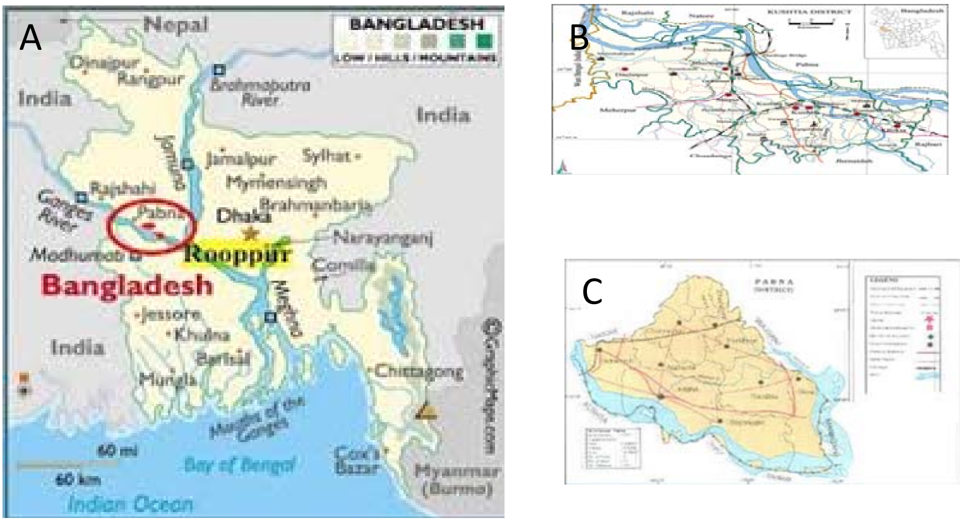

Fig.1. Location of Roper, Bangladesh (A); map of Cushier district (B); and map of Pane district (C)

2.2. *Preparation of soil and vegetable sample*

The samples were heated carefully in a muffle furnace (Carbolite type CSF 11/1). They were first heated at a low temperature and then slowly ramped upwards. The sample was dried unto 550°C to 600°C and the samples were transformed into ash. 2g of ash sample was mixed with dist. water, conc. HNO_3, and 3 to 5 drops of conc. Hal in a beaker. The sample was heated carefully over a hotplate. The solution was evaporated to near dryness. Again HNO_3 was added and evaporated to near dryness. Then dist. water was added and slowly evaporated upto 15 mL. Then the soil residue was separated by centrifugation. The solution was brought to a known volume, and an aliquot was transferred to a tarred planchet. Then the solution was evaporated on the planchet to dryness under an Infrared heating lamp. The heating rate was controlled so that the sample did not spatter. The planchet was allowed to cool and preserved in desiccators to avoid moisture sorption [7].

2.3. *Preparation of water sample*

About 1 L of each sample was poured into a 1 L beaker. 1 mL conc. HNO_3 was added to each water sample. Subsequently, the water samples were slowly evaporated on a waterbath near to dryness (15 mL approximately). During evaporation, the beaker was covered with a watchglass. Then it was transferred to a 2 inch stainless steel counting planchet and dried under IR lamp and cooled. The dry residue was weighed and kept in desiccators [8].

2.4. *Zinc sulphide scintillation detector*

ZnS scintillation counter is a dual phosphor detector or dual scintillation detectors coupling two scintillating materials to a photomultiplier tube (PMT). These detectors are sometimes referred to as a “phoswich” (for phosphor sandwich). The MPC-2000-B-DP contains a custom designed detector with a ZnS layer bonded to a plastic scintillator. The combination is optically coupled to a PMT. The outermost layer detects alpha particles, and the inner layer detects beta particles. The DP (phoswich) detector offers equivalent alpha efficiency, and slightly lower beta efficiency. Background performance is very much dependent on the environment [9]. Calculations were performed on the raw data in order to convert the raw counts from counts per minute (CPM) into disintegration’s per minute (DPM) and finally into units of activity per sample such as Bq Kg^{-1} and Bq L^{-1}. The dry residue of tap water samples were counted for gross alpha and gross beta activities using ZnS scintillation detector and gas proportional counter respectively. Known activity standard source Th-230 and Sr-90 were used for detector calibrations. The efficiency of the detector for gross alpha is 36.8% and for gross beta is 41%. The counting time was 120 min. for gross alpha and gross beta activities for each counting period. A blank planchete was used for background count. Subtraction of the background count from the sample count gives the net count of the environmental sample.

2.5. *Calculation of gross alpha/beta activity*

The activity of gross alpha/beta was calculated using the following equation:

$$DPM = NET\_CPM \times 100 / EFF \quad (1)$$

Where, DPM = alpha/beta disintegration per min, NET_CPM = Net alpha/beta count per min, and EFF = alpha/beta efficiency percent.

Error is the difference between a measured value and the true value of a quality or attribute. Thus, it is the factor that limits the precision and accuracy of the result of a measurement.

The term net count rate associated with the activity measurement is the difference between the gross count rate of the sample (which is the summation of background count rate and sample count rate) and the background count rate. Each count rate includes standard deviation expressed as,

$$\sigma = \pm\sqrt{\frac{As}{Ts}+\frac{Ab}{Tb}} \quad (2)$$

Where, σ = standard deviation, A_s = sample count rate in c.p.s., A_b = background count rate in c.p.s., T_s = sample count time, T_b = background count time. The measurement errors represent one- sigma uncertainties.

3. Results and Discussions

The measured activities of gross alpha and gross beta in soil, water and vegetable samples are given in Tables 1, 2 and 3 respectively.

3.1. *Gross alpha and gross beta activities in soil sample*

From Table 1, it is observed that the gross alpha activity ranges for soil samples from 1.13 to 5.66 Bq kg^{-1} with an average of 2.78±0.16 Bq kg^{-1}. The highest gross alpha activity in Soil-06 is 5.66±0.21 Bq kg^{-1} which is collected from Bag Gari Bridge area and the lowest gross alpha activity in Soil-10 is 1.13±0.11 Bq kg^{-1} which is collected from Dhoulotpur Gachi. The gross beta activity for soil samples is from 30.74 to 132 Bq kg^{-1} with an average of 71.85±1.99 Bq kg^{-1}. The highest gross beta activity found in Soil-09 sample is 132±2.07 Bq kg^{-1} which is collected from Golapnagor and the lowest gross beta activity found in Soil-02 sample is 30.74±1.93 Bq kg^{-1} which is collected from Gopinathpur middle of Bahadur and Pakshi**.** From Table 1, it is found that the gross beta activity in soil sample is 25 times higher than the gross alpha activity in soil sample.

3.2. *Gross alpha and gross beta activities in water sample*

The gross alpha activity for water samples is from 0.45 to1.36 mBql^{-1} with an average of 0.91 ± 0.18mBq L^{-1} as illustrated in Table 2. The highest gross alpha activities observed in Water-03 and Water-04 samples are 1.36±0.21 mBq L^{-1} which are collected from Chowton Moor, Bheramara and Bheramara 3No. Bridge, Powrashave Border. The lowest gross alpha activities in Water-09 and Water-10 are 0.45±0.13 mBq L^{-1} which are collected from Plant Area, location-(3) and Plant Area, location -(11)**.** It is also found that the gross beta activity for water samples ranges from 61.49 to 279 mBq L^{-1} with an average of 175 ± 4.02 mBq L^{-1}. The highest gross beta activity found in Water-08 sample is 279±4.17 mBq L^{-1} which is collected from Lalon shah Bridge 1 Km from Pabna and the lowest gross beta activity found in Water-02 sample is 61.49±3.86 mBq L^{-1} which is collected from Porankhali Bazar, Juniadah. The gross beta activity in water sample is higher than the gross alpha activity.

3.3. *Gross alpha and gross beta activities in vegetable sample*

From Table 3, it is observed that the gross alpha activity for vegetable samples ranges from 0.23 to 1.81 Bq kg^{-1} with an average of 1.0 ± 0.11 Bq kg^{-1}. The highest gross alpha activity in Kochu shak (Coco-yam) is 1.81±0.12 Bq kg^{-1} which is collected from Potirajpur, Muladhuli, Ishurdi area and the lowest gross alpha activity in Gajor (Carrot) is 0.23±0.07 Bq kg^{-1} which is collected from Porankhali Bazar, Juniadah. . It is also found that the gross beta activity for vegetable samples ranges from 305 to 1676 Bq kg^{-1} with an average of 930 ± 3.27 Bq kg^{-1}. The highest gross beta activity found in Kacha kola (Plantain) sample is 1676±3.89 Bq kg^{-1} which is collected from Dharampur Gov. Primary School Bheramara and the lowest gross beta activity found in Kochu shak (Coco-yam) sample is 305±2.72 Bq kg^{-1} which is collected from Potirajpur, Muladhuli, Ishwrdi. From Table 3, it is observed that the gross alpha activity in vegetable sample is much lower than the gross beta activity. Use of fertilizer can also increase the concentration of beta radioactivity. Naturally ^{40}K also increases the gross beta radioactivity,

Table 1. Gross alpha and gross beta activities in soil samples.

Location of sample collection	Sample code	Gross alpha activity Bq kg^{-1}	Gross beta activity Bq kg^{-1}
Opposite side of the Padma river and middle of two bridges	Soil-01	1.81±0.14	42.48±1.95
Gopinathpur, middle of Bahadur and Pakshi	Soil-02	2.94±0.16	30.74±1.93
Char Gopinathpur	Soil-03	2.27±0.15	69.18±1.99
Gopinathpur Centre	Soil-04	4.08±0.18	61.08±1.97
Golapnagor	Soil-05	2.27±0.15	106±2.04
Bag Gari Bridge area	Soil-06	5.66±0.21	48.54±1.97
Bangir Moor, Bahadurabadh	Soil-07	2.72±0.16	78.68±2.00
Madhabpur	Soil-08	2.72±0.16	76.66±2.00
Thakur Char Dhoulatpur Gov. Primary School	Soil-09	1.81±0.14	132 ±2.07
Dhoulotpur Gachia	Soil-10	1.13±0.11	73.63±1.99
	Average	2.78±0.16	71.85±1.99
	Maximum	5.66±0.21	132 ±2.07
	Minimum	1.13±0.11	30.74±1.93

Table 2. Gross alpha and gross beta activities in water samples.

Location of sample collection	Sample code	Gross alpha activity (mBq L^{-1})	Gross alpha activity (mBq L^{-1})
Gopinathpur Centre	Water- 01	0.91±0.20	132 ±3.96
Porankhali Bazar, Juniadah	Water- 02	0.91±0.17	61.49±3.86
Chowton Moor, Bheramara	Water- 03	1.36±0.21	269±4.15

Location of sample collection	Sample code	Gross alpha activity (mBq L^{-1})	Gross alpha activity (mBq L^{-1})
Bheramara 3no Bridge, Powrashave Border	Water- 04	1.36±0.21	223 ±4.09
Beside of Chandipur G.K Project	Water- 05	0.91±0.20	225 ±4.09
Naymail, Kachari, Mirpur Thana	Water- 06	0.91±0.20	73.63±3.88
Pabna 39 km Mile Board,Mirpur Thana	Water- 07	0.91±0.17	211 ±4.07
Lalon shah Bridge 1Km Pabna	Water- 08	0.91±0.17	279 ±4.17
Plant area, location-(3)	Water- 09	0.45±0.13	190 ±4.04
Plant area, location (11)	Water- 10	0.45±0.13	81.72±3.89
	Average	0.91± 0.18	175 ±4.02
	Maximum	1.36±0.21	279 ±4.17
	Minimum	0.45±0.13	61.49±3.86

Table 3. Gross alpha and gross beta activities in vegetable samples.

Location of sample collection	Sample name	Gross alpha activity (Bq kg^{-1})	Gross beta activity Bq kg^{-1}
Thakur Chair Dhoulatpur Gov. Primary School	Foolkopi (Cauliflower)	1.59±0.13	1471±3.74
Jagoshor, Porankhali Bheramara	Kacha papay (Green papaya)	0.45±0.09	1367±3.66
Dharampur Gov. Primary School Bheramara	Kacha kola (Plantain)	1.13±0.12	1676±3.89
Porankhali Bazar, Juniadah	Gajor (Carrot)	0.23±0.07	904±3.28
Health and Family Welfare Centre, Bheramara	Begun (Brinjal)	1.59±0.12	1660±3.87
Kharara, Mirpur Thana	Kakrol (Teasle Gourd)	0.45±0.10	332±2..75
Plant area, location-(3)	Mula (Radish)	1.81±0.14	807±3.20
Plant area, location-(4)	Lau shak (Bottle Gourd)	0.45±0.10	426±2.84
Potirajpur, Muladhuli, Ishwrdi	Kochu shak (Coco-yam)	1.81±0.12	305±2.72
PDB Colony, Joynagar, Ishurdi	Tamak (Leaf Tobacco)	0.45±0.10	349±2.77
	Average	1.0 ±0.11	930±3.27
	Maximum	1.81±0.12	1676±3.89
	Minimum	0.23±0.07	305±2.72

A comparison of gross alpha and gross beta radioactivity in soil samples of Bangladesh with different countries around the world is shown in Table 4. Compared to other countries like India, Serbia, Nigeria and Malaysia, the results of gross alpha and gross beta activities in soil sample of Bangladesh are lower [4,6.10,12-14]. A comparison of gross alpha and gross beta radioactivities in water samples of Bangladesh with different countries around the world is given in Table 5.

Table 4. Comparison of gross alpha and gross beta radioactivities in soil sample.

Country	Type of soil	Gross alpha (Bq kg^{-1})	Gross beta (Bq kg^{-1})
Rajasthan (India)	Surface	175-2260	
Serbia	Power Plant Area	66.7-102.4	285.7-607.4
Nigeria	Oil producing fields	152.11-322	311.15-615.5
Nigeria	Chemical fertilizers 1. Single super phosphate 2. NPK Agricultural farm soils 1. North 2. South	 60.0-100.0 20.0-90.0 8.0-40.00 10.00-20.00	 1340.0-1440.0 2410.0-4560.0 360.0-570.0 200.0-230.0
Malaysia	Ground Soils	15-9634	142-6173
Bangladesh (Present Study)	Surface Soils	1.13-5.66	30.74-132

Table 5. Comparison of gross alpha and gross beta radioactivities in water sample.

Country	Type of Water	Gross alpha (Bq L^{-1})	Gross beta (Bq L^{-1})
Nigeria	1. Dug well water 2. Rivers state 3.Ground water(Tap)	0.22×10^{-3}-2.99×10^{-3} 0.11-1.21 0.02-35.1	0.06×10^{-3}-0.58×10^{-3} 0.21-2.03 0.70-151.2
Turkey	1. Ground water 2. Thermal waters	0.08-0.38 0.09-2.58	0.12-3.47 0.25-2.61
Tamil Nadu, India	Drinking water	0.07-0.28	0.76-1.28
Brazil	Surface, Underground, Drinking waters	0.02-0.08	0.01-3.0
Dhaka, Bangladesh	Tap water	1.88×10^{-3}-8.16×10^{-3}	3.76×10^{-3}-29.3×10^{-3}
Dhaka, Bangladesh	Bottled water	$1.4\times10^{-3}\pm0.7\times10^{-3}$	$76.0\times10^{-3}\pm9.8\times10^{-3}$
Bangladesh (Present study)	Surface water	0.45×10^{-3}-1.36×10^{-3}	0.061-0.279

Comparing the values of gross alpha and gross beta activities with others, it is observed that gross alpha and gross beta activities of surface water samples in Bangladesh are lower than surface, underground and drinking water samples of other countries of the world like Nigeria, Turkey, India and Brazil [5,6,15]. It is also observed that the gross alpha and gross beta activities in surface water samples in Bangladesh are lower than the tap and bottled water samples of Bangladesh. The results showed that the activity concentrations of gross alpha and gross beta in surface water samples did not exceed WHO recommended levels and were comparable with the data available in other parts of the world [17].

A comparison of gross alpha and gross beta radioactivities in vegetable samples of Bangladesh with different countries around the world is shown in Table 6.

Table 6. Comparison of gross alpha and gross beta radioactivities in vegetable samples.

Country	Type of sample	Gross alpha Bq kg^{-1}	Gross beta Bq kg^{-1}
Rajasthan (India)	Plant	48.0-477.0	
Ghana	Medicinal Plants	11.73-132.67	124.34-790.58
Southwest India	food crops	497.0 ± 72.0	10946.0 ± 583.0
Bangladesh (Present study)	Vegetable	0.23-1.81	305-1676

In vegetable samples of Bangladesh the gross alpha and gross beta activities are lower than other plants and crop samples from the different parts of India. But gross alpha and gross beta concentration of vegetable samples are higher than the medicinal plant samples of Ghana [10, 16].

4. Conclusion

Natural soil, water and vegetables are not completely free from radioactive isotopes due to the presence of beta and alpha emitters from the natural decay series of uranium, thorium and actinium and other single isotopes such as ^{40}K. The main alpha emitters are ^{238}U, ^{234}U, ^{232}Th, ^{226}Ra and ^{210}Po and the main beta emitters are ^{40}K, ^{228}Ra, ^{210}Pb that can be present in environmental samples in different concentrations. From this study it is observed that the gross beta activity is higher than the gross alpha activity in the collected environmental (soil, water, vegetable) samples from different locations of Bheramara and Ishwardi near the proposed Rooppur Nuclear Power Plant area, Kushtia and Pabna of Bangladesh. In case of soil and vegetable samples of the present study the concentration of gross alpha and gross beta activities are typically lower than the other countries of the world. The gross alpha and gross beta activities in water sample are lower than the recommended value of WHO. There is a limited data for gross alpha and gross beta in Bangladesh and this study will help to provide baseline data for gross alpha and gross beta in environmental samples of Bheramara and Ishwardi near the proposed Rooppur Nuclear Power Plant area, Kushtia and Pabna, Bangladesh that can be used to evaluate the possible changes and the radiological impact on the public health in future.

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