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RADON CONCENTRATION IN GROUND WATER OF DHAKA CITY, BANGLADESH

Shikha Pervin [*1], Selina Yeasmin [1], Jannatul Ferdous [1], Afia Begum [2]
[1]Health Physics Division, Atomic Energy Centre Dhaka, 4 Kazi Nazrul Islam Avenue, Shahbag Dhaka-1000, Bangladesh
[2] Departments of Physics, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh

Abstract:
Water is the most important source of life and ground water may contain varying levels of radioactivity. So it is therefore important to measure radon concentration in ground water for public health and radiation protection. In this study, radon concentration was measured in ground water samples collected from water pumps of different locations at Dhaka city, Bangladesh. Twenty ground water samples were collected in July 2017to April 2018 for radon level measurement. Radon detector RAD7 (manufactured by Durridge Company, USA) with RAD H2O technique was used for the measurement. The highest radon concentration was found 13.00±0.70 Bq/L for the pump of sample ID GW1 and the lowest radon concentration 2.13±0.593 Bq/L for the pump of sample ID GW10.The activity concentration of radon in maximum water samples in Dhaka city was lower than the value 11.1 Bq/L recommended by United States Environmental Protection Agency (USEPA). The radon concentration was lowered from the activity concentration before storage. The highest value of annual effective dose for radon in ground water was found 0.04745 mSv/y According to recommendation of World Health Organization, the annual effective dose level for radon in drinking water is 0.1 mSv/y. These results indicate that there is no probability of health hazards for public due to presences of radon in ground water and it is safe for consumption**.**

Keywords: Ground Water; Radon; Rad7; Dhaka City; Annual Effective Dose.

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1. Introduction

Radon (^{222}Rn) is the major source of inner radiation exposure to human life which exists within air, water and soil [1]. It is a known cancer causing agent in human bodies and also the second most common cause of lung, skin, and leukemia cancers following smoking [2].^{222}Rn is a radioactive gas produced by the decay of naturally occurring radionuclide ^{226}Ra, which is the decay product in the uranium series [3]. The half of ^{222}Rn is 3.824 days and it emits alpha particle [4.] Radon gas always dissolves in water and its density is 7.5 times higher than air [3].

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If radon gas is inhaled, the ionizing alpha particles emitted by the decay products of ^{218}Po and ^{214}Po can interact together with the biological tissue in the lungs leading to DNA damage, and it refers to the ingestion of dissolved radon in water will result in a radiation dose to the inside layer of the stomach[5]. Radon gas can enter the dwellings through water system [6].As water makes up 70-75% of total body weight and indispensible part of life, human being meets their need from ground water and surface water [7]. The ground and surface waters gave different radon concentration because the radon in groundwater has its origin in the radioactive decay of radium and reflect nit only in chemical form but also in structural properties of rock in the aquifer [8].Radon released from water when temperature is increased, pressure is decreased and when water is aerated. Several methods have been developed to measure radon in water such as: Gamma Spectroscopy (GS), Lucas Cell (LC) and Liquid Scintillation (LS). According to Environmental Protection Agency the LS method is as accurate and sensitive as the LC method, but less labor intensive, and less expensive. In comparison with the above, the RAD H_2O offers a method as accurate as LS but faster to the first reading, portable, even less labor intensive, and less expensive. It also eliminates the need for poisonous chemicals [9].

2. Materials and Methods

2.1. Sampling Area

Dhaka is the capital city of Bangladesh, in southern Asia with a population of 18.89 million people. It is located in the central part of Bangladesh at 23°42′N 90°22′E, on the eastern banks of the Buriganga River. It has a tropical savanna climate. The city has a distinct monsoonal season, with an annual average temperature of 26 °C (79 °F) and monthly means varying between 19 °C (66 °F) in January and 29 °C (84 °F) in May. 82% of the city's water supply is abstracted from groundwater through 577 deep tube wells, while four relatively small surface water treatment plants provide the remaining 18%.Groundwater levels are dropping at two to three meters every year. The city's water table has sunk by 50 meters in the past four decades and the closest underground water is now over 60 meters below ground [10.]

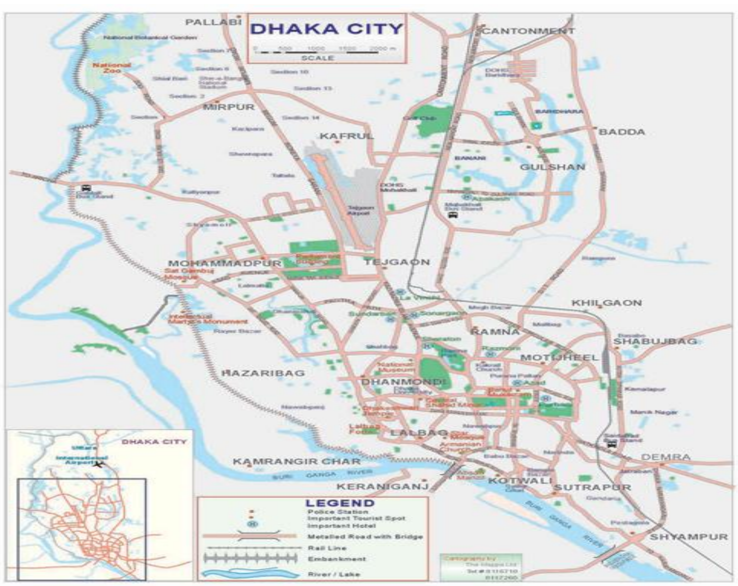

Figure 1: Map of the study area.

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2.2. Sample Collection and Preparation

Twenty ground water samples were collected from different pumps at different locations of Dhaka city (as shown in fig1), which are mainly used for drinking and also other everyday purposes. According to RAD7 manual, each sample was collected into 250ml vial and closed the vial immediately after collected so that it has never been in contact with the open air (Durridge RAD7 RADH$_2$O manual, 2012). After collecting each sample (within three hours) was taken in Health Physics Laboratory of Atomic Energy Centre, Dhaka for measuring radon concentration.

2.3. Radon Detector RAD7 with H$_2$0 Accessories

RAD7 is an electronic radon detector manufactured by Durridge Company, USA (as shown in fig. 2) with RAD H$_2$O technique (shown in fig. 3) used for monitoring radon concentration in ground water which has specific protocols for water tests. The equipment Durridge RAD7 was designed to detect alpha particles only. RAD7 uses a solid-state semiconductor detector that converts alpha radiation directly to an electrical signal with the advantage of electronically determining the energy of each alpha particle. The equipment can thus determine exactly by means of alpha spectrometry which isotope produced the radiation (Durridge RAD7 RADH$_2$O manual, 2012).

Figure 2: RAD7 detector

The RAD7 internal sampling cavity is a hemisphere of 0.7 liters coated internally with an electrical conductor. A solid-state semiconductor detector is placed at the center of the hemisphere. When a high voltage of 2,000 – 2,500 volts is applied to the conductor material of sampling cavity it creates an electric field across the cell volume, which drives the positively charged particles toward the detector surface [9,11].

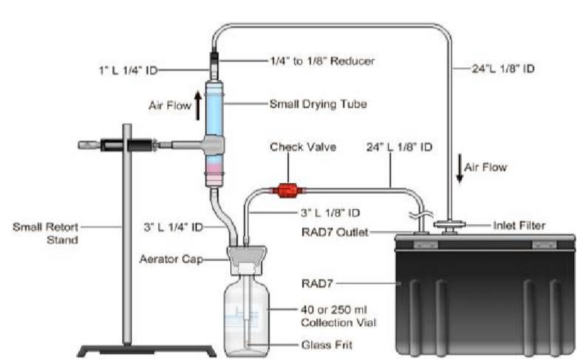

Figure 3: Schematic Diagram of RAD7 Detector with RAD H$_2$0 Accessories.

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2.4. Aeration

Radon gas is mildly soluble in water and being a gas, it is volatile. It tends to leave the water upon contact with air. This is known as aeration. The rate of radon transfer from water to air increases with temperature, agitation, mixing, and surface area

2.5. Humidity and Temperature

Relative humidity showed the greatest impact on measurement error in the presented results. For accurate readings, the RAD-7 detector should be dried out thoroughly before the measurement. If the RAD-7detector is thoroughly dried out before use, the relative humidity inside the instrument will stay below10% for the entire 30 min of the measurement. If not, then the humidity will rise above 10% the measurement time and the pump would be stopped.

2.6. Purging

After performing the radon measurement in water or air measurement, the RAD7's internal sample cell will continue to contain the radon that was measured. If this radon is still present when a new measurement started, it will erroneously influence the next measurement. A common cause of error is incomplete purging of the system before a measurement. If residual radon exists in the RAD7 and tubing when the RAD H_2Ovial is hooked up to it, that residual radon will be added to the radon provided by the aeration of the sample. In the case of a 40mL vial, 1 Bq/L of residual radon in the loop will be reflected as25 Bq/L additional radon in the original 40mL water sample.

Figure 4: Radon measurement in ground water samples in the Laboratory

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Figure 5: Aeration stage during radon measurement

2.7. Radon Concentration

The RAD7 calculates the sample water concentration by multiplying the air loop concentration by a fixed conversion coefficient that depends on the sample size. This conversion coefficient has been derived from the volume of the air loop, the volume of the sample, and the equilibrium radon distribution coefficient at room temperature. For 40mL sample volume the conversion coefficient is around 25 and for 250mL sample volume is around 4. The RAD7 does not presently make any correction for the temperature of the water sample. Theoretically such correction would slightly improve the analytical accuracy for the larger sample volume (250ml), but would make little or no difference for the smaller sample volume. The decay correction is a simple exponential function with a time constant of 132.4 hours. Decay correction can be used for samples counted up to 10 days after sampling, though analytical precision will decline as the sample gets weaker and weaker.

The decay correction factor (DCF) is given by the formula

DCF= exp (T/132.4)………………………………………………….. (1)

Where T is the decay time in hours [9]
Based on decay correction factor's table (RAD7 H20 manual), decay time of less than 3 hours require very small correction. The decay factor may be neglected for the samples counted quickly. Thus, the actual radon concentration for each sample was calculated as below [9]:

Corrected Radon Concentration
= Radon Concentration*DCF……………………. (2)

2.8. Annual Effective Dose

The annual effective dose to an individual for ^{222}Rn due to intake of water was evaluated using the following equation [11]:

$D_W = C_w Cr_w Dc_w$………………… (3)

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Where, $D_w$is the annual effective dose (sv/y) due to ingestion of radionuclides from the consumption of water,
C_w is the concentration of ^{222}Rn in the ingested water (Bq /L),
Cr_w is the annual intake of water (L/y),
D_{cw} is the ingested dose conversion factor for ^{222}Rn (Sv/Bq).

According to United Nations Scientific Committee on the Effects of Atomic Radiation [12], a dose conversion factor of 5 * 10^{-9} Sv/Bq has been used and considering that an adult (age>18 year), on the average, takes 730 L water annually.

3. Result and Discussion

Table 1 shown the radon concentration in Bq/L for ground water samples of Dhaka city During the measurement relative humidity ranged was 12 -20 % and temperature ranged was 18 - 26.8 ^{o}C. Highest radon concentration was found in the pump of Atomic Energy centre, Dhaka which was13.00±0.70 Bq/L and the lowest was 2.13±0.593 Bq/L in the pump of BSMMU, Shahbag, Dhaka

Table 1: Radon concentration in ground water samples of Dhaka City.

Sample ID	Location	Sample criteria	Temp (^{o}C)	Humidity (%)	Mean±SD in Bq/L
GW1	Atomic Energy Centre, Dhaka	Pump water	24.3	17	13.00±0.70
GW2	BUET	Pump water	20.7	17	8.70±1.21
GW3	Shantinagar	Pump water	22	16	3.81±0.70
GW4	BailyRoad	Pump water	19	16	2.17±0.614
GW5	Zigatula-1	Pump water	22	17	11.00±1.42
GW6	Rupnagar, Mirpur	Pump water	21.9	18	8.93±0.08
GW7	Mohammadpur	Pump water	18	17	6.54±0.703
GW8	Bonany Colony	Pump water	20.7	18	8.430±1.66
GW9	Agargoan	Pump water	21	16	5.66±0.865
GW10	BSMMU	Pump water	21	10	2.13±0.593
GW11	Dhaka University	Pump water	24	12	4.68±0.488
GW12	Tongi	Pump water	22	12	6.83±1.560
GW13	Duaripara Pump, Pollobi, Mirpur	Pump water	20.7	18	10.00±1.53
GW14	Zigatula-2	Pump water	20.7	15	7.80±0.75
GW15	Shoroardi Uddan, Shahbag	Pump water	26.8	20	12.00±1.16
GW16	BIRDAM Hospital	Pump water	22	19	6.21±0.3490
GW17	Azimpur	Pump water	21	19	8.430±1.66
GW18	Kamrangirchar	Pump water	20	18	8.130±0.521
GW19	Baridhara	Pump water	22	19	7.89±1.551
GW20	Hazaribagh	Pump water	22	18	5.89±2.351

The average value of radon concentration for the study is 7.13 Bq/L. United States Environment Protection Agency the allowed maximum contamination level for radon concentration in water is

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up to 11.1 Bq/L [13]. Except two or three samples, all the value of radon concentration in ground water samples is lower than the value recommended by USEPA.

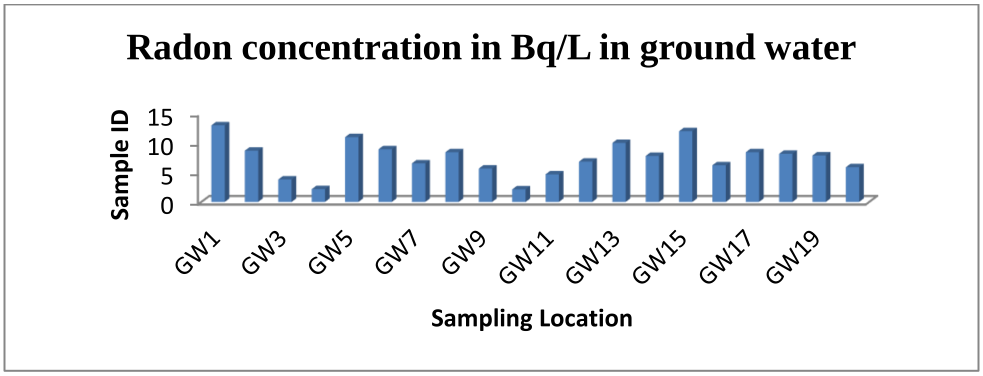

Figure 6: Variation of radon concentration in Ground water at different location of Dhaka City.

Table 2 shown that the annual effective dose

Table 2: Annual effective dose for ground water of Dhaka city

Sample ID	Sampling Location	Annual effective Dose in mSv/y
GW1	Atomic Energy Centre, Dhaka	0.04745
GW2	BUET	0.031755
GW3	Shantinagar	0.013906
GW4	BailyRoad	0.0079205
GW5	Zigatula-1	0.04015
GW6	Rupnagar, Mirpur	0.0325945
GW7	Mohammadpur	0.023871
GW8	Bonani Colony	0.0307695
GW9	Agargoan	0.020659
GW10	BSMMU	0.0077745
GW11	Dhaka University	0.017082
GW12	Tongi	0.0249295
GW13	Duaripara pump, Pollobi, Mirpur	0.0365
GW14	Zigatula-2	0.02847
GW15	Shoroardi Uddan, Shahbag	0.0438
GW16	BIRDAM Hospital	0.0226665
GW17	Azimpur	0.0307695
GW18	Kamrangirchar	0.029784
GW19	Baridhara	0.0287985
GW20	Hazaribagh	0.0214985

The highest value of annual effective dose was found 0.04745 mSv/yr for GW1 samples at the AECD water pump and the lowest value was found 0.00777mSv/yr for GW10 sample of BSMMU water pump with an average of 0.0270 mSv/yr. According to World Health Organization (WHO) and the Council of Europe Union (EU) the permitted level of annual effective dose in drinking water is up to 0.1mSv/Y or 100µSv/Y) [14, 15]. It was clearly seen from table 2 that the annual

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effective dose for all the samples at different locations of Dhaka city was below the permissible level.

Table 3: Comparison of the average value of the radon concentration with other countries (in Bq /L)

Country	**Radon activity concentration in Bq/L**	**Reference**
Syria	13 Bq/L	[16]
Iraq -River Hilla	0.181Bq/L	[17]
Kuwait	0.74 Bq/L	[18]
Jordon	3.9 Bq/L	[19]
Khartoum	59.2Bq/L	[20]
Punjab, India	2526 to 7750 Bq/m3	[1]
Northern Rajasthan, India	0.50 to 22Bq/L	[21]
Pakistan	2.0 to 7.9 Bq/L	[22]
Dhaka City	7.13 Bq/L	Present study

From the comparison of the average value of the radon concentration with other countries tabulated in table 3 indicate that the value of present study were below the value of Syria, Khartoum, Northern Rajasthan, India but slightly high compared to Iraq -River Hilla, Kuwait.

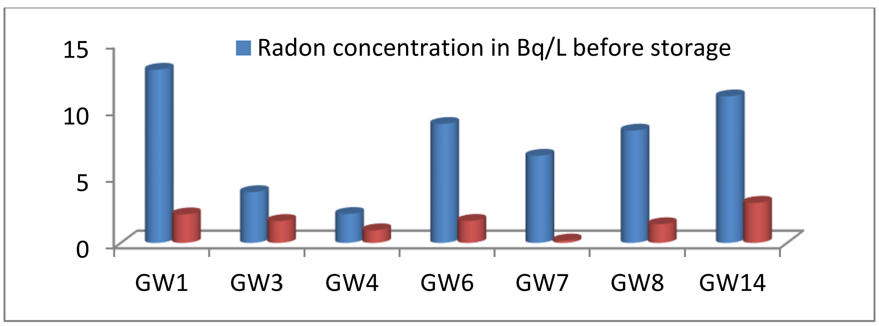

Figure 7: Changes of radon concentration in ground water at different location of Dhaka City.

Some of the samples were kept store for 30 days for further radon measurement. It was found that the radon concentration reduced from the fist measurement after sampling. From Figure 7, it was clearly seen that the radon concentration in ground water samples lowered from the concentration before storage.

4. Conclusion

The radon concentration of ground water and associated health hazards in the ground water samples in Dhaka city were investigated in this present study. The radon concentrations of maximum samples were found below the USEPA limit. Only two or three values of radon concentration were found slightly high than the USEPA limit of 11.1 Bq/L. The calculated annual effective doses to an individual for 222Rn due to intake of ground water for all samples were below the WHO limit. Therefore these results also indicate that there is no probability of health hazards for public due to presences of radon in ground water and it is safe for consumption in the study

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area. This was the first study of such type of radon measurement in ground water samples in Dhaka city by using this technique. So it's demanding larger and more comprehensive studies of all areas of the city.

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*Corresponding author.
E-mail address: shikha.pervin@ yahoo.com