JSR Publications

Available Online

J. Sci. Res. **13** (3), 879-890 (2021)

JOURNAL OF SCIENTIFIC RESEARCH

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Outdoor Environmental Radiation Monitoring and Estimation of Radiation Risk on Public in New Market Thana, Dhaka, Bangladesh

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Received 22 April 2021, accepted in final revised form 25 June 2021

Abstract

The Real-time outdoor environmental gamma radiation (RTOEGR) dose rates were monitored at New Market Thana in Dhaka city to generate a baseline database that would help to know any deviation after operation of Rooppur NPP. The RTOEGR monitoring was carried out using a digital portable radiation monitoring device (DPRMD). The RTOEGR dose rates at the area of New Market Thana were ranged from 0.103 ± 0.004 µSv/h to 0.168 ± 0.007 µSv/h with an average of 0.135 ± 0.004 µSv/h. The public's annual effective doses were calculated based on RTOEGR dose rates, and those were varied from 0.181 ± 0.007 mSv to 0.295 ± 0.007 mSv with an average of 0.238 ± 0.007 mSv. Excess Lifetime Cancer Risk (ELCR) on public health was estimated based on the annual effective dose. The Public's ELCR were from 0.720×10^{-3} to 1.174×10^{-3} with an average of 0.892×10^{-3}, which is higher than the worldwide standard value of 0.29×10^{-3}. The mean RTOEGR dose rate of the New Market Thana in Dhaka city is comparable to that of Sabzevar city (Iran), Kathmandu city of Tribhuvan University (Nepal), Baghdad city (Iraq), Kirikkale city (Turkey).

Keywords: Environment; Radiation; In-Situ; Public; ELCR.

doi: http://dx.doi.org/10.3329/jsr.v13i3.53112 J. Sci. Res. **13** (3), 879-890 (2021)

1. Introduction

People are exposed to natural sources of ionizing radiation continuously from the earth, construction materials, air, water, the universe. The presence of the naturally occurring radionuclides in the environment is the main contributor to the total effective dose received by the people. The greater part of public exposure to ionizing radiation contributes from natural radiation sources such as cosmic rays and terrestrial radiation [1]. High energy cosmic-rays depend on geological characteristics of a region, such as altitude, latitude, and lunar activity [2,3]. Natural radionuclides of terrestrial sources have very long half-lives or disintegrated from very long-lived primordial radionuclides (half-lives on the order of 10^9-10^{10} years), and these radionuclides have been produced solar

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processes prior to the earth creation. The terrestrial background level dose is evaluated mainly from three primordial radionuclides such as ^{40}K, ^{238}U and ^{232}Th and their decay products. These radionuclides are spread extensively and exist in nearly all geological materials in the earth's environment [4,5]. The deviation of terrestrial sources of ionizing radiation in a region is normally higher than that of cosmic rays [6]. Some regions in the world where the outdoor terrestrial sources of radiation level go beyond the worldwide mean value due to some radioactive minerals, and these regions identify as high background areas. The high background areas were found in some countries, namely Iran, India, China, Brazil, the USA, and Germany [7]. In addition to the natural sources of radiation, the background dose rates in a region were influenced by the anthropogenic radiation sources introduced into the environment through human activity [8]. Many radionuclides of the uranium decay products, thorium decay products, and potassium-40 (K-40) emit gamma-rays that contributed to public exposures in the outdoor environment. The gamma-rays are responsible for most external human exposures considering all types of ionizing radiation due to their high penetration capability [9]. Gamma-rays exist everywhere. Significant deviation has been reported to other countries [10-14] for gamma-ray dose rates in outdoor and indoor environments. Laboratory and In-Situ gamma spectroscopy methods are mainly used for environmental radiation monitoring and evaluation of activity concentration and dose rate in the outdoor environment for natural and anthropogenic radiation sources [15-20]. In the case of large-area environmental radiation monitoring, the In-Situ method is more suitable than laboratory soil analysis due to its chances of cross-contamination in the laboratory and time-consuming. The consequences of low-level ionizing radiation exposures on public health are expected to be small, but it is not possible to eliminate the impact of the natural radionuclides in the environment. Low-level ionizing radiation exposure from the natural radionuclides during a long period may lead to some risks to public health [21]. The expression 'excess lifetime cancer risk' (ELCR) is defined as the probability of getting cancer for all people.

It is mentionable that there are few large & old facilities situated in the New Market Thana, like New Market, Dhaka College, Bangladesh Council of Scientific and Industrial Research (BCSIR). New Market is the biggest and oldest shopping complex in Dhaka city. Many people used to visit New Market from all areas of Dhaka district and even outsides of Dhaka district for shopping along with their family members. Dhaka College is the oldest and largest college in Bangladesh. The New Market Thana is the busiest area in Dhaka city. The aim of the present study is to monitor the real-time radiation in the areas of New Market Thana, evaluate the annual effective dose to the public, and estimate the excess lifetime cancer risk (ELCR) on public health based on the annual effective dose.

2. Materials and Methods

2.1. *Equipment*

The RTOEGR dose rate was monitored using the DPRMD throughout the study. The DPRMD is equipped with a Geiger-Muller counter tube facilitating to detect not only gamma radiation but also alpha & beta particles. The DPRMD is designed and manufactured by Germany, built with a solid Novadur exterior. An optional fashionable leather holster with a belt strap can extra protect the DPRMD from the elements. The DPRMD complies with all the requirements of European CE standards and the American FCC 15 standard. The DPRMD monitors radiation day and night and logs data for later download. Its battery lasts for years due to the sophisticated electronics. The data of the DPRMD can transfer to the PC through the USB port. The DPRMD stores all registered pulses in its internal memory and keeps those pulses ready to use when needed. The DPRMD features an acoustic signal that sounds when the dose rate exceeds a certain level. The default alert level is 5 μSv/h. The data of the DPRMD can be read and processed quickly and conveniently on a PC using the Toolbox software with Windows 7 and above version. The DPRMD has a battery pointer, several unit conversions, real-time dose rate, cumulative dose display functions, and programmable logging and alert functions. The DPRMD accurately monitors dose rate within the range of 0.01-5000 µSv/h (User Manual-GAMMA SCOUT, 2014).

2.2. *Calibration of the equipment*

The DPRMD was calibrated after construction by the Company (GmbH & Co.KG, Germany). The DPRMD is calibrated every year using the standard gamma-ray sources like ^{137}Cs, ^{60}Co, and X-ray units from the Secondary Standard Dosimetry Laboratory (SSDL) under the Bangladesh Atomic Energy Commission (BAEC). The SSDL of BAEC has been available since 1991, which complies with the Primary Standard Dosimetry Laboratory (PSDL) of the National Physical Laboratory (NPL), United Kingdom. The SSDL of BAEC has an X-ray Unit (30 kV-225 kV) required to calibrate the radiation monitoring instruments. The SSDL of BAEC meets all the requirements of the International Atomic Energy Agency (IAEA)/World Health Organization (WHO) network of SSDLs. So, the RTOEGR dose rates of DPRMD comply with the international monitoring system.

2.3. *Description of the site and data collection procedure*

The New Market Thana area is 1.64 sq.km, and its location varies from 23°43' -23°44' north latitudes and 90°22'-90°23' east longitudes. Total population is 49,523 (male is 32685 and female is 16838) and population density is 30,197/sq.km [22]. The New Market Thana is the busiest area in Dhaka city because of different types of shopping centers like New Market, Gauchhia Market, Chandrima Super Market, Dhanmondi Hawkers Market, Katabon Market, Chadni Chawk Super Market, Anjana Plaza, Eastern Mallika, Multiplan Centre, Globe Shopping Complex, Badruddozza Shopping Centre, etc. People used to visit these shopping centers from other parts of Dhaka city and even outsides of Dhaka city for shopping. The map of the New Market Thana is shown in Fig.

1 [23]. There are few large and old facilities in the New Market Thana, like New Market, Dhaka College, Bangladesh Council of Scientific and Industrial Research (BCSIR), Teacher Training College (TTC), etc. Thirty-two monitoring points (MP) were selected at the outdoor environment in New Market Thana to collect the RTOEGR dose rates following In-Situ Method. The MPs were identified using the GARMIN eTrex HC series personal navigator. The device has a reputable Garmin high-sensitivity GPS and the best-featured mapping to make an incomparable portable GPS receiver [24]. The GPS location data of the MPs were ranged from E: $90^{o}22.980^{'}$ to E: $090^{o}23.200^{'}$ and from N: $23^{o}43.957^{'}$ to N: $23^{o}44.626^{'}$. The RTOEGR dose rates monitoring were carried out from March-April 2019 using the DPRMD. Every MP, the DPRMD was placed at 1 m height above the ground on a tripod, and the time for gamma radiation monitoring was 1 hour. The dose rates and GPS reading of 32 MPs are shown in Table 1.

2.4. *Annual effective dose and ELCR calculation*

The outdoor & indoor occupancy factors of the public are 0.20 and 0.80, respectively [25]. These occupancy factors are the fractions of a person's total time being exposed to a radiation field outdoor and indoor. The annual effective dose to the public in the outdoor environment due to radiation is calculated using the equation below:

$$\text{Annual effective dose } (\mu\text{Sv}) = \text{dose rate } (\mu\text{Sv.h}^{-1}) \times 0.2 \times 8760 \text{ h.yr}^{-1} \quad (1)$$

Excess lifetime cancer risk (ELCR) on public health is calculated based on the annual effective dose using the equation below:

$$ELCR = AED \times DL \times RF \quad (2)$$

Where AED is the annual effective dose to the public, DL is the duration of life of Bangladeshi people [26], and RF is the risk factor (Sv^{-1}) which is the fatal cancer risk per sievert. RF is considered a fatal cancer risk per sievert. The probability of getting the stochastic effects on the public health if public receives low-level ionizing radiation during a long time from the environment, International Commission on Radiological Protection (ICRP) suggested the value of RF is 0.057 [27] for the public, and Biological Effects of Ionizing Radiation (BEIR) suggested the value of RF is 0.064 [28] for the public.

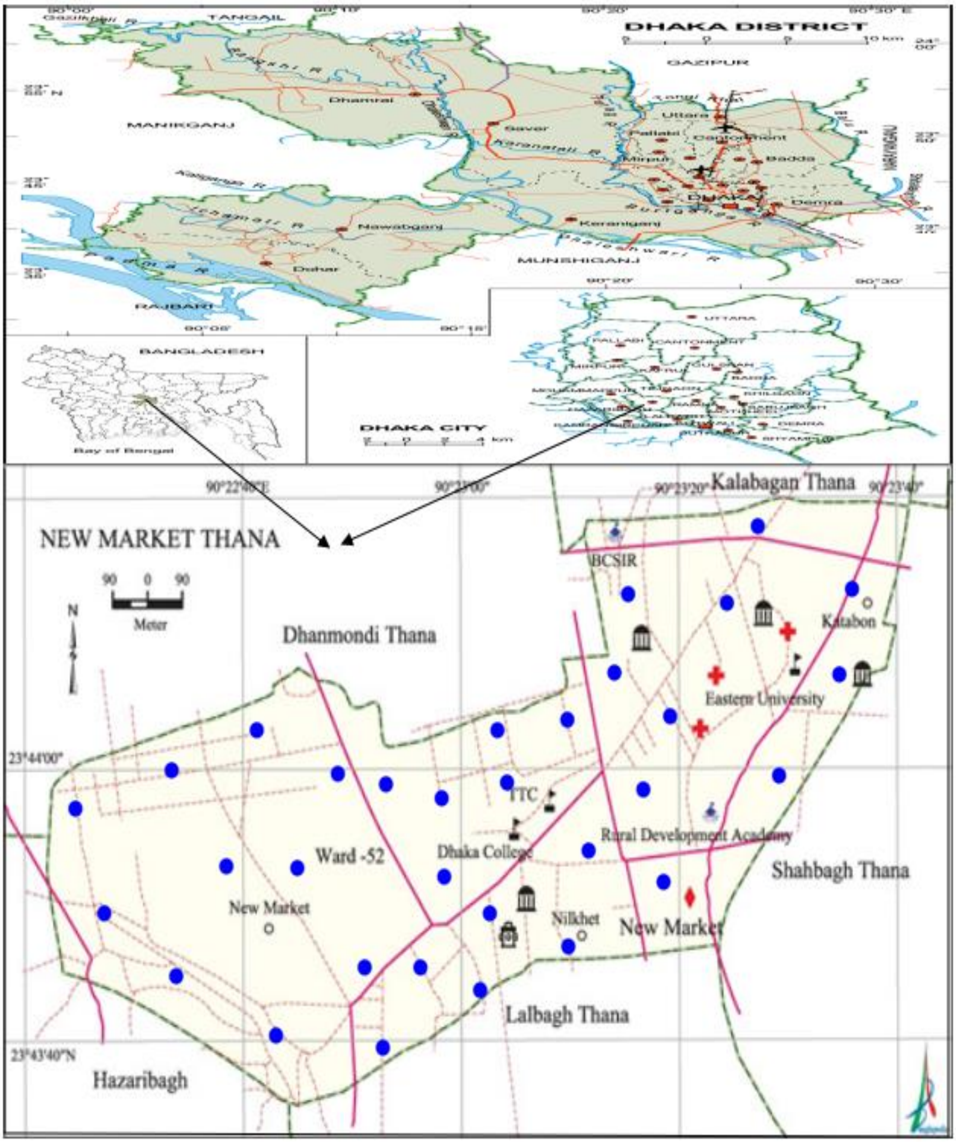

Fig. 1. Shows the MPs (•) of the New Market Thana in Dhaka city using the DPRMD.

3. Results and Discussion

3.1. *Collection of outdoor gamma-ray dose rate*

It was observed that the dose rate in 32 MPs at New Market Thana in Dhaka city contributed to the natural radionuclides existing in the earth's crust and cosmic rays.

3.2. *Dose rate and annual effective dose*

The RTOEGR dose rate of 32 MPs of the New Market Thana in Dhaka city was ranged from 0.103 ± 0.004 µSv/h to 0.168 ± 0.007 µSv/h with an average of 0.135 ± 0.004 µSv/h. The annual effective doses to the public were calculated based on the RTOEGR dose rates, and those were varied from 0.181 ± 0.007 mSv to 0.295 ± 0.007 mSv with an average of 0.238 ± 0.007 mSv. Table 1 shows the dose rate range, mean, and the annual effective dose to the public for each MP. Large variations of the RTOEGR dose rates were observed at different MPs depicted in Table 1. The variation of the RTOEGR dose rates might be created by the geological characteristics of the locations. The highest and the lowest RTOEGR dose rates were found to be 0.168 ± 0.004 µSv/h and 0.103 ± 0.004µSv/h in the Eastern University (3) and the Nilkhet (1), respectively. A higher value of the RTOEGR dose rate in the Eastern University (3) MP is the contribution of the construction materials of the buildings. On the other hand, the lower value of the RTOEGR dose rate in the Nilkhet (1) MP is due to the lack of construction materials of the buildings. The mean RTOEGR dose rate of the New Market Thana is lower than Ramna Thana in Dhaka city [29] and Shahbag Thana in Dhaka city [30]. The lower value of the mean RTOEGR dose rate of the New Market Thana compared to that of the other two Thanas in Dhaka city might be due to the lack of large hospitals and radiological facilities where radioactive substances are handling.

Table 1. The dose rates and calculated annual effective dose to the public at New Market Thana in Dhaka city.

MP No.	Name of location	Latitude/ Altitude	Gamma radiation dose rate (µSv.h^{-1})			Mean annual effective dose due to gamma radiation (mSv) ± SD
			Range	Mean	SD	
1	New Market (1)	N23°44.059 ′E90°23.035	(0.124-0.136)	0.131	0.003	0.229 ±0.006
2	New Market (2)	N23°44.009 ′E90°23.061	(0.127-0.139)	0.133	0.004	0.232 ±0.007
3	New Market (3)	N23°44.001 E90°23.088′	(0.139-0.152)	0.145	0.004	0.253 ±0.006
4	New Market (4)	N23°43.960 E90°23.070	(0.124-0.140)	0.130	0.005	0.227 ±0.009
5	New Market (5)	N23°43.942 ′E90°23.026	(0.092-0.118)	0.103	0.009	0.181±0.016
6	New Market (6)	N23°43.984 ′E90°23.051	(0.105-0.129)	0.117	0.007	0.205±0.010
7	Ward-52 (1)	N23°44.047 ′E90°23.012	(0.118-0.130)	0.124	0.004	0.216 ±0.007
8	Ward-52 (2)	N23°44.073 ′E90°23.016	(0.134-0.145)	0.139	0.003	0.244± 0.006
9	Ward-52 (3)	N23°44.086 ′E90°23.070	(0.090-0.120)	0.105	0.011	0.184 ±0.019
10	Ward-52 (4)	N23°44.051 ′E90°23.029	(0.120-0.145)	0.134	0.007	0.235 ±0.012

11	Nilkhet (1)	N23°43.958 E90°23.142′	(0.096-0.109)	0.103	0.004	0.181±0.007
12	Nilkhet (2)	N23°43.957 E90°23.200′	(0.112-0.125)	0.117	0.004	0.205 ±0.007
13	Nilkhet (3)	N23°44.987 ′E90°23.121	(0.086-0.120)	0.104	0.009	0.182 ±0.015
14	Nilkhet (4)	N23°44.993 ′E90°23.119	(0.115-0.134)	0.124	0.006	0.217 ±0.011
15	Nilkhet (5)	N23°44.984 ′E90°23.101	(0.101-0.110)	0.106	0.003	0.185± 0.005
16	Nilkhet (6)	N23°44.120 ′E90°23.037	(0.126-0.145)	0.135	0.006	0.236 ±0.011
17	Dhaka College (1)	N23°44.112 ′E90°23.006	(0.132-0.145)	0.139	0.004	0.244 ±0.007
18	Dhaka College (2)	N23°44.158 ′E90°22.991	(0.116-0.125)	0.120	0.003	0.211 ±0.005
19	Dhaka College (3)	N23°44.195 ′E90°23.020	(0.115-0.128)	0.122	0.004	0.213 ±0.007
20	TTC (1)	N23°44.199 ′E90°22.980	(0.122-0.139)	0.128	0.005	0.224 ±0.008
21	TTC (2)	N23°44.180 ′E90°23.013	(0.052-0.150)	0.121	0.028	0.212 ±0.049
22	TTC (3)	N23°44.173 ′E90°23.066	(0.133-0.145)	0.138	0.004	0.242 ±0.006
23	Rural Development Academy (1)	N23°44.154 ′E90°23.032	(0.128-0.170)	0.141	0.015	0.246 ±0.025
24	Rural Development Academy (2)	N23°44.148 ′E90°23.056	(0.097-0.197)	0.149	0.031	0.261±0.054
25	Rural Development Academy (3)	N23°44.331 ′E90°23.397	(0.120-0.136)	0.129	0.005	0.225 ±0.008
26	Eastern University (1)	N23°44.537 ′E90°23.844	(0.143-0.165)	0.159	0.006	0.277 ±0.010
27	Eastern University (2)	N23°44.626 ′E90°23.816	(0.161-0.175)	0.168	0.004	0.295± 0.007
28	Katabon (1)	N23°44.331 ′E90°23.397	(0.100-0.120)	0.108	0.006	0.188± 0.010
29	Katabon (2)	N23°44.334 ′E90°23.435	(0.125-0.134)	0.130	0.003	0.226 ±0.005
30	BCSIR (1)	N23°44.374 ′E90°23.005	(0.098-0.113)	0.106	0.004	0.185±0.007
31	BCSIR (2)	N23°44.344 ′E90°23.004	(0.103-0.130)	0.114	0.008	0.199± 0.015
32	BCSIR (3)	N23°44.335 E90°23.093′	(0.125-0.135)	0.130	0.003	0.227 ±0.005

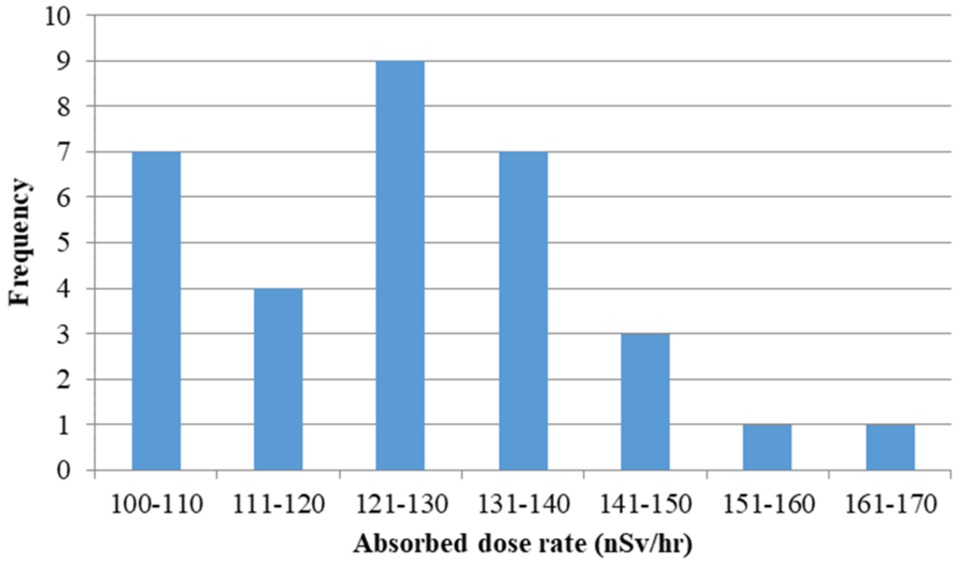

Fig. 2. Frequency distribution of the absorbed dose rate ($nSv.hr^{-1}$) at New Market Thana in Dhaka city.

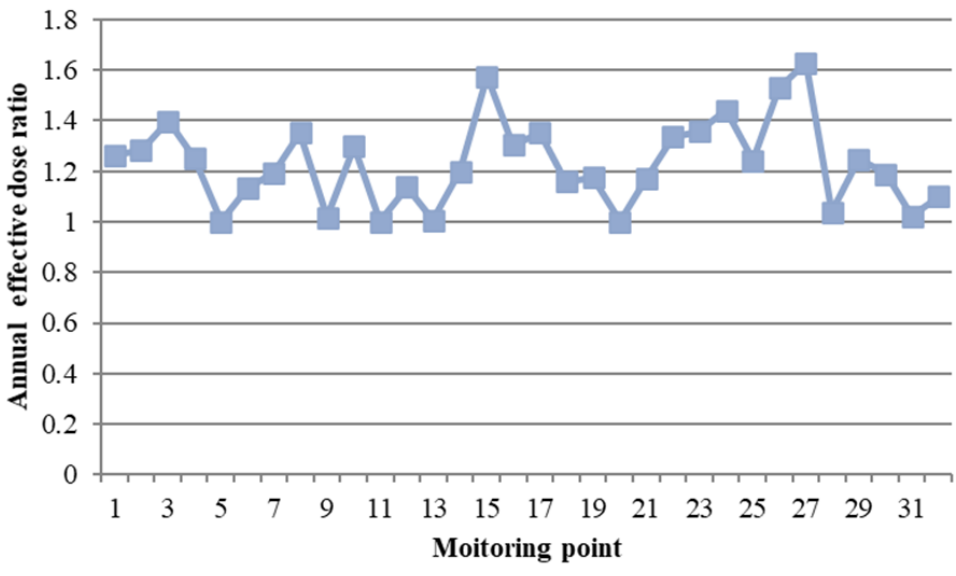

Fig. 3. Outdoor annual effective dose values normalized to the minimum annual effective dose for each MP.

The ELCR on public health was estimated based on the annual effective dose. The ELCR on public health was varied from 7.2×10^{-4} to 1.174×10^{-3} with an average of 8.92×10^{-4} as per ICRP recommendation [27]. The ELCR on public health was varied from

8.09×10^{-4} to 1.318×10^{-3} with an average of 1.002×10^{-3} as per BEIR recommendation [28]. The average ELCR on public health at New Market Thana is 3 times higher than that of the worldwide average of 0.29×10^{-3} [58].

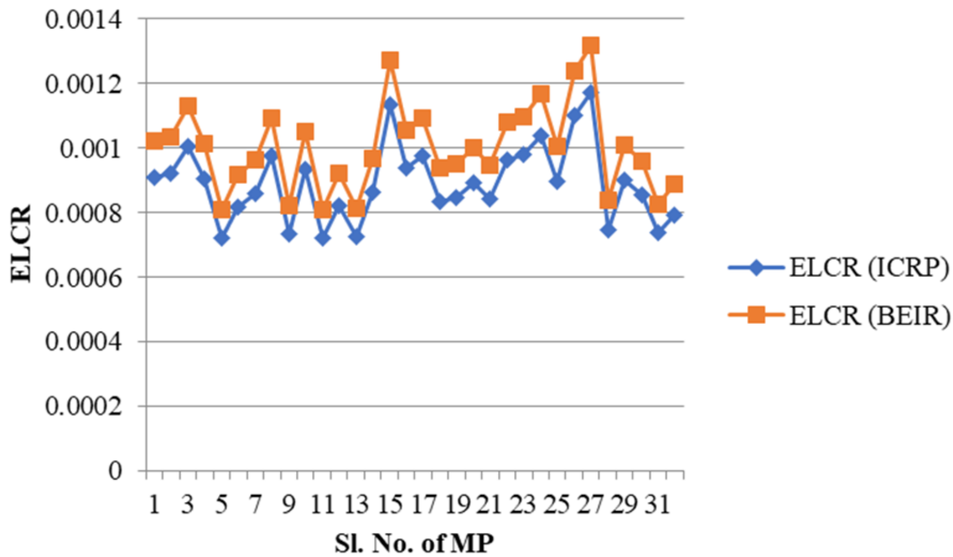

Fig. 4. Excess lifetime cancer risk (ELCR) on public health based on ICRP and BEIR recommendations.

From Table 2, it was observed that the mean RTOEGR dose rate of the New Market Thana in Dhaka city is lower than that of Iran, Chad, Nigeria, Turkey and higher than that of Egypt, India, Pakistan, Iraq. Furthermore, the mean RTOEGR dose rate of the New Market Thana in Dhaka city is comparable to that of Sabzevar city, Iran [38], Tribhuvan University, Nepal [43], Baghdad city, Iraq [54], Kirikkale city, Turkey [57].

Table 2. Comparison of outdoor dose rate, annual effective dose and ELCR values of New Market Thana, Dhaka, Bangladesh with other countries.

Country	Dose rate Range(mean) in μSv/h	Annual effective dose range (mean) in mSv	ELCR range (mean) $X10^{-3}$	Reference
Iran	0.429-0.781 (0.605)	0.527-0.958 (0.74)	2.956	31
Chad	-	0.028-1.807 (0.255)	0.058-3.794 (0.535)	32
Egypt	0.07-0.22 (0.16)	0.07-0.25 (0.16)	0.23-0.88 (0.56)	33
India	0.03-0.198 (0.106)	0.04-0.242 (0.072)	0.15-0.85 (0.25)	34
India	0.21-1.34 (0.106)	0.29-4.22	1.18-14.12	35
Iran	0.034-0.090	0.16-0.44	0.81-1.3	36
Pakistan	0.038-0.175 (0.087)	0.05-0.21 (0.11)	0.61-0.75 (0.37)	37
Iran	0.066-0.198 (0.134)	0.85	3.39	38
Iraq	0.026-0.084 (0.050)	0.03-0.10 (0.06)	0.11-0.34 (0.20)	39
Pakistan	0.056-0.148 (0.105)	0.928	0.352-0.792 (0.543)	40
Jamaica	0.008-0.230	0.557	0.0016-0.792 (0.163)	41

Morocco	0.009-0.091	0.05-0.56	0.19-1.96	42
Nepal	0.077-0.205 (0.115)	0.142	0.536	43
Nigeria	0.122-0.278 (0.203)	0.311	0.81	44
Palestine	0.011-0.083 (0.035)	0.014-0.101 (0.044)	0.70-1.33 (0.95)	45
Saudi Arabia	0.018-0.055 (0.035)	0.37	0.07-0.24 (0.20)	46
Tanzania	0.026-0.386	0.03-0.47	0.11-1.70	47
Turkey	0.021-0.826 (0.205)	0.026-1.013 (0.252)	1.0	48
Nigeria	0.147-0.228	0.183-0.419 (0.268)	-	49
Nigeria	0.120-0.234	0.23-0.36	0.37-3.70 (1.26)	50
Nigeria	0.112-0.143	0.119-0.153	0.418-0.534	51
Nigeria	0.15-0.33 (0.23)	1.46-2.92	4.59-10.22	52
Pakistan	0.189-0.269 (0.220)	0.30-0.50 (0.40)	1.20-1.60 (1.40)	53
Iraq	0.080-0.150 (0.111)	0.113-0.159 (0.136)	-	54
India	0.081-0.144	0.10-0.18	0.375-0.662	55
Switzerland	0.058-0.107	0.63-0.96 (0.79)	-	56
Turkey	0.023-0.320 (0.121)	0.04-0.59 (0.23)	0.14-2.07 (0.80)	57
Worldwide average	0.059	0.07	0.29	58, 34, 31
Bangladesh	0.103-0.168 (0.135)	0.28-0.67 (0.43)	0.72-1.174 (0.892)	This study

4. Conclusion

The monitoring of the RTOEGR dose rate is very necessary for the radiological mapping of a nuclear newcomer country like Bangladesh. The radiological mapping is required to know the deviation of the RTOEGR dose rate before and after operation of the Rooppur Nuclear Power Plant Project of Bangladesh and calculate the public exposure that contributes from the nuclear facility. The mean RTOEGR dose rate of the New Market Thana in Dhaka city is comparable to that of Sabzevar city (Iran), Kathmandu city of Tribhuvan University (Nepal), Baghdad city (Iraq), Kirikkale city (Turkey).

Acknowledgment

This research is funded by the Ministry of Science and Technology, Government of Bangladesh under the Special Research Allocation Project 2019-2020 & 2020-2021 (the grant serial number 523 MS & 519 MS).

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