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Measurement of Environmental Gamma Radiation Dose Rates and Estimation of Radiation Risk near the Construction Site of the Nuclear Power Plant, Indoor and Outdoor Locations of the Research Reactor, and Coal-Fired Thermal Power Plant Area

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Abstract: Gamma radiation dose rates have been measured at 300 monitoring points in the vicinity of the construction of the Rooppur Nuclear Power Plant (RNPP) site, the Centre of Research Reactor (CRR), and the Barapukuria Coal Mine Company Limited (BCMCL) in Bangladesh. The main objective of this study is to detect any potential release of natural or artificial radionuclides from these facilities. A Geiger Muller digital survey meter gamma scout, positioned 1 meter above ground level, was used for real-time gamma dose assessment at each monitoring point, and a GARMIN eTrex personal navigator was used to record Global Positioning System (GPS) coordinates. The mean gamma dose rates recorded in real-time were 0.100 ± 0.033 μSvh^{-1} for RNPP, 0.235 ± 0.007 μSvh^{-1} for indoor, and 0.173 ± 0.005 μSvh^{-1} for outdoor of the CRR in Atomic Energy Research Establishment (AERE) area, and 0.133 ± 0.014 μSvh^{-1} for the BCMCL. Corresponding average annual effective doses for these locations were 0.176 ± 0.059 mSvy^{-1}, 1.649 ± 0.049 mSvy^{-1}, 0.303 ± 0.008 mSvy^{-1}, and 0.233 ± 0.025 mSvy^{-1}, respectively. Additionally, the estimated lifetime cancer risk (ELCR) was determined for each study area, resulting in values of 0.74 × 10^{-3} for RNPP, 6.91 × 10^{-3} for indoor and 1.27 × 10^{-3} for outdoor CRR, and 0.98 × 10^{-3} for BCMCL, respectively. Based on the findings of this study, the estimated mean annual effective dose is not anticipated to pose a significant additional risk from a radiological health perspective.
Keywords: Gamma dose rate, Gamma scout, Rooppur nuclear power plant project site, Effective dose, ELCR.

1 Introduction

Radiation from numerous sources is ubiquitous on the soil surface and other parts of the environment; subsequently, people are continuously irradiated by natural sources of ionizing radiation in nature [1–5]. The dispersion of the radionuclides in the soil can be influenced by various factors besides geology, such as geological incidents in the region, the location's latitude and elevation, waste from industries, the application of pesticides and fertilizers, mineral processing, water purification, and the consumption of fossil fuels [6–9]. Besides natural radiation sources, artificial radioactivity sources also increase the amount of radiation in the environment directly [10–18]. Ionization can cause atomic alterations and the arrangement of chemical species that are detrimental to chromosomes in the water that make up most cells [1]. From both terrestrial and extraterrestrial origins, natural radiation has irradiated into the environment [2], [19–21]. The effects of ionizing radiation mainly depend on the nature and energy of the radiation, amount of dose, period of exposure, dose homogeneity, and shielding [1]. Radiation is a primary concern for the human body because it harms people directly, and in many cases, it may be the cause of death. However, a certain amount of radiation dose (1 mSvy^{-1}) is considered a permissible limit as the dose is too low to notice any harmful effects [1, 22]. The human body is continuously irradiated both externally (primordial, cosmogenic, and anthropogenic) and internally (the human body contains K-40) [1, 23–25]. Earth's crust contains primordial radionuclides from the beginning of the world; at the time of interaction between cosmic rays and the elements present in the environments, the cosmogenic radionuclides are produced, and lastly, the anthropogenic radionuclides are the result of human activities such as using various radioactive elements in different purposes, and these are spreading around the controlled area [23]. Coal, soil, and water are terrestrial elements and contain radioactivity, which can quickly increase the amount of background radiation in any region [26–34]. The

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distribution of external natural radiation depends on the geographical position [35–38]. According to UNSCEAR 2000, the value of natural radiation is 32nGyh^{-1} at sea level [35, 36]. The average outdoor absorbed dose rate is 59 nSvh^{-1} with a range of 18 - 93 nSvh^{-1}[36]. About 80% of the world's collective exposure to radiation comes from natural sources [36, 39, 40]. So, measuring the background level of radiation is very important to make baseline data.

Gamma rays are emitted from radionuclides like ^{238}U, ^{232}Th, ^{40}K, and many other isotopes. These unstable radionuclides release gamma rays to reach their stable state. Among all types of ionizing radiation, gamma has high penetrating power to enter a human body [41] and damage cells by its radiation energy when passing through body cells.

For this study, data were collected from three crucial areas of Bangladesh. These locations were the Rooppur Nuclear Power Plant (RNPP) project area, indoor and outdoor CRR in the Atomic Energy Research Establishment (AERE), and Barapukuria Coal Mine Company Limited (BCMCL) area.

Bangladesh's first nuclear power plant is under construction at Rooppur, located in Pabna district in the northwest part of the country. This site is located on the bank of river Padma, which flows from India, and it is known that the environmental radiation level in some places of India is 1.5 times higher than the world average value of 59 nGyh^{-1} [2, 6, 36]. Radionuclides from any nuclear power plant leakage on river sides can spread easily on broad areas as water flows more rapidly than any solid medium. From a previous study in radioactivity measurements of soil samples around the RNPP project area, the average activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K was 1.27, 2.25, and 1.95 times higher than those of the world average value [42].

In any place where a nuclear power plant project is running, it should be mandatory to make baseline data of the background normal operation of the nuclear facility or to measure the amount of radiation added in the environment from any accident or leakage from the running nuclear power plant. So, the RNPP area is a significant place in Bangladesh for this baseline dose rate measurement survey.

About 13 institutes of Bangladesh Atomic Energy Commission, including the Center for Research Reactor (CRR), Institute of Nuclear Science and Technology (INST), Secondary Standard Dosimetry Laboratory (SSDL), Institution of Radiation and Polymer Technology (IRPT), and Institute of Food and Radiation Biology (IFRB) in AERE campus which are situated in Savar upazila of Dhaka district. Dhaka is the world's 9th largest and 7th most densely populated megacity [43]. CRR has a BAEC TRIGA research reactor of 3 megawatts (MW) of power, and in INST radioisotope production Tc-99m, I-131, and other isotopes are produced for use in nuclear medicine centers all over Bangladesh [44]. A remarkable amount of low radioactivity waste in solid, liquid, and gaseous forms was produced from the operation and maintenance of research reactor TRIGA MARK-II [45]. Besides these, other institutes worked with radiation and various isotopes like FDG (F-18).

In the health physics and radioactive waste management unit of INST, all types of radioactive waste from each nuclear facility of the country were disposed of [44]. Among these materials Co-60, Cs-134, Cs-137, Sr-90, Tc-99m, Am-241 and P-32 are notable [44]. From a previous study by [45], the average activity concentration of U-238, Th-232, and K-40 in soil samples collected around AERE was higher than the average world value of 35 BqKg^{-1}, 30 BqKg$^{-1,}$ and 400 BqKg^{-1} respectively [36]. So, measuring the real-time dose rate concentration in the CRR environment in AERE is highly recommended. Several important monuments and organizations, like export processing zones, schools, colleges, universities, hospitals, garments industries, pharmaceutical industries, and others, are situated around this AERE area. Making a background radiation database is highly recommended to ensure the safety of radiation workers in that area and the public living or working around that campus.

About 38% of electricity is produced from coal combustion worldwide [46]. Globally, 3% of electricity generated increased from 2017-2018 just because various developing countries like Bangladesh, India, China, and Southeast Asia are coming forward to use coal as their primary element of power production [46]. A significant amount of inorganic properties, like trace amounts of NORM, can add extra radiation to the environment [46]. If any significant amount of radiation can be traced in any coal mine, it can easily be spread by air or contact with the person involved in this mining work. Among five discovered coal mines in Bangladesh, only Barapukuria Coal Mine Company Limited (BCMCL) is under production [32]. The workers of coal mines, the public lives around this mine area, and the environment can be affected by the radiation from various radionuclides contained in coal [32]. From a previous study in passive soil samples, average activity concentrations of Ra-226, Th-232, and K-40 were higher than that of the world average value [32, 36, 47]. So, protecting human resources and the environment from excess radiation is a significant concern. If baseline data are made and the exact reason behind the increased amount of radiation, it is easier to get protected and decrease the amount of health hazards.

This study aims to estimate the extent of natural or artificial radiation, if present, released from nuclear and radiological facilities operating within this area under study or neighboring countries, both during regular operation and in the event of an accident; this estimation will be achieved by conducting real-time gamma dose rate measurements in the RNPP project, CRR, and BCMCL areas. This study also requires the preparation of baseline data before installing any nuclear power plant in Bangladesh.

2 Materials & Methods:

2.1 Study Area

The data were collected from 300 monitoring points in three different regions (100 monitoring points in each area) of Bangladesh from August 2022 to February 2023. RNPP (GPS location of gamma radiation dose monitoring points from N 23°50′05.0″ to N 24°11′11.3″ and E 088°46′44.5″ to E 089°17′55.5″) is located in Pabna district of Rajshahi division on the bank of Padma river. AERE is located 40 km northeast of Dhaka city [48]. GPS location of gamma dose monitoring points from this area is N 23°57′2.58″ to N 23°57′12.12″ and E 090°16′30.54″ to E 090°17′53.1″. This area is just beside the Gazipur district. The last one, BCMCL is located at Parbatipur upazila in Dinajpur district (GPS location of gamma dose monitoring points of this area is N 25°32′33.84″ to N 25°33′56.76″ and from E 088°57′16.68″ to E 088°57′57.3″), and that is the only active coal mine of Bangladesh [49]. All three gamma dose monitoring areas are shown in Fig 1.

(a) RNPP area

(b) AERE area

(C) BCMCL area

Fig 1: Location of the outdoor environmental gamma radiation measurement area.

2.2 Instruments Used

For this study, a GARMIN eTrex HC series personal navigator was used to determine the location of the geographical position. A portable Geiger Muller (GM) digital survey meter (GAMMA SCOUT, model no: 071017) was used to collect the real-time gamma radiation dose rate concentration on the environment. This device is very useful for detecting the amount of alpha, beta, gamma, and x-rays in any monitoring point. This German-made device was developed with a Novadur outline. The measured radiation dose rate (μSv/hr) is displayed on its digital display. There's an analog logarithmic bar chart to visualize the size of the measured dosage rate rapidly. The unit encompasses a battery pointer, different unit changes, and a real-time measurement rate. The total value shows capacities, programmable logging, and alarm capacities. Progressed abilities incorporate PC information downloaded utilizing a USB cable and an ultralow current control circuit for extended battery life [50]. This device can measure radiation limit of 0.01 μSv/hr to 1000 μSv/hr [51].

The instruments that were used for this study were calibrated before data collection from the secondary standard dosimetry laboratory (SSDL) of the Atomic Energy Research Establishment (AERE), Bangladesh Atomic Energy Commission (BAEC).

2.3 Methodology

2.3.1 Outdoor and Indoor Gamma Dose Rates Determination

For absorbed dose rate monitoring, a digital Gamma Scout was set at 1 above the ground level and blocked alpha and beta counting mode, kept at 1 min at each monitoring point, and confirmed location latitude/ longitude with GPS. The absorbed dose rate (D_R) was shown on the monitoring screen of Gamma Scout in the μSvh^{-1} unit. Take a dose three times and calculate the average dose obtained from these values.

2.3.2 Outdoor and Indoor Annual Effective Dose Determination

The annual effective dose (AED) is calculated by the given formula mentioned below [36]:

$$AED_{In} = D_{Rin}\ (\mu Svh^{-1}) \times OF\ (0.8) \times \text{Total time}\ (8760\ hy^{-1}) \quad (1)$$
$$AED_{out} = D_{Rout}\ (\mu Svh^{-1}) \times OF\ (0.2) \times \text{Total time}\ (8760\ hy^{-1}) \quad (2)$$

The outdoor occupancy factor (OF) is 0.2, and the indoor occupancy factor (OF) is 0.8 for the public [35]. The OF is the ratio of time a person spends in a specific region.

2.3.3 Excess Lifetime Cancer Risk Estimation

The excess lifetime cancer risk (ELCR) factor is calculated by the formula given below [36]:

$$ELCR = AED \times DL \times RF \quad (3)$$

Where AED is the annual effective dose, DL is the duration of life for the public of Bangladesh [52], and RF is the fatal cancer risk factor in units per sievert. From the recommendation ICRP 103, the risk factor (RF) for the low-dose radiation stochastic effects is 0.057 for the general public [53].

3 Results and Discussion

From Fig 2, around the RNPP project area, the maximum gamma dose rate concentration of 0.217μSvh^{-1} was found on the monitoring point MP 51 (Philipnagar, Kushtia), and the minimum gamma absorbed dose concentration of 0.052 μSvh^{-1} was found on monitoring points MP 77 (Bahirchar 12 mile east para, Bheramara, Kushtia) and MP 79 (Near Laxmikunda, Pabna) and the average gamma dose rate on the environment found on RNPP project area is 0.100 ± 0.033 μSvh^{-1}.
Since the RNPP has not yet started operation, it does not release any additional amount of radioactivity into its surrounding environment.

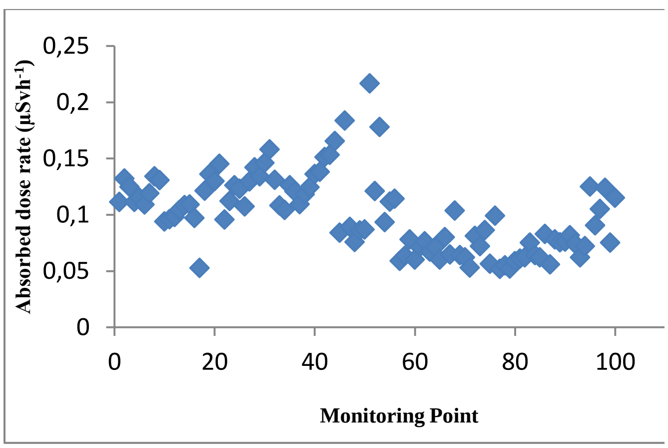

Fig 2: Absorbed dose rate at monitoring point surrounding the RNPP project area.

In Fig 3, the annual effective dose (AED) is shown for the monitoring points of the RNPP project area. This graph shows that the range of AED varies between 0.091 to 0.380 $mSvy^{-1}$ with an average value of 0.176 ± 0.059 $mSvy^{-1}$, which is lower than the recommended value of 1$mSvy^{-1}$[36].

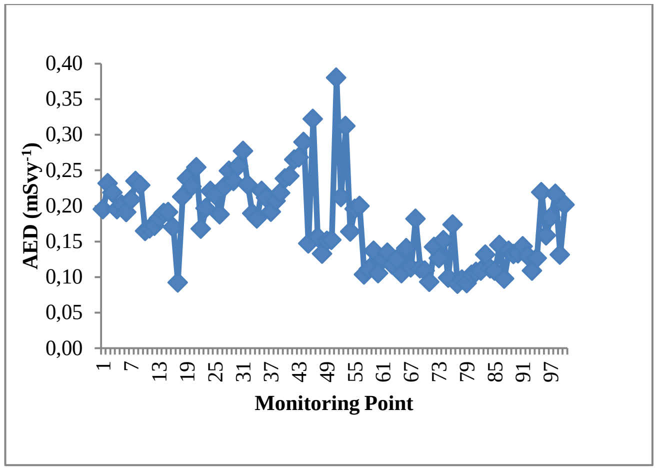

Fig 3: Annual effective dose rate at monitoring point surrounding the RNPP project area.

From Fig 4, ELCR for outdoor gamma dose concentration around the RNPP project area varies from the value 0.38×10^{-3} to 1.59×10^{-3} with an average value of 0.74×10^{-3}, which is higher than the world average value of 0.29×10^{-3}[36].

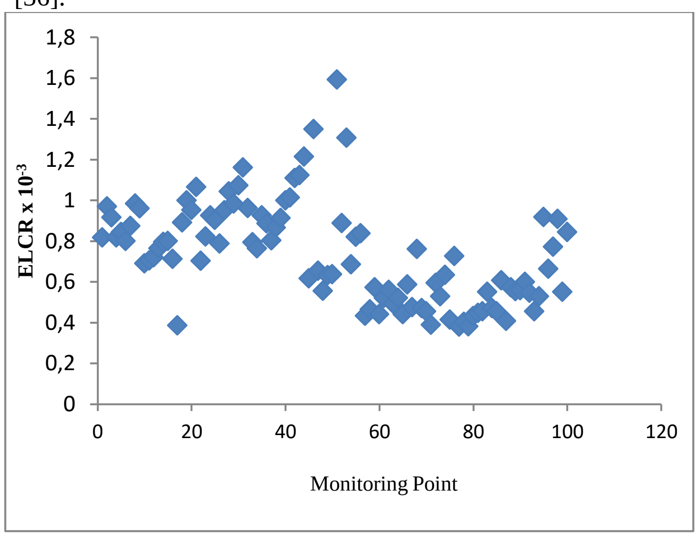

Fig. 4: Estimated lifetime cancer risk surrounding RNPP project area.

Table 1: Real-time background radiation dose, annual effective dose, and ELCR of AERE (Indoor).

SN.	Dose Rate Range (μSvh^{-1})	Mean Dose Rate (Avg. ± STD) μSvh^{-1}	AED ± STD ($mSvy^{-1}$)	ELCR×10^{-3}
1	0.139-0.144	0.141±0.002	0.988±0.019	4.14
2	0.328-0.333	0.330±0.002	2.315±0.018	9.70
3	0.172-0.179	0.176±0.003	1.231±0.025	5.16
4	0.175-0.178	0.177±0.002	1.238±0.011	5.19
5	0.174-0.178	0.176±0.002	1.235±0.015	5.18
6	0.175-0.179	0.177±0.002	1.240±0.014	5.20
7	0.178-0.181	0.180±0.001	1.259±0.011	5.28
8	0.180-0.184	0.182±0.002	1.275±0.014	5.35
9	0.183-0.187	0.185±0.002	1.296±0.014	5.43
10	0.183-0.184	0.183±0.001	1.284±0.004	5.38
11	0.218-0.221	0.220±0.001	1.539±0.011	6.45
12	0.164-0.169	0.166±0.002	1.165±0.018	4.88
13	0.138-0.143	0.140±0.003	0.983±0.018	4.12
14	0.156-0.159	0.158±0.002	1.105±0.011	4.63
15	0.234-0.237	0.236±0.001	1.651±0.011	6.92
16	0.273-0.275	0.274±0.001	1.917±0.008	8.04
17	0.279-0.282	0.280±0.001	1.964±0.011	8.23
18	0.455-0.459	0.457±0.002	3.200±0.015	13.42
19	0.188-0.192	0.19±0.002	1.331±0.014	5.58
20	0.229-0.231	0.230±0.021	1.611±0.147	6.76
21	0.206-0.210	0.208±0.002	1.457±0.014	6.11
22	0.485-0.488	0.486±0.002	3.408±0.011	14.29
23	0.24-0.244	0.242±0.002	1.696±0.014	7.11
24	0.235-0.237	0.236±0.001	1.654±0.007	6.93
25	0.225-0.230	0.228±0.003	1.598±0.019	6.70
26	0.215-0.217	0.216±0.001	1.514±0.007	6.34
27	0.201-0.204	0.202±0.001	1.418±0.011	5.94
28	0.175-0.177	0.176±0.001	1.233±0.007	5.17
29	0.145-0.149	0.147±0.002	1.028±0.015	4.31
30	0.156-0.159	0.158±0.002	1.105±0.011	4.63
31	0.149-0.156	0.153±0.004	1.074±0.027	4.50
32	0.159-0.165	0.162±0.003	1.133±0.021	4.75
33	0.154-0.158	0.156±0.002	1.093±0.014	4.58
34	0.110-0.113	0.112±0.002	0.782±0.011	3.28
35	0.351-0.355	0.353±0.013	2.478±0.146	10.39
36	0.202-0.214	0.207±0.046	1.451±0.098	6.08
37	0.867-0.899	0.878±0.018	6.153±0.127	25.80
38	0.208-0.212	0.210±0.002	1.471±0.014	6.17
39	0.175-0.189	0.181±0.007	1.266±0.052	5.31
40	1.260-1.290	1.270±0.015	8.947±0.107	37.51
41	0.151-0.157	0.154±0.003	1.081±0.021	4.53
42	0.148-0.157	0.151±0.004	1.061±0.035	4.44
43	0.122-0.127	0.125±0.002	0.873±0.018	3.66
44	0.124-0.129	0.127±0.003	0.887±0.018	3.72
45	0.132-0.137	0.135±0.002	0.946±0.019	3.96
46	0.128-0.135	0.131±0.003	0.920±0.025	3.86
47	0.135-0.141	0.139±0.003	0.972±0.023	4.07
48	0.139-0.145	0.142±0.003	0.995±0.021	4.17
49	0.254-0.278	0.266±0.012	1.861±0.084	7.80
50	0.152-0.158	0.155±0.003	1.086±0.021	4.55

Table 2: Real-time background radiation dose, annual effective dose, and ELCR of AERE (Outdoor).

SN.	Dose Rate Range (μSvh^{-1})	Mean Dose Rate(Avg. ± STD) μSvh^{-1}	AED ± STD ($mSvy^{-1}$)	ELCR×10^{-3}
1	0.158-0.169	0.164±0.006	0.287±0.010	1.20
2	0.124-0.135	0.128±0.004	0.223±0.006	0.94
3	0.127-0.135	0.131±0.004	0.230±0.007	0.96
4	0.129-0.134	0.132±0.003	0.230±0.004	0.97
5	0.123-0.128	0.125±0.003	0.220±0.004	0.92
6	0.126-0.130	0.128±0.002	0.223±0.004	0.94
7	0.136-0.141	0.138±0.003	0.242±0.004	1.02
8	0.140-0.144	0.142±0.002	0.25±0.004	1.04
9	0.146-0.149	0.147±0.002	0.258±0.003	1.08
10	0.140-0.150	0.145±0.005	0.254±0.009	1.07
11	0.170-0.177	0.174±0.004	0.305±0.006	1.28
12	0.166-0.172	0.169±0.003	0.296±0.005	1.24
13	0.173-0.180	0.177±0.003	0.31±0.007	1.30
14	0.177-0.180	0.179±0.002	0.313±0.003	1.31
15	0.179-0.182	0.180±0.002	0.316±0.003	1.32
16	0.512-0.607	0.562±0.055	0.985±0.096	4.13
17	0.150-0.156	0.153±0.003	0.268±0.005	1.13
18	0.233-0.237	0.235±0.002	0.411±0.004	1.72
19	0.284-0.286	0.285±0.001	0.499±0.002	2.09
20	0.175-0.177	0.176±0.001	0.308±0.002	1.29
21	0.166-0.169	0.168±0.002	0.294±0.003	1.23
22	0.186-0.189	0.188±0.002	0.328±0.003	1.38
23	0.178-0.188	0.188±0.001	0.329±0.002	1.38
24	0.178-0.181	0.180±0.002	0.315±0.003	1.32
25	0.130-0.133	0.132±0.002	0.230±0.003	0.96
26	0.154-0.157	0.155±0.001	0.272±0.003	1.14
27	0.135-0.139	0.137±0.002	0.240±0.004	1.01
28	0.120-0.124	0.122±0.002	0.214±0.004	0.89
29	0.101-0.104	0.103±0.001	0.179±0.003	0.75
30	0.109-0.112	0.110±0.002	0.193±0.003	0.81
31	0.112-0.115	0.113±0.002	0.198±0.003	0.83
32	0.123-0.127	0.125±0.001	0.219±0.004	0.92
33	0.140-0.144	0.142±0.002	0.248±0.004	1.04
34	0.160-0.164	0.162±0.002	0.284±0.004	1.19
35	0.139-0.144	0.141±0.003	0.247±0.005	1.04
36	0.149-0.154	0.152±0.003	0.266±0.005	1.12
37	0.135-0.140	0.138±0.002	0.241±0.004	1.01
38	0.119-0.125	0.122±0.003	0.213±0.005	0.89
39	0.154-0.182	0.172±0.015	0.301±0.028	1.27
40	0.149-0.154	0.151±0.003	0.265±0.004	1.11
41	0.157-0.163	0.160±0.003	0.280±0.005	1.18
42	0.145-0.148	0.148±0.003	0.259±0.006	1.09
43	0.135-0.140	0.138±0.002	0.241±0.004	1.01
44	0.130-0.134	0.132±0.002	0.230±0.004	0.96
45	0.148-0.252	0.217±0.050	0.379±0.104	1.59
46	0.210-0.214	0.212±0.002	0.374±0.004	1.56
47	0.408-0.413	0.410±0.005	0.718±0.010	3.01
48	0.164-0.170	0.167±0.003	0.290±0.005	1.23
49	0.238-0.245	0.241±0.004	0.420±0.006	1.77
50	0.248-0.256	0.252±0.004	0.440±0.007	1.85

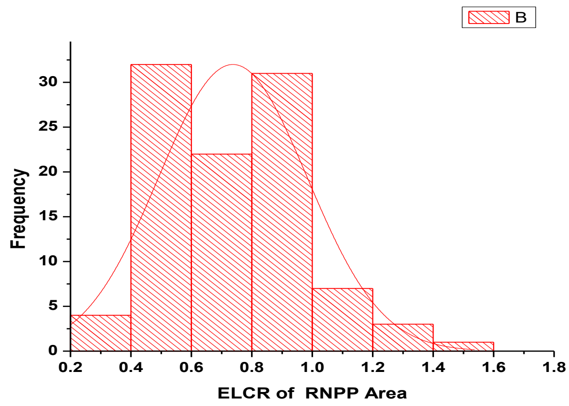

Fig .5: Frequency distribution of resultant ELCR around RNPP project area .

From Fig 5, most of the points have ELCR in the range between 0.4×10^{-3} - 0.6×10^{-3}, and the lowest number of monitoring points have ELCR in the range between 1.4×10^{-3} - 1.6×10^{-3}.

Radiation levels are monitored both indoors and outdoors in the AERE area due to the presence of many scientists and staff members working there. To ensure the safety of these radiation workers, indoor radiation dose measurements are deemed as crucial as outdoor radiation dose rate concentration measurements. These measurements play a significant role in calculating the workers' annual effective dose and health risks.

The gamma dose concentration of the monitoring point in and around the AERE area is shown in Table 1 (Indoor data) and Table 2 (Outdoor data).

From Table 1, the maximum D_R present on point MP 40, and the data collected from inside the source room of SSDL. The minimum D_R present on point MP 34, was collected from the control room of SSDL.

From Table 2, the maximum radiation dose rate concentration is noticed on MP 16 (middle portion of CRR tank), and 2nd maximum gamma dose is seen on MP 47 (Health Physics and Radioactive Waste Management Unit surface area). As the waste material of CRR is accumulated in the tank dedicated to the CRR unit, and radioactive waste material from various institutes all over the country is decomposed at the Health Physics and Radioactive Waste Management Unit, so in these places, radiation dose may be higher than in other areas.

The gamma dose rate concentration of the AERE area ranges between 0.103 to 1.276 μSvh^{-1} with an average value of 0.204 ± 0.006 μSvh^{-1}. The maximum dose (indoor) is noticed at the source room of SSDL, which is quite usual in these cases.

Annual effective dose (AED) for indoor gamma radiation concentration of AERE area ranged between 0.782 to 8.946 $mSvy^{-1}$ with an average value of 1.649 ± 0.049 $mSvy^{-1}$, which is lower than the permissible limit for radiation worker 20 $mSvy^{-1}$[36].

Annual effective dose (AED) for outdoor gamma radiation concentration of AERE area ranged between 0.179 to 0.985 $mSvy^{-1}$ with an average value of 0.303 ± 0.008 $mSvy^{-1}$.

The ELCR value for indoor dose rate ranged from 3.28 $\times10^{-3}$ to 37.51 $\times10^{-3}$ with an average value of 6.91 $\times10^{-3}$ which is 5.95 times higher than the world average value of 1.16 $\times10^{-3}$[54].

The ELCR value for outdoor dose rate ranged from 0.75 $\times10^{-3}$ to 4.13 $\times10^{-3}$ with an average value of 1.27 $\times10^{-3}$ which is 4.37 times higher than the world average value of 0.29 $\times10^{-3}$[36].

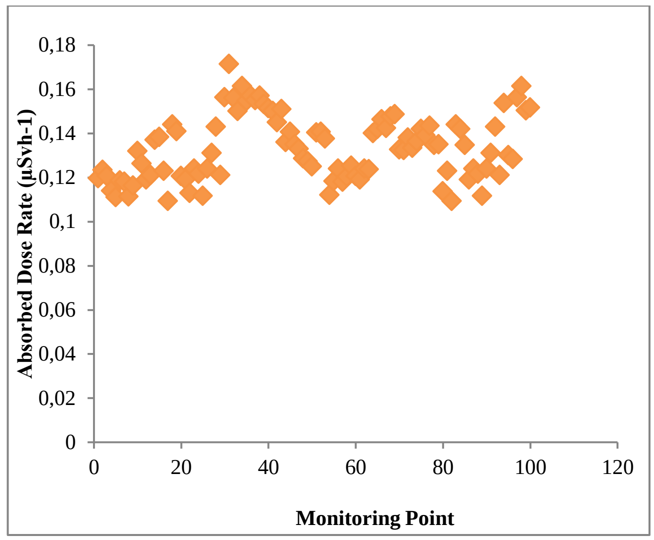

Fig. 6: Absorbed dose rate at monitoring point surroundings of BCMCL area.

From Fig 6, the minimum D_R for Barapukuria Coal Mine Company Limited (BCMCL) is seen on MP 82 to have a value of 0.109 μSvh^{-1} and a higher value for MP 31 with a value of 0.171 μSvh^{-1}. The average absorbed dose rate concentration for that monitoring area is 0.133 ± 0.014 μSvh^{-1}.

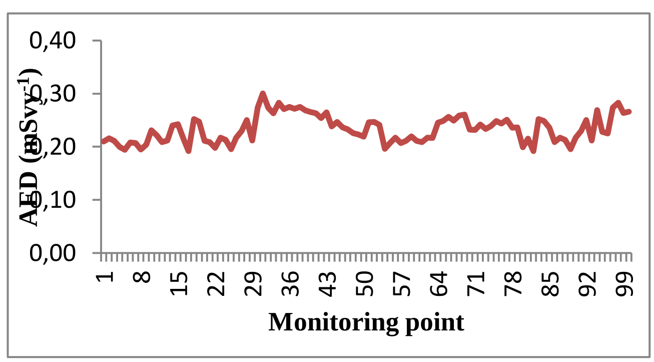

Fig. 7: Annual effective dose rate of BCMCL area.

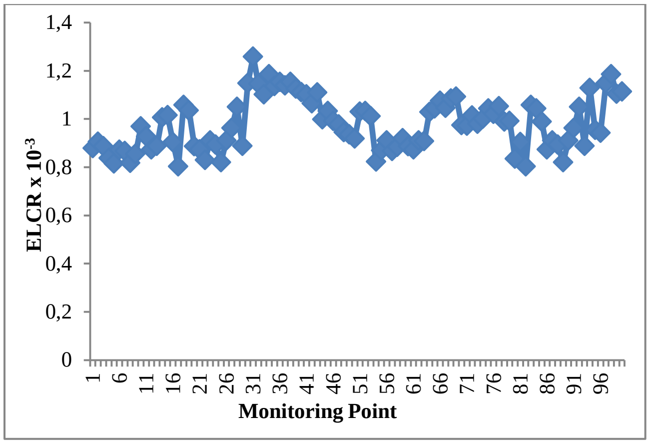

Fig .8: Estimated lifetime cancer risk of BCMCL area.

From Fig 8, the ELCR for the public works surroundings of the BCMCL area. This value ranges from 0.8 $\times10^{-3}$ to 1.26 $\times10^{-3}$ with an average value of 0.98 $\times10^{-3}$ which is greater than the world average value of 0.29 $\times10^{-3}$[36].

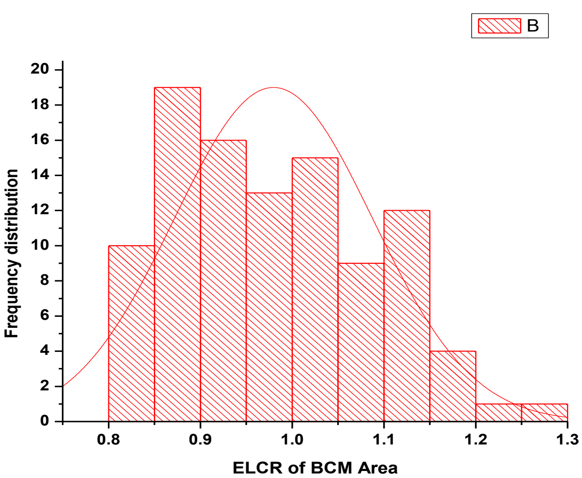

Fig 9: Frequency distribution of resultant ELCR around BCMCL area.

From Fig 9, most of the monitoring points have ELCR in the range between 0.85×10^{-3}- 0.90×10^{-3}, and the lowest number of monitoring points have ELCR in the range between 1.2×10^{-3}- 1.4×10^{-3}. No monitoring point has an ELCR lower than the value 0.8 $\times10^{-3}$.

Table 4 indicates that Kerala, India, and Tehran, Iran, exhibit higher indoor AED (Annual Effective Dose) and ELCR (Excess Lifetime Cancer Risk) values compared to those observed in this study. Conversely, other locations show lower AED and ELCR values for the indoor concentration of CRR (Controllable Releasing Rate) in the AERE area.

The likely reason behind the higher resultant AED value compared to others could be attributed to the specific monitoring area's location. Given that CRR contains active radionuclides and other institutes within AERE conduct research involving radioactive substances, detecting some level of radioactivity in the room where different types of sources are kept or indoor areas is not considered abnormal. However, it is important to note that the measured indoor AED does not exceed the permissible limit for radiation workers.

4 Discussions

Bangladesh is currently on the verge of commissioning a nuclear power plant to meet the nation's electricity demands. Consequently, it is crucial to establish a baseline for background radiation data, which is needed to know the changes after operation of RNPP. Once the power plant is operational, this baseline data will serve as a reference point to compare the existing gamma radiation levels with any additional radiation resulting from potential leaks or accidents. Based on real-time radiation dose measurements at three locations, the findings reveal that the dose rate (DR) ranges from 0.052 to 1.276 µSvh-1, and the annual effective dose (AED) ranges from 0.091 to 8.946 mSvy-1. Notably, certain points within the AERE (Bangladesh Atomic Energy Commission's largest establishment, dealing with radioactive materials and nuclear reactors) exhibit higher dose rates compared to other areas. This is expected, especially in the source room or vicinity of the radioactive source. As a large number of people are working at AERE where most institutes are working with radioactive nuclides besides CRR facilities so it is very sensitive to measure the indoor radiation dose for occupational exposure. The maximum value of AED measured from indoor data and for outdoor data all values are in normal ranges. At RNPP, which does not yet have

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