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Study of Gross Alpha and Gross Beta Activity in Bottled Water in Dhaka City of Bangladesh

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Abstract: Gross alpha and gross beta particle activity was selected for the screening of radioactive species. The purpose of this study is to determine gross alpha and gross beta activities in bottled water samples. Sixteen different branded bottled water samples were collected from different markets in Dhaka city and analyzed by dual phosphor Zinc Sulphide Scintillation Detector, ZnS(Ag) for the measurement of gross alpha and gross beta activity. The observed gross alpha activity concentration ranged from 0.73 ± 0.02 $mBqL^{-1}$ to 0.96 ± 0.07 $mBqL^{-1}$ with an average 0.83 ± 0.057 $mBqL^{-1}$ while gross beta activity concentration ranged from 65.54 ± 0.98 $mBqL^{-1}$ to 77.29 ± 2.04 $mBqL^{-1}$ with an average 71.47 ± 3.44 $mBqL^{-1}$. The obtained results showed that the average activity concentrations of alpha and beta emitting radionuclides in the bottled water samples did not exceed WHO recommended limits and The Environmental Conversation Rule of Bangladesh, 1997. The results of gross alpha and gross beta activities in bottled water were compared with the corresponding global values. To ensure the safe level of radioactivity in drinking water, however, periodic monitoring of water quality for compliance is necessary. This study will help to prepare baseline data for gross alpha and gross beta radioactivity in bottled water that can be used to evaluate the possible changes and the radiological impact on the public health in future.

Key words: Gross alpha and gross beta radioactivity, bottled water and zinc sulphide scintillation detector, ZnS(Ag).

Introduction

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 (Agbalagba and Avwiri, 2012). 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 (Bronzoviæ1 et al., 2006). 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 the human beings (Ferdous et al., 2012).

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Waters contain 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 resulting in the ingestion of radioisotopes of terrestrial origin 0.29 mSv, from 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. The ^{238}U represents 99.28% of the natural uranium which is found in the whole Earth's crust in form of uranium ores (Sousa Silva and Pecequilo, 2011). The main emitters of alpha that can be present in water 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 (Ferdous et al., 2012). The identification and concentration of each radionuclide present in the water requires expensive time-consuming analyses that are many times unnecessary. In general, gross alpha and beta analysis, one of the simplest radio analytical procedures, is used as the first step as a screening method, for being a very fast, safe and low cost method (Sousa Silva and Pecequilo, 2011). This study will be helpful to prepare baseline data for gross alpha and gross beta radioactivity in bottled water sample, which will be used as finger print for the comparison of radioactivity level.

Sample Collection and Sample Preparation

In order to measure gross alpha and gross beta activity in bottle waters, sixteen bottled water samples were collected randomly from different markets of Dhaka city. All the containers were of the same geometry and the samples were of about one litre each. The samples were appropriately coded from 1 to14. Sixteen 1L capacity Pyrex beakers were washed with distilled water and 1N HNO_3, then left to dry to avoid sample contamination. About 1L of each sample was poured into a Pyrex beaker. One millilitre 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 bottled water samples were slowly evaporated by water bath treatment at 105°C in order to reduce its volume near to dryness. During evaporation of 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 IR lamp, cooled and weighed to determine dry residue. The sample residue was kept in desiccators to avoid moisture (U.S. EPA-900, 1980).

Zinc Sulphide Scintillation Detector

ZnS Scintillation counter is a dual phosphor detector or dual scintillation detectors coupling two scintillating materials to a photomultiplier tube. These detectors are sometimes referred to as a "phoswich" (for phosphor sandwich). The MPC-2000-B-DP contains a custom designed detector with a zinc sulphide 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 (Manual MPC - 2000). Calculations must be performed on the raw data in order to produce a meaningful report. These calculations 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 $Bqkg^{-1}$ and BqL^{-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. ZnS scintillation counter is a dual phosphor detector coupling two scintillating materials to a photomultiplier tube. Known activity standard source 230-Th and 90-Sr 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 minutes for gross alpha and gross beta activities for each counting period. A blank planchette was used for background count. Subtraction of the background count from the sample count gives the net count of the water sample.

Calculation of Gross Alpha/Beta Activity

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

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

where DPM = Alpha/Beta disintegration per minute, NET_CPM = Net alpha/beta count per minute and EFF = Alpha/Beta efficiency percent.

Error Calculation

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 and the standard deviation of the net count rate can be expressed as

$$\boldsymbol{\sigma} = \pm\sqrt{\frac{\mathbf{A_s}}{\mathbf{T_s}} + \frac{\mathbf{A_b}}{\mathbf{T_b}}} \quad (2)$$

where **σ =** standard deviation, $\mathbf{A_s}$ = sample count rate in c.p.s., $\mathbf{A_b}$ = background count rate in c.p.s., $\mathbf{T_s}$ = sample count time and $\mathbf{T_b}$ = background count time.

The standard deviation is also a measure of the dispersion of a collection of numbers. It can apply to a probability distribution, a random variable, a population or a data set. The standard deviation is usually denoted with the letter **σ.** The measurement errors represent one-sigma uncertainties.

pH Meter

A BOECO BT600 Laboratory Microprocessor pH/ORP was used for measuring the pH values of bottled water samples which were collected from different markets of Dhaka city. The wetting cap must be pulled off for the calibrating and measuring operations. To ensure precise calibration, hot steam sterilized, certified buffer ampoules in accordance with DIN 19 266 are used. The refilling hole of the pH combination electrodes with liquid electrolyte must be open during the calibrating and measuring operations (Manual of pH, BT-600).

Results and Discussion

Gross Alpha and Gross Beta Activity in Bottled Water Sample

The measured activity of gross alpha in bottled water samples of different markets in Dhaka city are gathered in Table 1. It is observed that the highest gross alpha

Table 1: Gross alpha and gross beta activity in bottled water samples

Name of the sample	*Gross alpha activity (mBqL^{-1})*	*Gross beta activity (mBqL^{-1})*
Mum	0.76 ± 0.04	68.72 ± 1.63
Fresh	0.79 ± 0.05	74.02 ± 1.57
Jibon	0.85 ± 0.06	77.29 ± 2.04
Muskan	0.96 ± 0.07	69.73 ± 1.44
Dada	0.83 ± 0.05	74.08 ± 1.97
Pani	0.92 ± 0.07	67.92 ± 1.23
Spa	0.84 ± 0.04	73.07 ± 2.10
Pran	0.86 ± 0.05	68.96 ± 1.33
Acme	0.85 ± 0.05	74.36 ± 1.91
Ifad	0.79 ± 0.03	71.78 ± 1.87
Farweast	0.83 ± 0.05	67.21 ± 1.24
Evain	0.78 ± 0.05	71.08 ± 1.76
ICL	0.87 ± 0.06	76.51 ± 1.55
Falguni	0.81 ± 0.05	73.98 ± 1.48
Aquafina	0.73 ± 0.02	69.32 ± 1.53
Dancan	0.84 ± 0.05	65.54 ± 0.98
Average	0.83	71.47
Standard deviation	0.057	3.44
Maximum	0.96 ± 0.07	77.29 ± 2.04
Minimum	0.73 ± 0.02	65.54 ± 0.98

activity found in bottled water samples is 0.96 ± 0.07 $mBqL^{-1}$ and the lowest gross alpha activity found in bottled water samples is 0.73 ± 0.09 $mBqL^{-1}$. The average gross alpha activity found in the bottled water samples is 0.83 ± 0.057 $mBqL^{-1}$. The measured activity of gross beta in bottled water samples of different markets in Dhaka city are shown in Table 1. It is observed that the highest gross beta activity found in bottled water samples is 77.29 ± 1.94 $mBqL^{-1}$ and the lowest gross beta activity found in bottled water samples is 65.54 ± 1.59 $mBqL^{-1}$. The average gross beta activity found in bottled water samples is 71.47 ± 0.12 $mBqL^{-1}$.

From Figure 1, it is observed that the highest gross alpha activity is found in 'Muskan' among the bottled water in Dhaka city and the lowest gross alpha activity is found in 'Aquafina'. The gross alpha activity in water sample primarily comprised uranium decay products such as ^{226}Ra. WHO recommends the parameter of gross alpha activity concentration to be 0.5 BqL^{-1}. If the gross alpha activity does not exceed 0.5 BqL^{-1}, it can be assumed that the annual total indicative dose is less than 0.1 mSv per year. The results obtained show that the measured activity of gross alpha in all bottled water samples are less than 0.5 BqL^{-1} which is the limit recommended by WHO (Guidelines for Drinking-water Quality, 2006).

It is found from Figure 2 that the highest gross beta activity is found in 'Jibon' and the lowest gross beta activity is observed in 'Dancan'. The gross beta activity in water sample primarily comprised uranium decay products such as ^{228}Ra and non-decay series ^{40}K. WHO recommends the levels of gross beta activity concentration to be 1.0 BqL^{-1}. If the gross beta activity does not exceed 1.0 BqL^{-1}, it can be assumed that the annual total indicative dose of adults is less than 0.1 mSv per year. The results obtained show that the measured activity concentrations of gross beta in all bottled water samples are less than 1.0 BqL^{-1} which is the limit recommended by WHO (Guidelines for Drinking-water Quality, 2006).

The activity of gross alpha and gross beta in the bottled water samples were studied and compared with the global values in Table 2. This comparison has shown

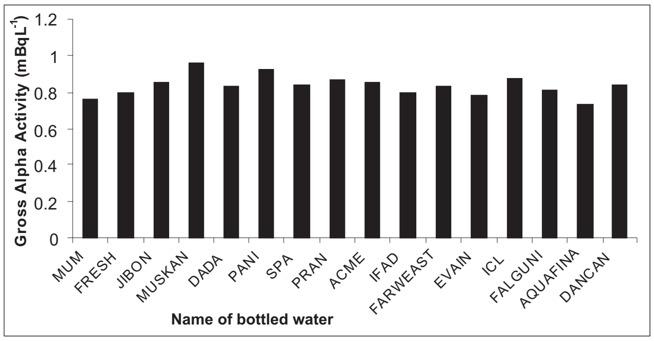

Figure 1: A bar diagram of gross alpha activity in bottled water samples.

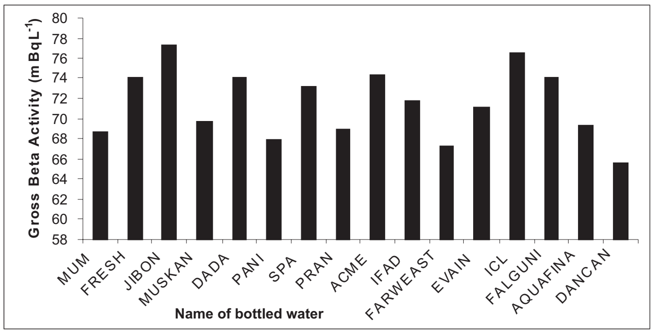

Figure 2: A bar diagram of gross beta activity in bottled water samples.

Table 2: Comparison with other countries

Country	*Type of water*	*Gross alpha (BqL^{-1})*	*Gross beta (BqL^{-1})*
Greece	Bottle water	0.008-0.094	0.071-0.350
Australia	Drinking water	0.7-1.40	0.98-1.15
Mexico	Mineral water	<0.011-0.415	<0.026-0.695
Turkey	Tap water	0.0002-0.015	0.0252-0.2644
Brazil	Ground water	0.001-0.4	0.12-0.86
Italy	Tap water Tap water Tap water	<0.0077-0.349 <0.008-0.186 <0.01812-0.1282	<0.025-0.273 <0.048-0.150 <0.04157-0.25859
India	Surface water	0.061-0.127	0.144-0.361
Dhaka, Bangladesh	Tap water	0.0037 ± 0.0015	0.0604 ± 0.023
Bangladesh (Present study)	Bottle water	0.00087 ± 0.00002	0.10232 ± 0.00012

that the measured gross alpha activity in bottled water samples of Bangladesh is higher than the tap water samples of Turkey (Dalma et al., 2006) and is lower with respect to the tap water samples of Bangladesh, Italy and India (Ferdous et al., 2012; Forte et al., 2002; Jha et al., 2009), the mineral water samples of Mexico (Davilla Rangel et al., 2001), drinking water samples of Australia (Crodriguez et al., 2009), ground water samples of Brazil (Malanca et al., 1998), and bottled water samples of Greece (Karamanis et al., 2007). Similarly it is also evaluated that gross beta activity in bottled water samples in Bangladesh is higher than the tap water samples of Bangladesh, Turkey and Italy (Ferdous et al., 2012; Dalma et al., 2006; Forte et al., 2002), the mineral water samples of Mexico (Davilla Rangel et al., 2001), and bottled water samples of Greece (Karamanis et al., 2007) but is lower than the surface water samples of India (Jha et al., 2009), ground water samples of Brazil (Malanca et al., 1998) and the drinking water of Australia (Crodriguez et al., 2009). The results showed that the activity concentrations of gross alpha and gross beta in bottled water samples did not exceed WHO recommended levels (WHO, 2006) and were comparable with the data available in other parts of the world. From the present study, it is also observed that the measured gross alpha and gross beta activities in bottled water samples in Bangladesh are also lower than the Environment Conservation Rules, 1997 of Bangladesh which recommended levels for gross alpha activity is 0.01 BqL^{-1} and gross beta activity is 0.1 BqL^{-1} (Environment Conservation Rules, 1997). So it can be assumed that the bottled water samples available in Dhaka as well as in Bangladesh are safe for public health.

pH in Bottled Water Samples

A BOECO BT600 Laboratory Microprocessor pH/ORP was used for measuring the pH values of bottled water samples which were collected from different markets of Dhaka city. The recommended guideline values for drinking water are presented in Table 3.

The presence of dissolved solids in water does affect its taste. Water with pH lower than 4.0 have a sour taste and above 8.5 an alkaline bitter taste (EC 1998). High pH induces the formation of tri-halomethanes, which are toxic. pH below 6.5 starts corrosion in pipes, thereby releasing toxic metals such as Zn, Pb, Cd and Cu, etc. The amount of radioactive material in a sample of air, water, soil, or other material can be assessed using several analyses (Bronzoviæ1 et al., 2006). It is found that the bottled water samples analyzed had pH values between 6.9 and 7.1. The highest value of pH is found 7.5 in the sample ‘Fresh’ and the lowest value of pH is found 6.9 in the sample ‘Dada’. The observed values of pH in bottled water samples did not exceed the recommended limits of Bangladesh Environment Conservation Rules, 1997 (Environment Conservation Rules, 1997).

Table 3: Physical parameters of fourteen Bangladeshi bottled water

Sl. No.	*Name of the samples*	*pH*
1	Mum	7.0
2	**Fresh**	**7.1**
3	Jibon	7.4
4	Muskan	7.3
5	**Dada**	**6.9**
6	Pani	7.1
7	Spa	7.0
8	Pran	7.0
9	Acme	7.0
10	Ifad	7.3
11	Farweast	7.1
12	Evain	7.3
13	ICL	7.2
14	Falguni	7.2
15.	Aquafina	7.0
16.	Dancan	7.0

Conclusion

The gross alpha and gross beta activity measurement method is a screening technique for monitoring of drinking water. No radionuclide specific information can be obtained from this method. In the present study, the different branded bottled water samples in Bangladesh were analyzed for the gross alpha and gross beta activities using Zinc Sulphide Scintillation Detector ZnS(Ag). The average activity of gross alpha and gross beta in the bottled water samples are 0.83 ± 0.057 $mBqL^{-1}$ and 71.47 ± 3.44 $mBqL^{-1}$ which are below the WHO recommended limits and the Environmental Conservation Rule of Bangladesh, 1997. The variation in their activity levels have been observed to be lying within the activity values measured all over the world. It suggests that the radioactivity in bottled water for the people residing in Dhaka city is not yet a problem. The data gathered in this study will provide base–line radiometric values of bottled 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 beta activities in drinking water and the radiological impact on the public health.

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