International Journal of scientific research and management (IJSRM)
||Volume||4||Issue||09||Pages||4478-4486||2016||
Website: www.ijsrm.in ISSN (e): 2321-3418

Seasonal Variation of Terrestrial Gamma Radiation Dose and Evaluation of Annual Effective Dose in AECD Campus, Dhaka, Bangladesh

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Abstract:
Background: Seasonal variations of environmental terrestrial gamma dose rates were measured at the Atomic Energy Centre Dhaka (AECD) campus in Shahbag Thana under Dhaka City from January to December 2015. Aim of the study: This kind of study is required to detect the natural and artificial radionuclides (if any) releasing from nuclear facilities in the country or from neighbouring countries. Materials and Methods: The measurement was performed using a portable High Purity Germanium (HPGe) detector (Model No. GEM25P4-83). The portable HPGe detector was placed at 1 meter above the ground facing downward and data acquisition time was 10,000 sec. Four locations were selected in the AECD campus to obtain the spectrum and those locations were marked out using global positioning system. Results: The average dose rate of the four locations from location-1 to location-4 were 0.428 ± 0.041, 0.344 ± 0.073, 0.355 ± 0.049 and 0.405 ± 0.054 μGy.h^{-1} respectively. The average dose rate of six seasons such as winter, spring, summer, rainy, autumn and late autumn were 0.377 ± 0.088, 0.421 ± 0.071, 0.385 ± 0.066, 0.358 ± 0.031, 0.281 ± 0.106 and 0.421 ± 0.023 μGy.h^{-1} respectively. The annual effective dose of the population due to the terrestrial gamma radiation were also calculated and it was varied from 0.208 - 0.627 mSv. The mean annual effective dose was found to be 0.472 ± 0.081 mSv which is comparable to the worldwide average value of 0.48 mSv.y^{-1}. Conclusion: It was observed that winter, spring, summer and late autumn season's dose rates are higher than those of rainy & autumn seasons.

key words: Terrestrial radiation, effective dose, In-situ, HPGe.

1. Introduction

The majority of human exposure to ionizing radiation occurs from natural sources including cosmic rays and terrestrial radiation [1]. Exposure to extraterrestrial origin radiation, galactic cosmic rays and energetic particles from solar particle events depends mostly on geographical characteristics of a place such as altitude, latitude and solar activity [2, 3]. Natural radionuclides of terrestrial origin have very long half-lives or driven from very long-lived parent radionuclides which have been created stellar processes before the earth formation. Excluding exposure from direct cosmic rays and cosmogenic radionuclide from extraterrestrial sources, natural exposures arise mainly from the primordial radionuclides such as 238U & 232Th series and 40K which are spread widely and are present in all most geological materials in the earth's environment [4, 5]. Unlike the pollutants with anthropogenic sources that are introduced into the environment through human activity [6], terrestrial origin radionuclides are naturally present at trace levels in all environmental compartments. Most radionuclides in the uranium series, thorium series and 40K emit gamma radiation giving rise to human exposures from gamma rays outdoor. Gamma ray accounts for the majority of external human exposures to radiation from all type of sources due to its high penetration ability [7]. Gamma radiation is ubiquitous. Great variations have been observed in environmental radiation levels and several international studies have been characterized gamma dose rates both in outdoor and indoor environments [8-12].

Both laboratory and in-situ gamma spectroscopy are often used for monitoring and assessment of radioactivity and radiation dose rates in the environment due to both natural and anthropogenic sources [13-18]. In-situ techniques for measuring the activity concentration resulting from the gamma radiation and characterizing its sources with gamma ray spectrometer have been used successfully in the outdoor environment [13, 19-21].

The theoretical principles of in-situ gamma-ray spectrometry were developed in the early 1970s [13]. The three-factor assay formula is given by

$$\frac{N_f}{I} = \frac{N_f}{N_o} \cdot \frac{N_o}{\Phi} \cdot \frac{\Phi}{I} \text{..........................(1)}$$

Where N_f is the full-energy peak count rate of the measured radionuclide (in counts per second), N_o is the full-energy peak count rate of that radionuclide for a parallel beam of gamma-rays that is incident on the detector parallel to its symmetry axis, Φ is the gamma-ray un-scattered flux on the detector ($cm^{-2}.s^{-1}$) and I is the exposure rate (μR/hr). Φ/I is the ratio of the flux due to gamma-rays of energy E to the corresponding exposure rate for that nuclide; this value was taken from Beck's tabulated data [13] and it is expressed in ($\gamma.s^{-1}.cm^{-2}/\mu R.h^{-1}$).

The gamma dose rate can be calculated by the formula:

$$D = k \sum_i \frac{(N_f)_i}{(N_f / I)_i} \text{..........................(2)}$$

Where the sum is extended over all the peaks registered by the detector; $(N_f)_i$ are the counts per second of the peaks experimentally measured and k is the conversion factor from Roentgen to Gray.

The presence of naturally occurring radionuclides in the environment may result in an external and internal dose received by a population exposed to them directly and through the ingestion and inhalation pathways. The assessment of the radiological impact on a population as a result of the radiation emitted by these radionuclides is important since they contribute to the collective dose of the population [22]. The aim of the present study is to measure the environmental terrestrial gamma radiation dose rate in and around the Atomic Energy Centre, Dhaka (AECD) campus and to determine the annual effective radiation doses to which people are exposed from terrestrial gamma radiation.

2. Materials and Methods

2.1 In-Situ gamma-ray spectrometer

An ORTEC HPGe detector was used. It is a portable instrument with a p-type crystal, a dewar for the liquid nitrogen along with digiDART. Gamma –ray spectra were measured by a tripod-mounted, downward-facing HPGe detector (ORTEC, Model: GEM25P4-83, CFG: POPTOP, Serial No.: 50-TP12792A) of 25% relative efficiency within the energy range 50 keV-2 MeV compared with a 3 in. by 3 in. NaI(Tl) detector and 1.70 keV FWHM (both at 1332 keV) energy resolution, located 1m above ground. Spectra of 8192 channels were analyzed by the Maestro-32 MCA Emulsion Software.

2.2 Gamma-ray calibration sources

Measurement of N_o/Φ was performed at a 1m distance by a fixed radionuclide gamma-ray standard sources containing the following radionuclides (energies in keV, emission probabilities in %): ^{133}Ba (276.398, 7.164; 302.853, 18.33; 356.017, 62.05; 383.851, 8.94), ^{137}Cs (661.660, 85.1), ^{60}Co (1173.237, 99.90; 1332.501, 99.982). Gamma-ray emission rates of the standards were calculated from the standards, certificates, correcting from the lapse of time from the reference date. The flux is given by the gamma-ray emission rate divided by 4π and by $1m^2$ (100^2 cm^2). A second order polynomial least-squares fitting determined the $\log(N_o/\Phi)$ versus log(gamma-ray energy) dependence, which is followed by the Eq. $\ln(N_o/\Phi) = 4.48 - 1.03\ln E$ where E is in MeV.

2.3 The Site

The study site is located from E: 90^{0}23'44.27" to E: 90^{0}23'49.56" and from N: 23^{0}43'49.44" to N: 23^{0}43'52.72". Four locations were selected to measure the environmental terrestrial gamma dose rates in the AECD campus in Shahbag Thana under Dhaka City. The measurements were performed from January-December 2015. The numbers of measurement in each location were shown in Table 1. The environmental terrestrial gamma dose rate was measured for 10,000 sec for each monitoring point. Fig. 1 shows the location of the Atomic Energy Centre, Dhaka in Shahbag Thana under Dhaka City where environmental terrestrial gamma radiation measurement was performed using portable HPGe detector. Table 1 gives the description of the monitoring points (MPs). Four locations in the site were marked out usingGlobal PositioningSystem(GPS).

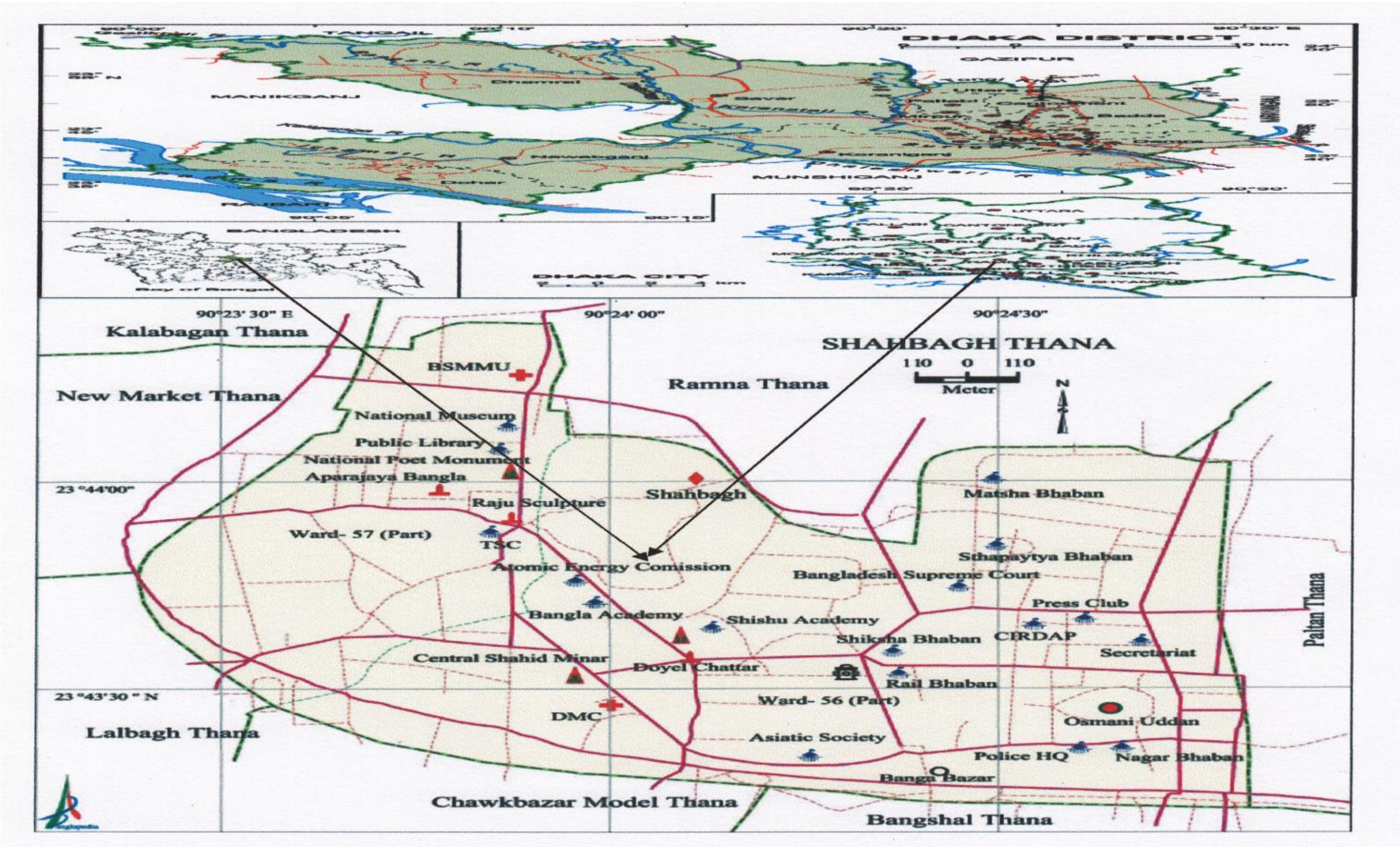

Figure 1: Shows the location of the Atomic Energy Centre, Dhaka in Shahbag Thana under Dhaka City where environmental terrestrial gamma radiation measurement was performed using portable HPGe detector.

3. Results and Discussion

3.1 Collection of field gamma-ray spectrum

There are six seasons in Bangladesh, namely winter, spring, summer, rainy, autumn and late autumn. Measurement of seasonal variation of environmental terrestrial gamma-ray dose rate was carried out at the AECD campus in Shahbag Thana under Dhaka City during January-December 2015 following In-situ technique. Collected spectra have been analyzed in order to determine the dose rate from natural radionuclides.

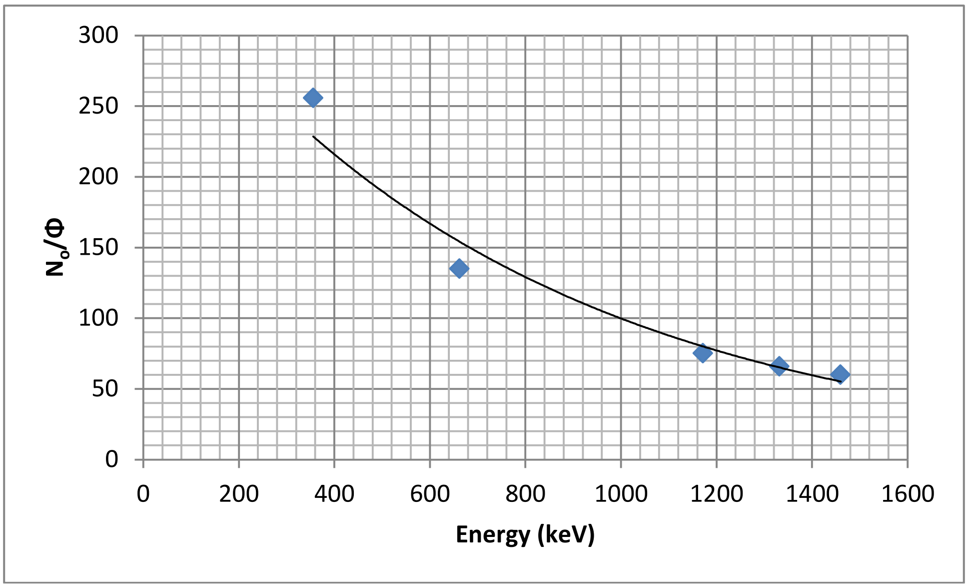

Figure 2: Variation of N_o/Φ with energy.

3.2 Absorbed dose rate and annual effective dose

The absorbed dose rates were ranged from 0.170-0.511 μGy.h^{-1} during the entire period of the study. From Table 1, it is observed that the lowest and the highest dose rates were found to be 0.169925 and 0.510964 μGy.h^{-1} in the autumn and spring respectively. The highest absorbed dose rate in spring was also reported by other author [23]. Using the conversion factor of 0.7 Sv Gy^{-1} as recommended by UNSCEAR 2000 [24], and considering that people in Bangladesh spend approximately 20 % of their time outdoor and remaining 80% of time indoor; the annual effective dose received by people in Dhaka City due to the terrestrial gamma radiation is given in Table 1. The annual effective dose of the population due to the terrestrial gamma radiation were also calculated and it was varied from 0.208 - 0.627 mSv. The mean annual effective dose was found to be 0.472 ± 0.081 mSv which is comparable to the worldwide average value of 0.48 mSv.y^{-1} [25]. This type of study is very important for radiation protection purpose in the country because the usage of radioactive material is increasing day by day in the various fields like medicine, industry and research. Moreover, environmental radiation and radioactivity monitoring is crucial to generate the baseline data from natural sources and releasing (if any) from nuclear installations in the country or from neighbouring countries. This kind of study will also be needed for measurement of environmental radioactivity in and around the Rooppur Nuclear Power Project (RNPP) site.

Table 1: The absorbed dose rate and annual effective dose rate in six seasons at AECD campus, Shahbag Thana under Dhaka City.

DOI: 10.18535/ijsrm/v4i9.06

Season	Latitude/Altitude	Total counts in the peaks	Absorbed dose rate ($\mu Gy.h^{-1}$)	Annual effective dose ($mSv.y^{-1}$)
Winter	N 23°43' 50.30"	5744.769 ± 75.79	0.411891	0.505143
(January-	E 90° 23' 46.78"			
February)	N 23°43' 51.70"	4805.90 ± 69.32	0.344576	0.422588
	E 90° 23' 45.81"			
	N 23°43' 51.02"	6232.10 ± 78.94	0.446832	0.547995
	E 90° 23' 48.51"			
	N 23°43' 52.21"	5645.65 ± 75.13	0.404785	0.496428
	E 90° 23' 48.62"			
	N 23°43' 50.30"	5189.97 ± 72.04	0.372114	0.456361
	E 90° 23' 46.78"			
	N 23°43' 52.21"	5881.02 ± 76.68	0.42166	0.517124
	E 90° 23' 48.62"			
	N 23°43' 51.02"	6081.05 ± 77.98	0.436003	0.534714
	E 90° 23' 48.51"			
Spring	N 23°43' 51.70"	5922.74 ± 76.95	0.424652	0.520793
(March-	E 90° 23' 45.81"			
April)	N 23°43' 50.30"	7126.56 ± 84.42	0.510964	0.626646
	E 90° 23' 46.78"			
	N 23°43' 52.21"	4703.29 ± 68.58	0.337219	0.413565
	E 90° 23' 48.62"			
	N 23°43' 51.02"	5719.00 ± 75.62	0.410044	0.502878
	E 90° 23' 48.51"			
Summer	N 23°43' 50.30"	6259.09 ± 79.11	0.448768	0.550369
(May-June)	E 90° 23' 46.78"			
	N 23°43' 51.02"	6506.00 ± 80.66	0.46647	0.572079
	E 90° 23' 48.51"			
	N 23°43' 51.70"	5187.25 ± 72.02	0.371918	0.45612
	E 90° 23' 45.81"			
	N 23°43' 52.21"	4756.03 ± 68.96	0.341001	0.418204
	E 90° 23' 48.62"			
	N 23°43' 50.30"	4340.19 ± 65.88	0.311185	0.46495
	E 90° 23' 46.78"			
	N 23°43' 51.02"	6427.80 ± 80.17	0.460864	0.381637
	E 90° 23' 48.51"			
	N 23°43' 51.70"	4217.58 ± 64.94	0.302394	0.565204
	E 90° 23' 45.81"			
	N 23°43' 52.21"	5287.66 ± 72.72	0.379118	0.370856
	E 90° 23' 48.62"			
Rainy	N 23°43' 52.21"	4564.68 ± 67.56	0.327281	0.401377
(July-	E 90° 23' 48.62"			
August)	N 23°43' 50.30"	5065.69 ± 71.17	0.363203	0.445432
	E 90° 23' 46.78"			
	N 23°43' 51.02"	4848.41 ± 69.63	0.347624	0.426326
	E 90° 23' 48.51"			

	N 23°43' 50.30"	5693.26 ± 75.45	0.408198	0.500614
	E 90° 23' 46.78"			
	N 23°43' 52.21"	4808.00 ± 69.33	0.344726	0.422772
	E 90° 23' 48.62"			
Autumn	N 23°43' 50.30"	5319.00 ± 72.93	0.381364	0.467705
(September-	E 90° 23' 46.78"			
October)	N 23°43' 51.02" E 90° 23' 48.51"	4084.92 ± 63.91	0.292883	0.359192
	N 23°43' 52.21"	2369.99 ± 48.68	0.169925	0.208396
	E 90° 23' 48.62"			
Late Autumn	N 23°43' 50.30" E 90° 23' 46.78"	5958.04 ± 77.18	0.427183	0.523897
(November-	N 23°43' 52.21"	6059.02 ± 77.84	0.434423	0.532776
December)	E 90° 23' 48.62"			
	N 23°43' 50.30"	5389.39 ± 73.41	0.386411	0.473894
	E 90° 23' 46.78"			
	N 23°43' 52.21"	6083.50 ± 77.99	0.436178	0.534929
	E 90° 23' 48.62"			

Table 2: Seasonally minimum, maximum and mean dose rate

Season	**Minimum dose rate** ($\mu Gy.h^{-1}$)	**Maximum dose rate** ($\mu Gy.h^{-1}$)	**Mean ± SD** ($\mu Gy.h^{-1}$)
Winter	0.344576	0.446832	0.376545 ± 0.088174
Spring	0.337219	0.510964	0.420719 ± 0.071288
Summer	0.302394	0.46647	0.385215 ± 0.066411
Rainy / Monsoon	0.327281	0.408198	0.358206 ± 0.030717
Autumn	0.169925	0.381364	0.281391 ± 0.106187
Late Autumn	0.386411	0.436178	0.421049 ± 0.023417

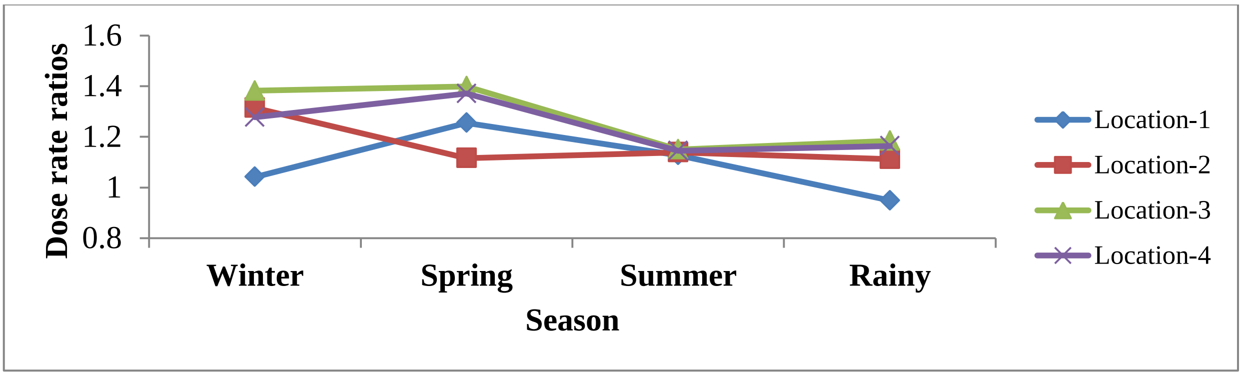

Figure 3: Seasonal absorbed dose rate values normalized to the corresponding autumn values for each location.

Variation of gamma absorbed dose rate values in winter, spring, summer and rainy seasons were normalized to the corresponding values of autumn at four locations (figure 2). From figure 2, it is observed that gamma absorbed dose rate ratio was found to be more in winter and spring seasons in the area than that in summer and rainy reasons. Accumulation from radon gas near ground surface during winter and spring seasons contribute to the higher gamma absorbed dose rate during winter and spring. Whereas during rainy season, the radon exhalation rate from soil surface is reduced due to the filling up of pore spaces in the soil. Furthermore, during rainy season radon and its progeny will be washed out leading to decrease in their concentration in the lower atmosphere [26, 27]. The frequency distribution of the terrestrial gamma absorbed dose rates in air follow a normal type distribution as shown in figure 3.

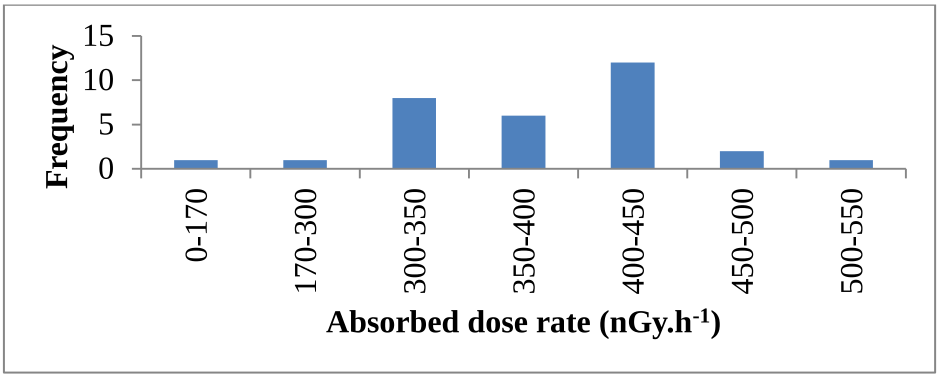

Figure 4: Frequency distribution of the absorbed dose rates (nGy.h^{-1}) at AECD campus in Shahbag Thana under Dhaka City.

4. Conclusion

During winter, spring, summer, rainy, autumn and late autumn the average dose rates were found to be (0.405409 ± 0.088174), (0.42072 ± 0.071288), (0.385215 ± 0.066411), (0.358206 ± 0.030717), (0.281391 ± 0.106187) and (0.421049 ± 0.023417) μGy.h^{-1} respectively. It can be concluded that winter, spring, summer and late autumn dose rates are higher than rainy & autumn seasons. The annual effective dose of the population due to the terrestrial gamma radiation were varied from 0.208 - 0.627 mSv with an average of 0.472 ± 0.081 mSv. This type of study is very important for radiation protection purpose in the country because the usage of radioactive material is increasing day by day in the various fields like medicine, industry and research, etc. Moreover, environmental radiation and radioactivity monitoring is crucial to generate the baseline data from natural sources and releasing (if any) from nuclear installations in the country or from neighbouring countries. This kind of study will also be needed for measurement of environmental radioactivity in and around the Rooppur Nuclear Power Project (RNPP) site area.

5. Acknowledgement

The authors would like to thank the Bangladesh Atomic Energy Regulatory Authority for giving them opportunity to use the portable HPGe detector.

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