Natural Radionuclides Present in Air and Water near Nuclear Research Reactor Savar Bangladesh

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Abstract—The radioactivity levels of naturally occurring radionuclides ^{226}Ra, ^{228}Ra and ^{40}K in eighteen water and eight air samples, collected from Savar Atomic Energy Center Bangladesh, were determined using gamma ray spectrometry system using a High Purity Germanium (HPGe) detector of 40% relative efficiency. The air samples had activity concentrations of ^{226}Ra, ^{228}Ra and ^{40}K varied from 1.49±0.00 to 613.56±0.01, 0.00±0.01 to 79.90±0.02 and 19.70±0.05 to 206.82±0.00 mBq/m^{3}respectively. The calculated average activity concentrations of ^{226}Ra, ^{228}Ra and ^{40}K in the collected air samples were 267.49±0.01 mBq/m^3, 10.94±0.01mBq/m^3 and 70.03±0.05mBq/m^3, respectively. The average activity concentration of ^{228}Ra and ^{40}K in the present study is lower than that of the world-wide average value but the concentration for^{226}Ra in some places area bit higher than the world average of 420 mBq/m^3. The ^{228}Ra/^{226}Ra ratio for air samples varied between 0.01 and 4.39 with an average of 0.62. The activity concentrations of ^{226}Ra, ^{228}Ra and ^{40}K in the collected water samples varied between 3.83±0.85 to 5.51±0.89, 0.27±0.17 to 2.14±0.26, 48.31±3.97 to 148.14±25.28 mBq/L respectively; while the calculated average activity concentrations of ^{226}Ra, ^{228}Ra and ^{40}K in the collected water samples were 4.86±0.88 mBq/L, 1.17±0.21 mBq/Land 70.03±0.05mBq/L, respectively. These radioactivity of ^{226}Ra, ^{228}Ra and ^{40}K average are far below than the World Health Organization (WHO) permissible levels of 1.0, 0.1 and 10 Bq/L respectively. The ^{228}Ra/^{226}Ra ratio for water samples varied between 0.05 and 0.39 with an average of 0.24.These results indicates that overall the water and air of the studied Savar region is safe from radiological risks and will not be harmful effect to the environment. The results of this study may provide valuable information about radiation threats and also serve as the baseline data in the monitoring of environmental radioactivity in Bangladesh under study.

Index Terms—Air samples, Gamma-ray spectrometry, Radioactivity, Water samples,Water and air parameters,Water and air water monitor

1 INTRODUCTION

THE natural or artificial radioactive elements existing in the environment are key sources of radiation exposure for humans and comprise the background radiation. Knowing the distribution of these radionuclides is essential for evaluating the effects of radiation risks. The terrestrial background is due to numerous radioactive nuclides that are existing in air, soil, water and building supplies whose amountdifferconsiderablysubject to the geological and geographical topographies of anarea. The cosmic radiationbegins from space as cosmic rays whose impact to the background variesprimarily with altitude and latitude. In addition, the level of background radiation in an area is significantly affected from man-made sources e.g. nuclear activities and accidents [1]. Research is ongoing in detercting natural radioactivity in air, soil and drinking water samples all over the world. Survey have been accomplishedspecifically in northern Turkey, which were significantly affected during the Chernobyl nuclear disaster[2]. But the extent in such research is typicallyincomplete and data for other parts of the country are needed for a complete valuation of the country's background radiation level.

Background radiation

Background radiation has natural and man-made sources: cosmic rays, terrestrial radiation, and radiation in food. Human encounter these in their normal activities. Airlines passengers during flights receive small quantities of cosmic radiation from outer space. Terrestrial radiation consisits of several natural radioactive sources, e.g. Radon, in the air and water. Food that contains isotopes e.g.^{14}C and ^{40}K could lead to small radiation doses. In addition, plants and creatures/animals that uptake radioactive elements from soil or food could accumulate radioactive materials. The averaged annual natural radiation a person in USAmeets is around 3.1mSv [3], mainly contributed from Radon gas (2mSv) in the air. Also, the actual dose changes from place to place by at least a factor of 10. Because of that, if only average value of the background radiation is considered, then this can give a measurement error in dermining a person's detection of radiation.

Some places in a country can have higher dose rates than the country dose averages. Generally, in the world remarkably high natural background locations areRamsar, Iran;Guarapari, Brazil;Karunagappalli, India;Yangjiang, China and Arkaroola, Australia [4]. The highest level of purely natural radiation recorded on the Earth's surface was 90 μGy/h on a Brazilian black beach consisting of monazite. This is equivalent to 0.8 Gy/yr for year-round continuous exposure, but the ratesdiffer seasonally and are much lower in the nearest residences. Tourist beaches in Guarapari and Cumuruxatiba were evaluated at 14 and 15 μGy/h.

In the U.S., RadNet has over 100 air monitors nationwide for

measuring β particle rate and γ radiation in the air, and it collects drinking water samples for γ composite analysis from 78 locationsthroughout the country [5].NAREL's radiological methodologies report informs that various detectors are working to examine the radioactivity and dose level of the water and air samples [6].

Air

Due to atmospheric testing of nuclear explosive devices and releases from nuclear reactors, mankind has significantly increased the radiation in our environment. Radionuclides found in radioactive fallout (e.g. ^{131}I, ^{133}I, ^{134}Cs, ^{137}Cs, ^{95}Zr, ^{141}Ce, ^{95}Nb, ^{132}Te) and in the Chernobyl fallout (e.g. ^{131}I and ^{137}Cs) contribute a lot to human exposure. Maximum permissible dose (MPD) for non-occupationally exposed individual is given as 1mSv/yr. Ionizing radiation is dangerous at high doses, and therefore it is essential to know the level of radiation within our living environment due to health risks involved[7].

There several studies performed by researchers around the world to figure out the amount of radioactivity in the atmosphere. Fifty four (54) radioactive sediment samples obtained from 18 places along theVojvodinaarea of the Danube were used to determine the type of radioactivity in that area.^{232}Th and ^{40}K were found, and also^{137}Cs content of Chernobyl origin was detected. These results are associated with those obtained through four years right after the Chernobyl nuclear disaster[7]. For the last several decades until a few years back, uranium mines were used in Central Portugal and wastewaters from uranium ore milling facilities were discharged into rivers. After testing, it was concluded that current levels of enhanced radioactivity do not show a substantial radiological risk either to aquatic living environment or to consumers having freshwater fish[8]. A short review is made on atmospheric radionuclides with emphasis on their activity concentrations in the troposphere, mostly for surface air over Europe. Those species which have activity concentrations above about 1 mBq/m^{3}and the sources of the present radionuclides are discussed[9].

Determinations of ^{210}Pb in aerosol of particle sizes of 0.015-16 μm have been examined from air volumes of 35-100 m^3 by alpha-spectrometry via ^{210}Po after equilibrium has been established, i.e. within a few years later, or directly by equipments using pulse shape analysis right after sample collection. Similarly, the ^{210}Bi/^{210}Pb and the ^{210}Po/^{210}Pb ratios were attained [10]. The size distributions of the cosmogenic^{7}Be and of the long-lived radon progeny ^{210}Pb in ambient aerosols were examined continuously from December 1994 to late March 1996 in ground air at a location in southern part of Germany. Comparing the activity median diameters observed in summer with those in winter, it was observed that there was on average significantly lower diameters in summer indicating shorter residence times in the summer months[11]

Water

Natural radioactivity in water has been tested in various countries. Radioactivity has been analyzed in Balkan sites [12]. Outdoor radioactivity of air, water and soil were measured of Sanlufta area, Turkey [13]. Radioactivity in community water supplies was also tested in Nigeria [14]. Natural radioactivity in Algeria was also analysed in the bottled waters[15]. Surface and ground water was tested for natural radionuclidesin Ogba, Egbema and Ndoni Local Government Area of Rivers State, Nigeria [16]Radioactivity was determined in Euphrates river[17]. Natural radio-isotopes in mineral waters obtained in bottles were tested from Poland[18]. Natural radioactivity in Australian bottled water was also analyzed [19]. Natural radioactivity of ground water in mountains of Poland were analyzed [20]. Radioactivity of drinking water in Nigeria was tested [21]. Measurement of 226Ra in water in river was done in Malaysia [22]. Natural radioactivity in fossil groundwater in Middle East was also tested [23]. In the district of Kuala Krairadioactivity of ^{226}Ra, ^{228}Ra and ^{40}K in soil was measured by gamma spectrometry [24]. Natural radioactivity in bottled mineral,natural spring, and therapeutic waters in Poland were also analyzed [25]. Radioactivity was tested for drinking water in Spain[26]. Radionuclides in drinking water was tested also in USA [27]. Natural radioactivity (^{226}Ra and ^{228}Ra) in public water supplied were analyzedusing a gamma-ray spectrometer[28]. In Finland, natural radioactivity in drinking water was tested[29]. Bottled mineral waters were tested for radioactivity in Algeria[30]. Radioactivity of drainage ponds and wetlands were analyzed in Illinois, USA[31]. Radioactivity was also tested in sediments of Karnaphuliriver and Bay of Bengal Bangladesh[32]. IAEA has an updated database for natural materials(biological and environmental reference materials)[33]. Natural radionuclides were also analyzed in soil of western Macedonia [34].

Naturally occurring radionuclides such as ^{238} U, ^{232}Th and ^{40} K and their progeny existing in air, water and soil causes radiation exposure for the population. The activity levels of these nuclides are analyzed in many countries as well as in Bangladesh to evaluate radiation level in the environment. Several studies have been performed to regulate the activity of naturally occurring radionuclides in the air and water samples throughout Bangladesh and to derive the radiation hazard parameters to start the radiation background database. There are not many studies performed for the northern Bangladesh, one work reports on the area of elevated radiation background in Bangladesh. There are many techniques to examine the amount of radioactivity in the environment. One of the extensively used techniques is gamma-ray spectrometry which is common to all low-level radioanalysis and can be applicable to other environment contaminants [35]. The analysis was performed using high resolution γ-ray spectroscopy with an HPGe detector in a low background conformation in Health Physics Division, Bangladesh Atomic Energy Centre (BAEC), Dhaka.

2 MATERIALS AND METHODS

2.1 Sample Collection

Sampling site was chosen in the North-western part of Dhaka, Savar for the collection of air and water samples. Savar has a

latitude of 23°58′N and longitude 90°20′ E. Air was collected from the Savar research reactor site and also water was collected from various locations around the research reactor. Air filter was used and put on for one hour each time the reading was taken around the Savar research reactor. Water data were collected from various water bodies (surface water from ponds) around the reactor in one liter bottles. Both the air and water samples were obtained while the reactor was in active mode.

2.3 Sample Preparation

Air samples were collected and the air filters were first put into polythene bags and kept inside the detector for measurement of radioactivity. Each water samples in 1 liter bottles were first transferred into 1 liter Pyrex beckers and mixed with 1 ml Nitric acid. The 1 liter becker with the water sample were put into a water bath to warm up. The water evaporates and reduces to 250 ml of water. Then water sample was cooled. This reduced treated water sample was then transferred into a container and put into the detector for radioactivity measurements.

2.4 Radioactivity Measurements

Radioactivity in air and water samples were measured by gamma ray spectrometry system. The gamma ray spectrometry system comprised of a High Purity Germanium (HPGe) detector, a detector shield, a linear amplifier, a preamplifier, a multichannel analyzer, high voltage power supply and a printer. The mass of the samples were differentdue to the various density of the sample material. The counting time was 5000 s for each sample. Direct determination of ^{226}Ra and ^{228}Ra in the samples without any chemical treatment using semiconductor γ-ray spectrometer is difficult because radionuclides do not emit any high intensity γ-rays (lines) of their own. But they have several progenies which are more intensive having activities equal to their parents in the state of equilibrium [36]. Therefore, the analysis of the radionuclides counted on detecting emissions from their progenies. The radioactivity concentration of ^{226}Ra was obtained from γ-ray energies of its daughter ^{214}Bi (609.31 keV) while the ^{228}Ra was obtained from γ-ray energies of its daughter ^{228}Ac (911.07 keV). The radioactivity concentration of ^{40}K was obtained from the γ-ray energy of 1460.80 keV. The efficiency calibration of the detector was obtained by standard sources and the geometry of the counting samples was the same as that of the standard samples. Having established the efficiency curve, the measurements of radioactivity in plant and soil samples were carried out. Due to the to naturally occurring radionuclides being present in the environment around the detector, prior to sample counting, two background counts were taken during weekends for 5000 s each. The average of this background was then subtracted from the samples counted during that week. The integral counts under the interested gamma-energy peaks were done. The gamma activity was obtained by the measured efficiency of the detector from the following equation[37]:

$$A = \frac{C}{\varepsilon(E) \times P\gamma(E) \times W}$$

where, A is the activity in Bq/kg; C is the net gamma counting rate in count per second (cps); ε(E) is the efficiency of the detector at energy E (keV); Pγ is the photon emission probability at energy E (keV) intensity of the radionuclide and W is the dry mass of the sample.

3 RESULTS AND DISCUSSION

3.1 Radioactivity Concentration of ^{226}Ra, ^{228}Ra and ^{40}K in air

The activity concentrations of ^{226}Ra (^{238}U Chain) for air of Savar were found to be within the range of 1.49±0.00to 613.56±0.01mBq/m^3 (Table 1).The average value for ^{226}Ra of air of Savar was found 267.49±0.01mBq/m^3. The average activity concentration of ^{228}Ra (^{232}Th Chain) in air from Savar was 10.94±0.01mBq/m^{3}with a range of 0.00±0.01to 79.90±0.02mBq/m^3. The radioactivity concentration of ^{40}K (non-chained) ranged from 19.70±0.05to 206.82±0.00mBq/m^3 with an average value of 70.03±0.05mBq/m^3. Radioactivity of ^{226}Ra, ^{228}Ra and ^{40}K was measured near the savar research reactor when the reactor was in active mode. The ^{228}Ra/^{226}Ra ratio for air samples varied between 0.01 and 4.39 with an average of 0.62.

3.2 Radioactivity Concentration of ^{226}Ra, ^{228}Ra and ^{40}K in water

Radioactivity of ^{226}Ra, ^{228}Ra and ^{40}K was measured near the Savar research reactor when the reactor was in active mode. The activity concentrations of ^{226}Ra (^{238}U Chain) for water of Savar were found to be within the range of 3.83±0.85 to 5.51±0.89mBq/L (Table 2).The average value for ^{226}Ra of water of Savar was found to be 4.86±0.88mBq/L which is within the range of the world average of 500 mBq/L [1]. The average activity concentration of ^{228}Ra (^{232}Th Chain) in water from Savar was 1.17±0.21mBq/L with a range of 0.27±0.17to 2.14±0.26mBq/L. Water samples containing ^{228}Ra were belowthe range compared to the world average value of 200 mBq/L [1]. The radioactivity concentration of ^{40}K (non-chained) ranged from 48.31±3.97 to 148.14±25.28mBq/L with an average value of 70.03±0.05mBq/L which is less than the world average of 400 mBq/L [1]. The ^{228}Ra/^{226}Ra ratio for water samples varied between 0.05 and 0.39 and having an average ratio of 0.24.

Table 1. Radioactivity concentration in air near BAEC, Savar, Dhaka while the research reactor was active.

Sample Code	Activity concentration in air (mBq/m^3)			
	^{226}Ra	^{228}Ra	^{40}K	^{228}Ra/^{226}Ra
A1	37.00±0.00	8.29±0.01	29.55±0.05	0.22
A2	379.53±0.01	2.14±0.01	29.55±0.05	0.01
A3	16.04±0.00	7.75±0.01	19.70±0.05	0.48
A4	344.36±0.01	17.64±0.01	29.55±0.05	0.05
A5	480.68±0.01	0.00±0.01	9.85±0.05	0.00
A6	296.24±0.01	3.21±0.01	59.09±0.05	0.01
A7	437.15±0.01	10.42±0.01	29.55±0.05	0.02
A8	61.06±0.00	8.02±0.01	39.40±0.05	0.13
A9	373.00±0.01	79.90±0.02	59.09±0.05	0.21
A10	613.56±0.01	5.35±0.01	19.70±0.05	0.01
A11	3.09±0.00	1.60±0.01	88.64±0.05	0.52
A12	482.97±0.01	14.43±0.01	78.79±0.05	0.03
A13	173.67±0.01	2.67±0.01	59.09±0.05	0.02
A14	592.94±0.01	7.75±0.01	128.03±0.05	0.01
A15	516.19±0.01	8.28±0.01	147.73±0.05	0.02
A16	3.90±0.00	5.61±0.01	108.34±0.05	1.44
A17	1.95±0.00	8.55±0.01	118.18±0.05	4.39
A18	1.49±0.00	5.35±0.00	206.82±0.00	3.59
Average	267.49±0.01	10.94±0.01	70.03±0.05	0.62

Table 2. Radioactivity concentration in water near BAEC, Savar, Dhaka while the research reactor was active.

Sample Code	Activity concentration in water (mBq/L)			
	^{226}Ra	^{228}Ra	^{40}K	^{228}Ra/^{226}Ra
A1	5.20±0.88	0.27±0.17	48.31±3.97	0.05
A2	5.24±0.89	1.50±0.25	70.85±2.43	0.29
A3	5.51±0.89	2.14±0.26	148.14±25.28	0.39
A4	4.62±0.87	1.46±0.24	66.34±2.42	0.32
A5	5.51±0.89	1.51±0.25	69.56±2.42	0.27
A6	3.83±0.85	1.39±0.24	79.22±2.44	0.36
A7	4.76±0.87	0.58±0.02	56.68±2.41	0.12
A8	4.23±0.86	0.54±0.22	97.26±2.46	0.13
Average	4.86±0.88	1.17±0.21	79.55±5.48	0.24

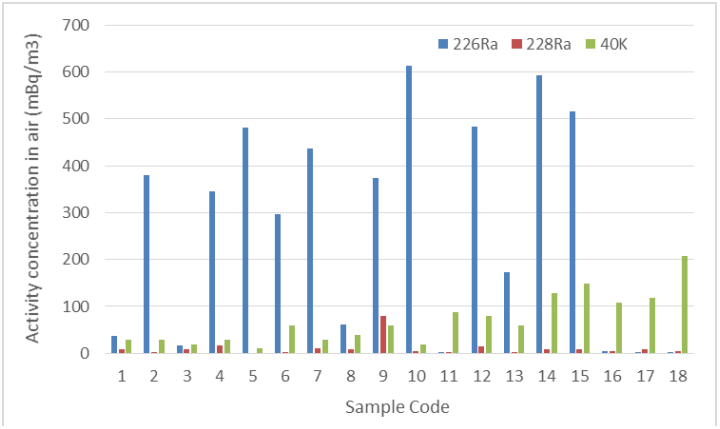

Fig. 1. Activity concentrations of air near the Savar Atomic Energy Center, Dhaka.

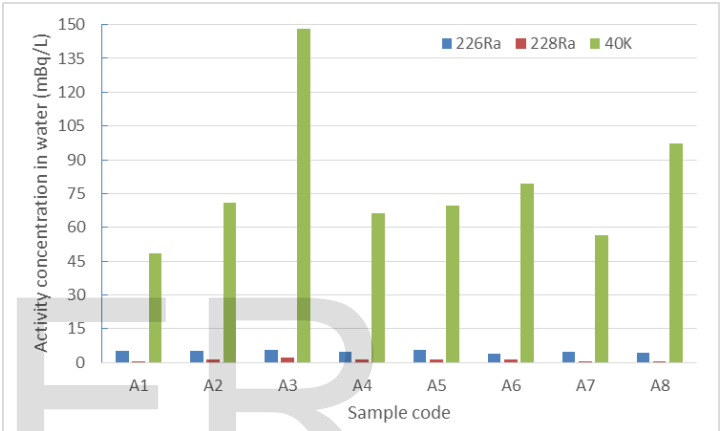

Fig. 2. Activity concentrations of water near the Savar Atomic Energy Center, Dhaka.

4 Conclusion

As the level of activity concentrations of natural radionuclides in most of the the air and all water samples under investigation were overall within the range of the world average, it might not pose any radiation hazard to the population. As a higher concentration of radioactive substances in the environment is undesirable, investigations should be undertaken to detect the concentration of radionuclides in air and water in order to take necessary radiological and dosimetric measures with the aim of minimizing the harmful effects of ionizing radiation. It is hoped that the data presented here will help establish a baseline for radioactivity concentrations of various locations in the Savar areas of Dhaka, Bangladesh.

Air and water monitoring is a continuous process which is needed to monitor for knowing the concentration of radionuclides present in air and water. A determination of the concentration and the distribution of air and water radioactivity are vital in establishing reference data, allowing the observation of possible changes due to radiological pollution. The concentrations of different radionuclides in air and water particle of present study will be helpful to monitor and compare the concentration of radionuclides in air and water samples around

Research Nuclear Power Plant in savar and also the new under construction of Ruppur Power plant, which is close to Dhaka. To establish the base line data, it will be useful to monitor and measure concentration of radionuclide in air and water particles.

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