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Assessment of Gross Alpha and Beta Activity on Surface Water Collected from AERE, BCM, and RNPP Construction Site Area, Bangladesh

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Abstract: For this study, surface water was collected from Atomic Energy Research Establishment (AERE) (50 samples), Barapukuria Coal Mine (BCM) (50 samples), and Rooppur Nuclear Power Plant (RNPP) construction site area (44 samples) from individual sampling points. Sample collected, prepared, and measured radiation concentration (gross alpha and beta) in the year 2023. All samples were prepared by following the guidelines of EPA 900 and measured in the screening method with a ZnS scintillation counter. For the sample of AERE, the mean activity of gross alpha was 0.0071±0.0008 BqL^{-1} and the average activity of gross beta was 0.1228±0.0204 BqL^{-1}. For the sample of BCM, the average gross alpha activity was 0.0056±0.0008 BqL^{-1} and the average gross beta activity was 0.1000±0.0206 BqL^{-1}. For the sample of RNPP, mean gross alpha activity was 0.0031±0.0007 BqL^{-1} and mean gross beta activity was 0.1356±0.0207 BqL^{-1}. The average annual effective dose (AED) for the samples of AERE was 0.034 mSvy^{-1}, for samples of BCMCL was 0.0276 mSvy$^{-1,}$ and for the samples of RNPP construction site was 0.0363 mSvy^{-1}. All the measured AED values were less than the WHO reference value, which is 0.1 mSv^{-1}.

Keywords: Gross alpha beta, surface water, AERE, BCM, RNPP, Scintillation counter, EPA, AED.

1 Introduction

Water is the vital element after air to live on this earth. Water may contain radioactive materials as it comes from ground sources, and the radiation activity in water primarily arises from terrestrial radionuclides and daughters of U-238 and Th-232 nuclides, and K-40 in topsoil and rock bed [1]. Different types of radionuclides can get into solution with water according to the geochemical and mineralogical elements of topsoil and bedrock [2]. These radionuclides can be transferred in water and go into the food ecosystem by using water for irrigation or farming purposes. The issues consist of relieving the negative impact of modern society and safe water distribution in ecosystems where the weather is unstable and the populace is developing [3].

Precipitation and different groundwater reservoirs are basic surface water resources. Primarily, streams, boreholes, dams, ponds, and waterfalls are great sources to find surface water [4]. Public activities and environmental events take part in the continuous contamination of water sources and totally diminish the water quality [5]. The release of waste and garbage into the ecosystem and rivers by mills, factories, and hospitals is a major contributor to the issues of water decontamination [6]. Rivers, canals, and pond water should be judged as a probable source of contamination [7].

Alpha, beta, and gamma radiation are frequently incorporated from the U-238 and T-232 series, known as Rn-222 and Rn-220. The radioactive daughters, which are gaseous elements, can produce notable airborne particle activity. These radionuclide particles contribute to the radiation activity of precipitation and groundwater [8]. So, directly or indirectly, by gaseous progeny products of radon and thorium, these molecules entered into bodies through water to the living organ [9]. The water sources region is affected by the concentration of environmental radionuclides decay [10]. It can also be noticed that these concentrations arise in summer because of excessive dissipation and the increase in the amount of melting salt on the comparatively hot water [11].

In the case of gross alpha counting, measure the counts of the entire alpha-emitting nucleus after the Rn-222 is eradicated. Similarly, in the case of gross beta counting, the total counts of beta emitters are kept out of H-3, C-14, and other weak beta emitters [12]. Alpha particles have

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radiation effects twenty times greater than gamma and X-rays in damaging cells and heading towards internal organ damage [13]. Gross alpha in water samples is represented by the disintegration series of U-238 and Th-232, while the activity of gross beta is represented by Ra-228, Pb-210, and K-40 [14].

For this study, the entire surface water samples were collected from pond water of different locations at AERE and BCM area, and Padma River, which flows beside the RNPP in Bangladesh. First sampling location, AERE has its nuclear research reactor and radioactive waste management unit, so there is a possibility of getting higher radiation than the background level in this area. The second sampling region (BCM) is situated adjacent to this coal mine, and it is possible to get radiation from the water of this lake. The third sampling location (RNPP) is adjacent to the construction site of the nuclear power plant of Bangladesh, so investigating the background radiation level is crucial for this site.

From a previous study, the mean radioactivity of U-238, Th-232, and K-40 in soil samples was measured to be 37.8 $Bqkg^{-1}$, 58.2 $Bqkg^{-1,}$ and 790.8 $Bqkg^{-1,}$ respectively, which were collected from the area of AERE. The results of that study were greater than the world average value of U-238, Th-232, and K-40 radionuclides [15, 16]. From the background study of radiation in the BCM area, the measured mean activity of U-238, Th-232, and K-40 were 36.75, 76.79, and 607.18 $Bqkg^{-1,}$ respectively, in passive soil samples which were large compared to the world average values (35, 30 and 400 $Bqkg^{-1}$ respectively) [16, 17]. In functional soil samples, the activity of Ra-226, Th-232, and K-40 was 27.89, 41.52, and 632.45$Bqkg^{-1,}$ respectively, and the values were 32.82, 56.01, and 777.41$Bqkg^{-1,}$ respectively, in the submissive soil samples, which were greater than the worldwide average value [16, 18]. There is no record of measuring the activity concentration of gross alpha, gross beta in these regional water sources. Gross alpha activity ranged from 0.00045 to 0.00136 BqL^{-1} with an average of 0.00091± 0.00018 $BqL^{-1,}$ and the activity of gross beta ranged from 0.061.49 to 0.279 BqL^{-1} for water samples collected from near the RNPP construction site [19].

Ensuring human resources and biodiversity from excess radiation is a prime concern. If baseline data are measured and identify the exact reason behind the rising amount of radiation, it is possible to get protection and reduce the amount of health hazards easily. The method of distinguishing a specific radionuclide in surface water is lengthy and costly. The most common practice is utilizing a screening method that does not depend on the character of individual radionuclides [1]. According to WHO, the limits of the gross alpha and beta are 0.5 BqL^{-1} and 1 $BqL^{-1,}$ respectively [20].

The main focus of this study is to measure the level of gross alpha and gross beta activity and its health risk to the public for the surface water of AERE, BCM, and the area near the construction site of RNPP.

2 Materials and Methods

2.1 Study Area

The Atomic Energy Research Establishment area is situated at Savar Upazila, which is 40 km away from the capital city, Dhaka. Sampling GPS location of AERE ranges from N 23°57′2.58″ to N 23°57′12.12″ and E 090°16′30.54″ to E 090°17′53.1″. This region is located in the southern part of a Pleistocene terrace and the Madhupur tract. Madhupur Clay of the Pleistocene age and alluvial deposits of recent age covering the city and surroundings [21]. BCM is the only active coal mine in Bangladesh [22]. It is located in the northern part of Bangladesh in Dinajpur district sample collection of this area ranges from N 25°32′33.84″ to N 25°33′56.76″ and from E 088°57′16.68″ to E 088°57′57.3″.

The first nuclear power plant of Bangladesh is being constructed beside the Padma River at Rooppur, Pabna in Bangladesh. The sampling area lies between the latitudes of N 23°50′05.0″ to N 24°11′11.3″ and E 088°46′44.5″ to E 089°17′55.5″. Geologically, the Padma River within the considered locale comprises sediment, dregs, especially sand, and rock of Holocene age [23]. The geological survey of Padma River residue within the Rajshahi division proposes that the residues were inferred from a source range containing generally felsic to halfway volcanic rock, conceivably from the Himalayan belt and the Ganga river basin [24].

People who live near these areas utilize water from these sources for different purposes in their daily lives, and water from these sources will also be used as a coolant substance for any emergency when necessary. Considering these terms, the sampling area has been chosen.

2.2 Sample Collection and Preparation

For assessing the radiation activity of gross alpha beta in water (surface) samples, which were randomly collected from AERE (50 samples), BCM (50 samples), and near the RNPP area (44 samples). The samples were collected manually into a cleaned plastic bottle of 1L capacity. Then the samples are identified by an individual code number and then relocated to the chemistry analysis laboratory of the Health Physics Division, Atomic Energy Centre, Dhaka. 144 Pyrex beakers of 1L volume were cleaned with distilled water and kept aside for some time to dry out to avoid contamination with any chemical particles. Each 1 L of water sample is transferred into a Pyrex beaker. About 1 ml of concentrated HNO_3 was mixed with individual water samples to avoid contact with organic components and changes in the oxidation state of the ions available in the specific samples. Subsequently, the surface water samples were steadily vaporized by water bath and hot plate treatment at 85°C to decrease their volume close to dryness (5 ml approximately). The Pyrex beakers were sealed with a watch glass at the time of evaporation of all the samples. Then those reduced samples were shifted to a stainless steel planchette with a size of 2 inches in diameter and dried beneath the IR lamp, cooled down, and weighed to measure dry residue. The sample residues were stored in a desiccator to protect them from dampness [25].

2.3 ZnS Scintillation Counter

In this study, a ZnS Scintillation detector (Model: MPC-900-DP-02) was used for measuring gross alpha-beta count monitoring. There is a custom-designed detector with a zinc sulfide layer bonded to a plastic scintillator. Alpha particles are detected by the outermost layer, and beta particles are detected by the inner layer. The detector has a 2.25-inch diameter, hemispherical gas-flow proportional counter, and can be operated along with or without a computer. The detector has three modes, which are alpha-beta together, only alpha, and only beta modes. Standard sources Th-230 (alpha source) and Sr-90 (beta source) of known activity were used for calibrating the detector. The efficiency of the detector for gross alpha is 36.8% and gross beta is 40.6% [26]. The lower level of detection (LLD) of the detector was calculated using the following Equation (1) [27]:

$$LLD = \frac{\frac{2.71}{count\ time} + 3.29\sqrt{[\frac{Bkg\ cpm}{count\ time}\left(1+\frac{count\ time}{Bkg\ time}\right)]}}{\frac{E}{100}} \quad (1)$$

Where Bkg cpm represented the background count per minute, and E represented the counting efficiency.

The calculated values of LLD of this detector were 0.289 cpm and 9.909 cpm for gross alpha and beta, respectively.

For quality control and assurance of this work, each sample was measured four times, and before starting sample measurement, the detector was calibrated with a standard source. Additionally, background count is measured before each measurement to ensure the precision of this study. During the measurement, the sample was placed closest to the top of the sample carrier because alpha and beta particles radiated at minute angles from the samples kept in deep planchettes can lose energy during interaction with the planchette walls.

2.4 Calculation of gross alpha/beta activity

The following equation (2) was used to evaluate the activity of gross alpha/beta [28]:

$$A = \frac{Net\ CPM \times 100}{V \times 60 \times Eff} \quad (2)$$

Where A is the activity of gross alpha/beta, net CPM represents the alpha/beta count per min, which is the result of background count subtraction from sample count, V is the initial volume of sample, and Eff is the alpha/beta efficiency in percentage.

Error Calculation

An error is considered the difference between the calculated value and the absolute value of a quality or attribute.

Net count per second is the result of subtraction the background count per second from the gross count per second of the sample. Each count per second has a standard deviation, which was evaluated by the following equation (3) [29] as:

$$\sigma = \pm\sqrt{(\frac{As}{Ts} + \frac{Ab}{Tb}} \quad (3)$$

Where, σ is the standard deviation, A_s was the sample count rate (c.p.s.), A_b was the background count rate (c.p.s.), T_s was the sample count time (s), and T_b was the background count time (s).

2.5 Annual effective Dose

It is very easy for ingested radionuclides to be absorbed into the body fluids and get into the internal organs [26]. Because of the hazardous characteristics of these radionuclides on the human body, it is crucial to evaluate the annual effective dose of alpha and beta. Considering water for drinking purposes, the effective dose due to ingestion of gross alpha and gross beta for 1 year was evaluated by using equation (4) [12, 13, 26]:

$$AED = A_{\alpha\beta} \times DI_w \times DCF \quad (4)$$

Where, AED is the annual effective dose ($mSvy^{-1}$), $A_{\alpha\beta}$ is the activity concentration of alpha/beta (BqL^{-1}), DI_w is the amount of water intake in a year (approximately 730 Ly^{-1}), DCF is the dose conversion factor (for alpha is 2.80×10^{-4} and for beta is 6.90×10^{-4}) [20, 30].

3 Results and Discussion

3.1 Activity of Gross Alpha

The gross alpha activity of collected water samples from three different geological regions of national importance is presented in Figure 01.

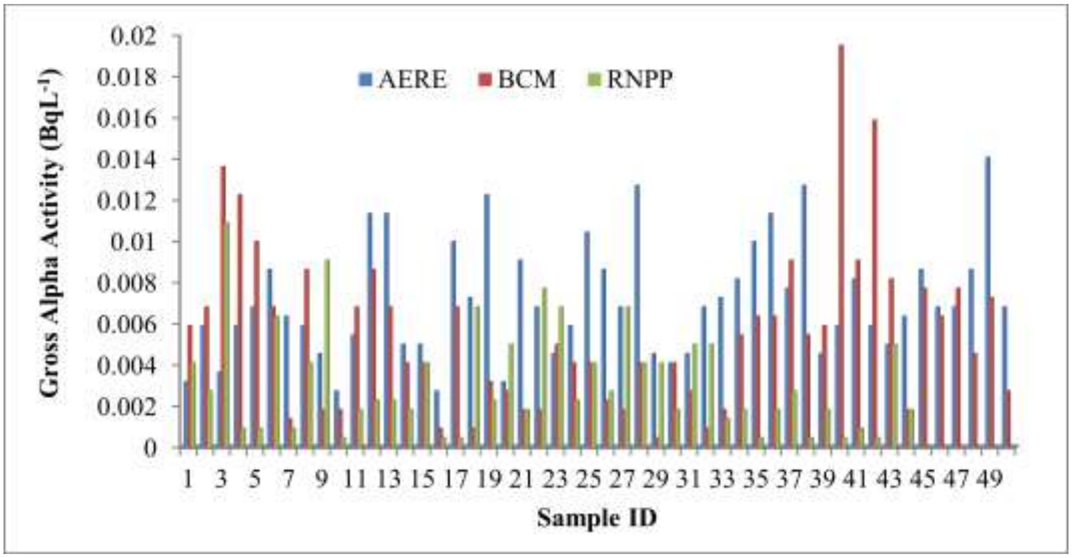

Fig.1: Gross alpha activity of water sample collected from AERE, BCM, and RNPP.

It can be noticed from Figure 01 that the average gross alpha activity was higher on samples collected from the AERE area. The minimum level of gross alpha activity was calculated for the sample collected from the BCM area. The range of gross alpha activity was 0.0027±0.0007 to 0.0140±0.001 BqL^{-1} with an average value of 0.0071±0.0008 BqL^{-1} for the sample of AERE, 0.0005±0.0006 to 0.0195±0.0012 BqL^{-1} with an average value of 0.0056±0.0008 BqL^{-1} for the sample of BCM, and 0.00045±0.0006 to 0.0108±0.001 BqL^{-1} with a mean value of 0.0031±0.0007 BqL^{-1} for the sample of RNPP construction site.

A nuclear reactor of 3MW and the only radioactive waste management unit of Bangladesh is situated at AERE, and a large amount of coal is mined every year from the BCM area. These can be affected by alpha radiation.

The results of gross alpha activity level of the measured samples were beyond the World Health Organization (WHO) accepted limit (0.5 BqL^{-1}) for drinking water [20].

3.2 Activity of Gross Beta

Gross beta activity of collected surface water samples is presented according to the sampling area in Figure 2.

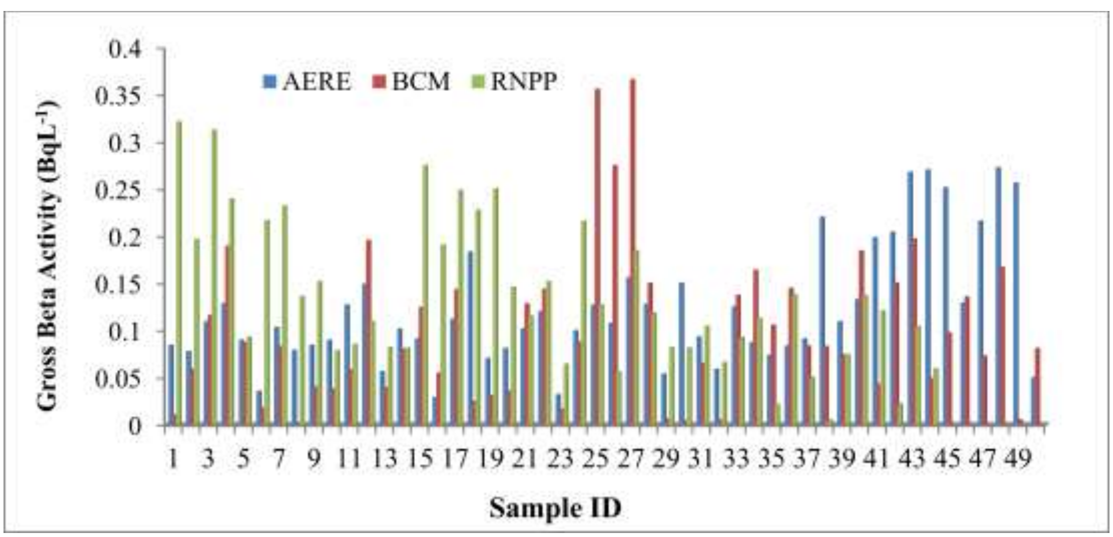

Fig. 2: Gross beta activity of water sample collected from AERE, BCM, and RNPP.

From figure 02 it is notice that the ranged of gross beta activity was 0.0287±0.0203 to 0.2726±0.0206 BqL^{-1} with an average value of 0.1228±0.0204 BqL^{-1} for the sample of AERE, 0.0008±0.0203 to 0.3657±0.021 BqL^{-1} with an average value of 0.1000±0.0206 BqL^{-1} for the sample of BCM and 0.0049±0.0205 to 0.3210±0.0209 BqL^{-1} with a mean value of 0.1356±0.0207 BqL^{-1} for the sample of RNPP region.

Nuclear reactor radioactive waste management unit at AERE, coal mining from BCM area, and the location of RNPP on the bank of Padma River, which has local islands made with sand locally called chor, can be affected by the amount of beta radiation.

The results of gross beta activity level of the measured samples were beyond the accepted limit of WHO (1.0 BqL^{-1}) for drinking water [20].

Table 1: Comparison among the gross alpha/beta activities of this study with the activity measured in other countries of the world and WHO WHO-recommended maximum value.

Sl no.	Country	Detection System	Water type	Gross alpha activity (BqL^{-1})	Gross beta activity (BqL^{-1})	Reference
01.	Nevsehir, Turkey	Gas proportional counter	Ground	80 - 380	120-3470	[1, 26]
02.	Brazil	Surface Barrier Detector	Ground	0.001-0.400	0.120-0.860	[26, 28]
03.	Eastern Black Sea, Turkey	Berthold LB770	Tap	0.0002-0.015	0.025-0.264	[26, 31]
04.	Seven provinces, China	Alpha/Beta multi counter (MPC-9604)	Tap	0.010-1.69	0.045-0.327	[26, 32]
05.	Milano, Italy	LSC	Tap	0.007-0.35	0.025-0.273	[26, 33]
06.	Adana, Turkey	Berthold LB770	Tap	0.0010	0.086	[26, 34]
07.	Saudi Arabia	LSC	Ground	3.51	3.48	[26, 35]
08.	China	Kaplan Meier method	Drinking	0.000498-0.4	0.005-1.26	[26, 36]
09.	Greece	Alpha spectrometry	Bottled	0.082	0.283	[26, 37]
10.	Jordan	HPGe Gamma Detector	Bottled	0.29-31.46	0-50.14	[26, 38]
11.	Ghana	Automatic gross alpha-beta counter	Ground	0.0049-0.086	0.026-1.867	[26, 39]
12.	Katsina State, Nigeria	Gas proportional counter	Ground	0.080-2.300	0.120-4.970	[26, 40]
13.	Batman, Turkey	Berthold LB770	Drinking	0.0108-0.0734	0.003-0.347	[26, 41]
14.	Australia	LSC	Drinking	1.40	1.15	[26, 42]
15.	United Arab Emirates	LSC	Ground	0.01-19.5	0.13-6.6	[26, 43]
16.	Bucovina, Romania	ZnS Scintillation detector	Spring	0.001-0.0055	0.016-0.031	[44]
17.	Delta Company, Nigeria	Gas proportional counter	Ground	0.0064	0.0182	[26, 45]
18.	Zhuhai City, China	Reverse osmosis membrane method	Ground	0.14	4.22	[26]
19.	Northern Vietnam	Gas proportional counter	Spa and mineral	0.0046-0.119	0.001-0.189	[26, 46]
20.	Karnataka state, India	-	Ground	0.00069-0.01526	0.0146-0.1085	[26, 47]
21.	Dhaka Bangladesh	ZnS (Ag) Scintillation detector	Tap	0.00046-0.016	0.0032-0.0579	[26]
22.	WHO Recommended value	-	Drinking	0.5	1.0	[20]
23.	**This Study**					
	AERE	ZnS (Ag) Scintillation detector	Surface water	0.0071±0.0008	0.1228±0.0204	-
	BCM			0.0056±0.0008	0.1000±0.0206	-
	RNPP			0.0031±0.0007	0.1356±0.0207	-

The gross alpha/beta activities of the investigated samples were less than the activity of samples from Turkey, China, Saudi Arabia, Australia, and the United Arab Emirates [1, 26, 32, 35, 42, 43]. However, the radiation activity of samples from Dhaka, Bangladesh, and Karnataka, India, was lower than the results of this study [26, 47]. These significant differences among these results might occur due to water sources, detectors, methods, and geological characteristics of sampling points.

3.3 Annual Effective Dose

According to the measured value of gross alpha/beta in these collected surface waters, annual effective doses were evaluated and represented in Figure 3.

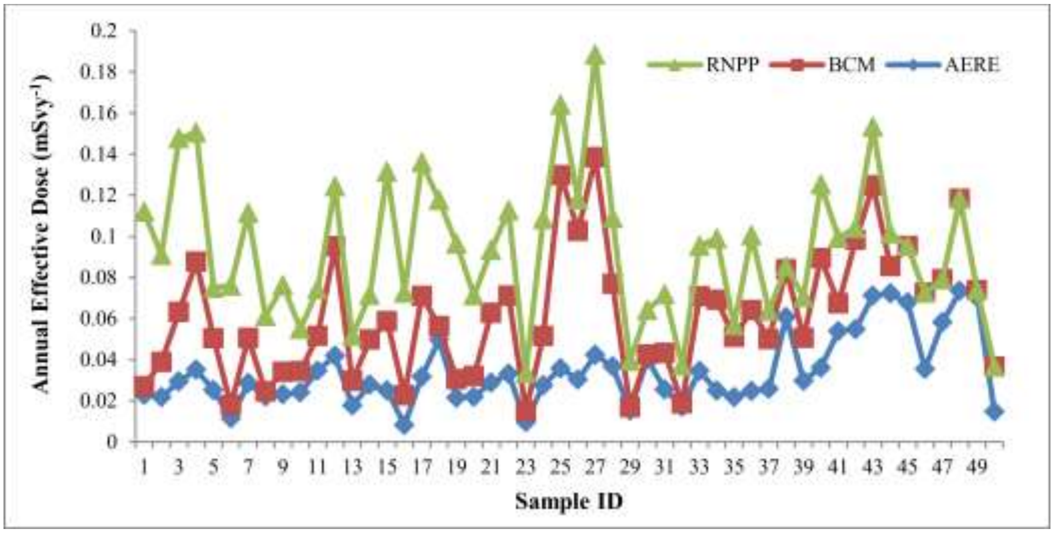

Fig.3: Annual effective dose of water sample collected from AERE, BCM, and RNPP.

Among these three regions total AED for gross alpha/ beta, on average, the lower level of AED measured for the water samples of AERE and higher level of AED noticed for the surface water of the RNPP area. The range of AED value for AERE lies between 0.0082 to 0.0735 mSvy^{-1} with an average value of 0.034 mSvy^{-1}. The value of AED for the sample collected from the BCM area lies between 0.0015 to 0.0961 mSvy^{-1} with an average value of 0.0276 mSvy^{-1}. The level of AED for the collected samples of RNPP construction sites is 0.0014 to 0.085 mSvy^{-1} with an average value of 0.0363 mSvy^{-1}. Any of these evaluated AED values was higher [48-50].

Than the acceptable public annual effective dose limit (0.1 mSv^{-1}) [51].

4 Conclusions

In this study, the activities of gross alpha/beta were measured for 144 water (surface) samples, which were collected from three important regions of Bangladesh: AERE, BCM, and RNPP. The RNPP is not in operation yet; on the other hand 3 MW nuclear reactor and a radioactivity waste management unit are in AERE, and BCM is the only active coal mine in Bangladesh. A large number of manpower and the public are involved in these areas for work purposes and use water from the reservoir for sample collection. The average activity of gross alpha was 0.1228±0.0204 BqL^{-1} for the sample of AERE,0.1000±0.0206 BqL^{-1} for the sample of BCM, and 0.1356±0.0207 BqL^{-1} for the sample of RNPP region. The average activity of gross beta was 0.1228±0.0204 BqL^{-1} for the sample of AERE, 0.1000±0.0206 BqL^{-1} for the sample of BCM, and 0.1356±0.0207 BqL^{-1} for the sample of RNPP region. There was no gross alpha/beta activity of surface water measured for this study that was higher than the acceptable limit of WHO, which value is 0.5 BqL^{-1} for gross alpha and 1.0 BqL^{-1} for gross beta. From this study, these waters are safe for daily use according to the limit of gross alpha/beta and AED. The average AED were 0.034 mSvy^{-1}, 0.0276 mSvy$^{-1,}$ and 0.0363 mSvy^{-1} for the regions of AERE, BCM, and RNPP, respectively. The output of this study can be utilized as a reference for preparing national baseline data of gross alpha/beta radioactivity measurement in water samples. Further investigation is required for detailed radioactivity measurement of other radiations and chemical properties in these samples.

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