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Study of ambient radiation exposure in Bagmati Province, Nepal

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Abstract

This research investigates the ambient background ionizing radiation (BIR) levels of five locations across seven districts within Bagmati Province, Nepal, using a 451P Pressurized Ion Chamber Survey Meter. These locations include the Araniko Highway, Makawanpur Highway, B.P. Highway, Kavrepalanchowk, and Kathmandu Valley. The study aims to evaluate the variations in BIR levels, quantify associated radiological hazard indices, and compare the results with a prior study conducted in 2023 using a RadAlert™ 100 radiation monitor. The acquired measurements reveal an average BIR of (0.016 ± 0.001) mR/hr, which exceeds the global average (0.013 mR/hr) by approximately 1.2 times. This can be primarily attributed to the region's geological composition. The highest BIR level was observed in Kathmandu Valley (0.017 mR/hr), and the lowest one was recorded along the Araniko Highway (0.014 mR/hr). Calculated hazard indices such as equivalent dose rate (EDR), absorbed dose rate (ADR), annual effective dose equivalent (AEDE), and excess lifetime cancer risk (ELCR), suggest that despite the moderately increased BIR levels, there is no significant radiological threat or hazard to the public health. Comparison with the 2023 study highlights the influence of measurement devices on recorded values, with RadAlert™ 100 yielding higher values than the Survey Meter. This study underscores the importance of continuous radiation monitoring for public health safety and provides updated data for radiological assessments in the Bagmati Province.

Keywords: Background radiation, Ionizing radiation, Radiation dose, IRCP dose limit

1.0 Introduction

Humans are constantly exposed to radiation of various forms. This can come from different natural as well as artificial sources, making it an unavoidable aspect of our environment. While artificial radiation originates from easily avoidable sources like nuclear power plants and medical machines (X-rays, CT scans, etc.), natural background radiation is commonly detectable in various geological formations such as the Earth's crust, rocks, soil, air, water, and vegetation (Sanjel, n.d.). Such natural radiation also emerges from cosmic radiation of the outer space and from radioactive materials found within the Earth. It is so omnipresent that there is no place on earth that has no natural radioactivity (UNSCEAR, 1982).

Exposure to high levels of artificial radiation can cause various health problems such as cancer, cardiovascular diseases, cataract, teratogenic effects, etc. Ionization molecules in living organisms by radiation can even induce cellular damage, specifically to the DNA (Al-Jundi, 2002). However, natural ambient radiation, which is present everywhere in low levels, hasn't shown detrimental consequences to human health as of yet. Natural background radiation is heavily influenced by factors such as cosmic radiation and terrestrial radiation from natural radioactivity in geographical structures. It varies globally from 1.00 to 13.00 millisieverts (mSv) per year (Radiopaedia, 2023).

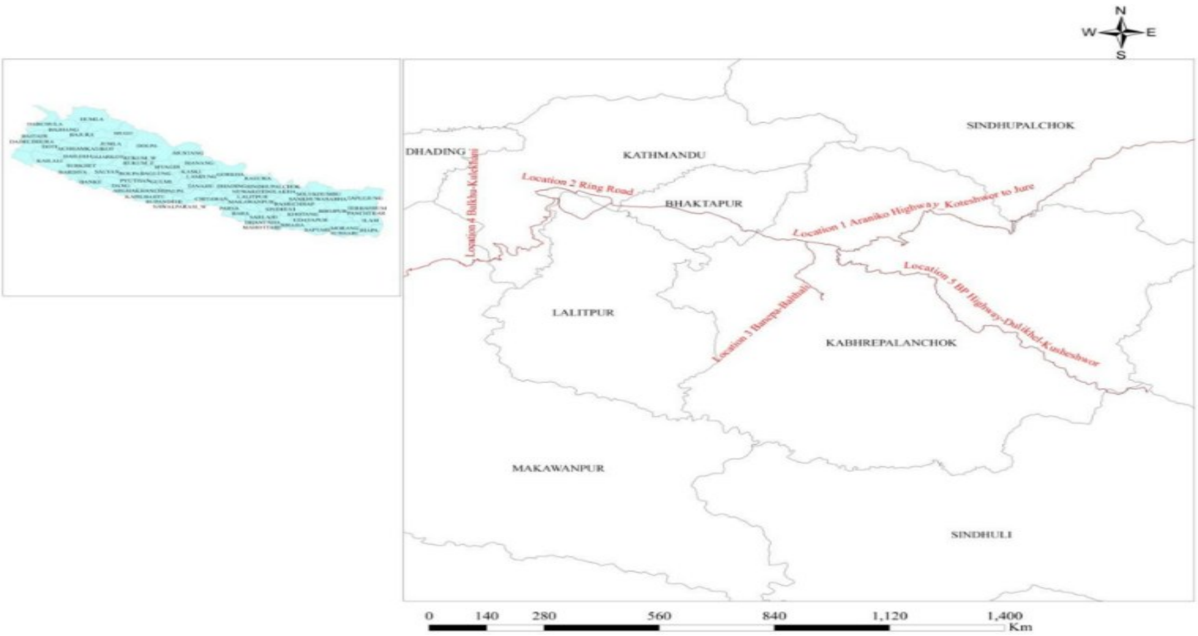

Fig. 1: Representation of locations of Bagmati Province.

While the average equivalent dose rate recommended by the International Commission on Radiological Protection (ICRP) is 1 mSv/yr, the International Atomic Energy Agency (IAEA) states that a person is exposed to approximately 2.4 mSv of background ionizing radiation (BIR) per year (Vennart, 1991). The value, however, may change by several hundred percentages depending upon the geographical location. The measurement of such BIR is important for researchers and policymakers to know and to understand its impact on the overall health of the population.

It is to be noted that similar researches have been conducted previously in the Bagmati Province using devices like RadAlert^{TM} 100, Thermo Luminescent Dosimeter (TLD) and Survey Meter (Sanjel, n.d.). However, further research is necessary to track the fluctuations of ambient radiation levels in this area. Furthermore, this province houses a dense settlement of communities, making it even more urgent and necessary to assess the potential health hazards surrounding it. For this, we must identify the areas with elevated radiation levels surpassing the recommended limit of 1.00 mSv/yr by ICRP. Thus, this research aims to provide clarity on background radiation and its consequences on human health by measuring the fluctuation of radiation levels in Bagmati Province.

2.0 Materials and Methodology

A 451P Pressurized Ion Chamber Survey Meter (Fig.1) was used to detect the background radiation for this study. This Survey Meter is capable of detecting X-rays, Beta rays above 1 MeV, and Gamma rays greater than 25 keV. The Survey Meter detects Beta and Gamma radiation with an accuracy of around ±10% in temperatures ranging from -20 °C to 50 °C (-4 °F to 122 °F), and relative humidity 0 % to 100 %. The typical energy dependence of this device on Nitrogen Gamma rays are 110% to 120% of indicated readings as determined at the University of Lowell. Survey Meters are typically used to monitor radiation levels in and around laboratories where radioactive materials or other radiation sources are present. Since the device is handheld and portable, this study used it to detect the background radiation of 5 places within Bagmati Province, namely Araniko Highway (Koteshwor to Barhabise), Makawanpur Highway (Dakshinkali to Kulekhani), B.P. Highway (Dhulikhel to Sindhuli), Kavrepalanchowk (Banepa and Panauti), and Kathmandu Valley (Ring Road).

Fig. 2.: 451P Pressurized Ion Chamber Survey Meter

We had previously conducted a study of background radiation levels in these places for a month in 2023 using RadAlert^{TM} 100 Handheld Nuclear Radiation Monitor. However, the current study conducted in February 2024 uses a Survey Meter in the same locations to evaluate the fluctuations and difference in readings. Consequently, we calculated the equivalent dose rate (EDR), absorbed dose rate (ADR), annual effective dose equivalent (AEDE), and excess lifetime cancer risk (ELCR) to determine the possible health risks associated with exposure to radiation.

Firstly, the device was calibrated using Cesium-137 as the standard radionuclide to ensure accurate readings and consistency. The calibrations should be done at a certified test range, which is typically at 660 µSv/hr (66mR/hr), i.e. two-thirds of the maximum reading. The device was turned on for an hour in each location to collect data every passing minute. The background ionizing radiation levels were direct observations taken in the unit µR/hr which were then converted to mR/hr using equation (1) as given below:

$$1 \text{ mR/hr} = 1/1000 \ \mu\text{R/hr} \quad (1)$$

To gain more insight on it, the equivalent dose rate was calculated by using the following equation:

$$1\text{mR/hr} = 0.96*24*365/100 \text{ mSv/year} \quad (2)$$

Next, the absorbed dose rate was calculated using the relation given below:

$$1\text{mR/hr} = 8.7\text{nGy/hr} \quad (3)$$

Then, using the conversion factor of 0.7 Sv/Gy recommended by UNSCEAR and from the absorbed dose in the air to the effective dose and occupancy factor of 0.2 for outdoors, the annual effective dose equivalent (AEDE) was calculated using the following equation:

$$\text{AEDE (mSv/yr)} = \text{Absorbed dose (nGy/hr)} * 8760 \text{ hr} * 0.7 \text{ Sv/Gy} * \text{occupancy factor} \quad (4)$$

Finally, by using the value obtained for AEDE, the excess lifetime cancer risk (ELCR) hazard index was calculated using equation (5). For this, the average lifespan in the context of Nepal was taken to be 66.2 years and risk factor was taken as $5x10^{-2}$ as recommended by ICRP for stochastic effects.

Excess Lifetime Cancer Risk (ELCR) = AEDE * Average Duration of Life * Risk Factor (5)

3.0 Results and Discussions

The study was conducted across 5 different locations within Bagmati Province, Nepal, which covered seven districts of the province. These sites included the Araniko Highway, B.P Highway, Makawanpur Highway, Kavrepalanchowk, and Kathmandu Valley. The background ionizing radiation exposure rate in each area is as represented in Fig. 3 and their comparative means and corresponding standard deviations over the number of radiological data are as shown in Table 1.

Table 1: Measured background ionizing radiation and estimated hazard indices of different Places.

Location	Average Background Ionization Radiation (mR/hr)	Equivalent Dose Rate (mSv/yr)	Absorbed Dose Rate (nGy/hr)	Annual Effective Dose Equivalent (mSv/yr)	Excess Lifetime Ccancer Rrisk (10^-3)
Araniko Highway	0.014 ± 0.002	1.156	119.635	0.147	0.486
B.P. Highway	0.016 ± 0.003	1.368	141.521	0.174	0.574
Kathmandu Valley	0.017 ± 0.003	1.392	143.994	0.177	0.585
Kavrepalanchowk	0.016 ± 0.002	1.324	137.012	0.168	0.556
Makawanpur Highway	0.016 ± 0.002	1.304	134.929	0.165	0.548
Average	**0.016 ± 0.001**	**1.309 ± 0.092**	**135.418 ± 9.522**	**0.166 ± 0.012**	**0.550 ± 0.039**

The BIR levels differed from place to place. However, it was found that all five places were considerably consistent to the average level of 0.016 mR/hr, which indicates fine distribution of doses. The highest BIR level was measured to be in Kathmandu Valley, which was 0.017 mR/hr, with an equivalent dose rate (EDR) of 1.392 mSv/yr. Whereas, the lowest BIR level was found in Araniko Highway with 0.014 mR/hr and an EDR of 1.156 mSv/yr. Apart from these, the BIR levels of B.P Highway, Makawanpur Highway, and Kavrepalanchowk were found to be 0.016 mR/hr. The average value of BIR measured in the province was slightly more than the world average i.e. 0.013 mR/hr (Rafique et al., 2014; WorldStat, n.d.; Vennart, 1991), also represented in Fig. 4. The overall average BIR of Bagmati Province is (0.016 ± 0.001) mR/hr, which is around 1.2 times higher than the recommended limit. This can be attributed to the geological formations in the province, having big rocky mountains that contain naturally occurring radionuclides.

Compared to the 2023 study in Bagmati Province, which reported an average BIR of 0.025 ± 0.002 mR/hr using a RadAlert™ 100 device, this 2024 study reports a significantly lower BIR of (0.016 ± 0.001) mR/hr (Karki et al., 2023). This significant decrease in value is mostly attributed to the different machines used for measurement in the two studies. The study of natural background radiation conducted in 2023 used a RadAlert^{TM} 100 radiation monitor, which is known to give comparatively higher values than the Survey Meter used for this study. This is typically because a RadAlert radiation monitor may overestimate radiation that other meters "ignore" as background noise. Just like the previous study, the lowest BIR level is once again found to be in Araniko Highway. However, the highest BIR level, which used to be in Kavrepalanchowk according to the previous study, is now in Kathmandu Valley. The juxtaposition of background ionizing radiation between the 2023 study and 2024 study is also represented in Table 2.

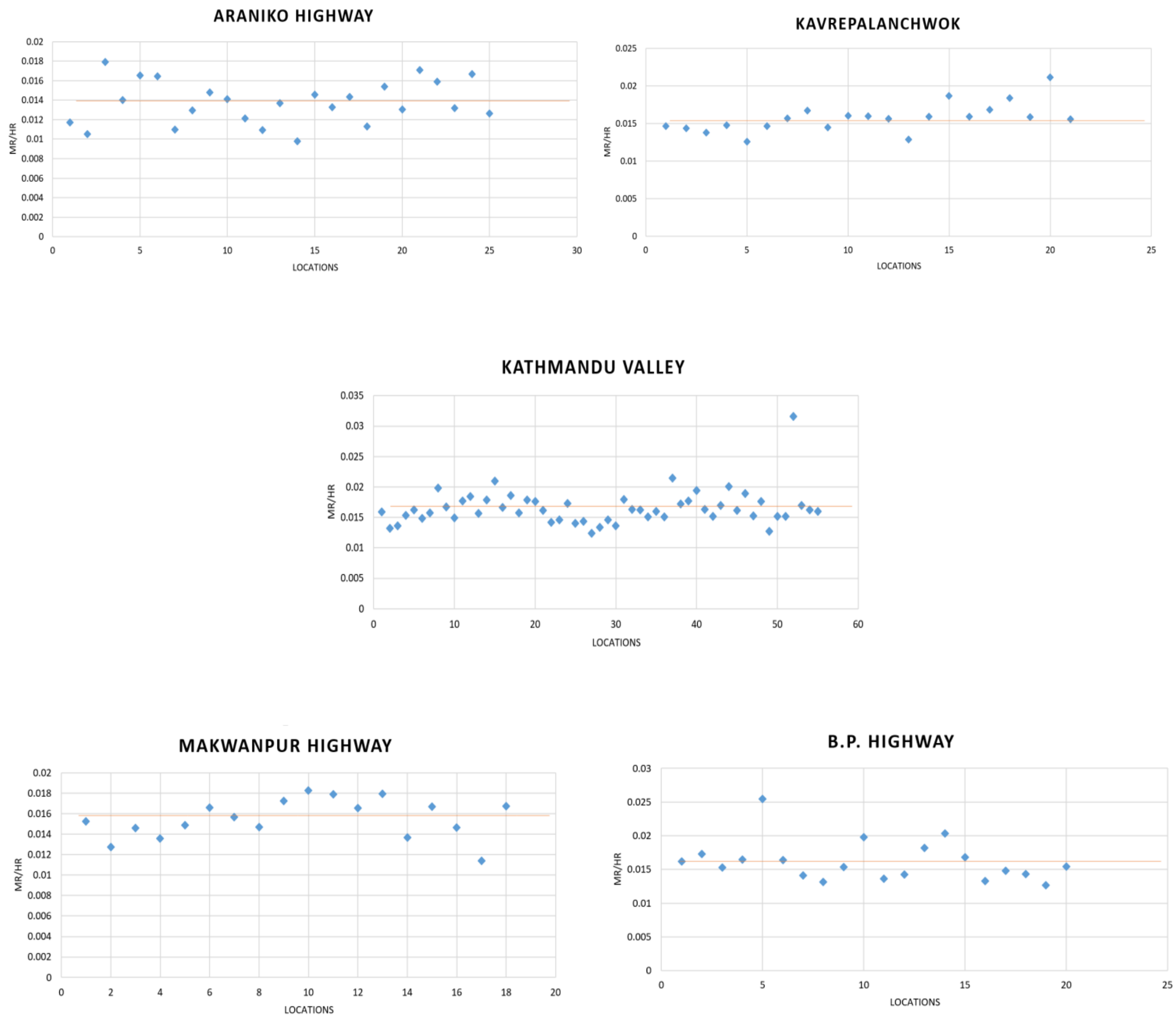

Fig. 3: Background ionizing radiation of 5 different places covering seven districts of Bagmati province.

After the calculation of BIR levels of all locations, the hazard indices were calculated as listed in Table 1. The equivalent dose rate (EDR) was calculated using equation (2), which was found to be 1.309 ± 0.092 mSv/yr and the absorbed dose rate (ADR) was calculated using equation (3), with the value obtained being 135.418 ± 9.522 nGy/hr. The average EDR of province was 1.309 times higher than the recommended limit i.e. 1 mSv/yr and the average ADR was around 2.29 times the worldwide average i.e. 59.0 nGy/hr (Ezekiel, 2017). The annual effective dose equivalent (AEDE) of Bagmati province was also found to be evenly distributed across the various locations. The calculated AEDE from Table 1 indicates that the geological formation of these locations is heavily contaminated with radiological elements. Lastly, the excessive lifetime cancer risk was found to be 0.486, 0.574, 0.548, 0.556, and 0.548 for Araniko Highway, B.P. Highway, Kathmandu Valley, Kavrepalanchowk, and Makwanpur Highway respectively. The values obtained were smaller than those obtained in the 2023 study of natural background radiation in the Bagmati Province.

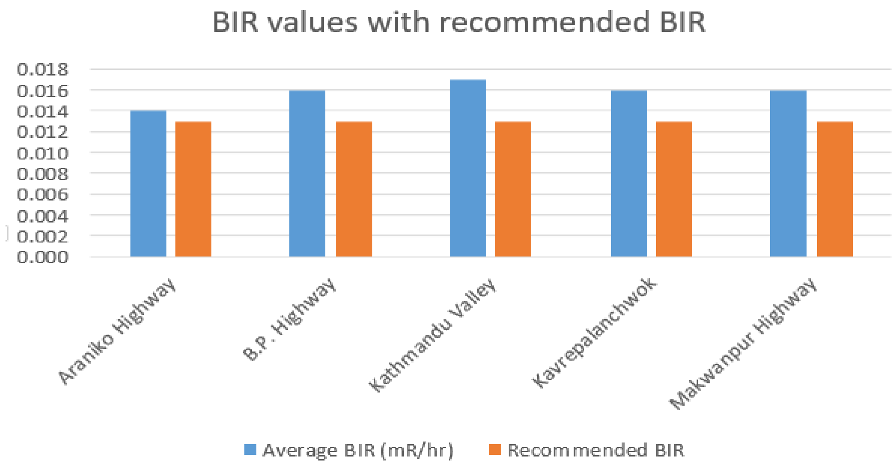

Fig 4. Background ionizing radiation (BIR) with recommended limit at different places.

The indices measured in this study are nearly identical to those reported in other studies conducted in Delta, Enugu, and Ebonyi States of Nigeria. The background ionizing radiation (BIR) levels in Bagmati Province, Nepal, Delta State, and Enugu State are all approximately 0.016 mR/hr, whereas Ebonyi State records a slightly lower BIR level of 0.0145 mR/hr (Karki et al., 2023; Ugbede, 2018; Ugbede et al., 2020). Accordingly, the values for equivalent dose rate, absorbed dose rate, annual effective dose rate, and excess lifetime cancer risk are also quite similar across these regions.

Table 2: Comparison between the BIR of Bagmati province of 2023 and 2024.

	Araniko Highway	B.P. Highway	Kathmandu Valley	Kavrepalanchwok	Makwanpur Highway
Average BIR (mR/hr) 2023	0.022 ± 0.003	0.027 ± 0.004	0.025 ± 0.005	0.028 ± 0.006	0.024 ± 0.004
Average BIR (mR/hr) 2024	0.014	0.016	0.017	0.016	0.016

Table 3: Comparison of background ionizing radiation and estimated hazard indices of Bagmati Province, Nepal with different states of Nigeria and the recommended limits.

Hazard Indices	Our Work	Delta State, Nigeria [9]	Enugu State, Nigeria [10]	Ebonyi State, Nigeria [11]	Recommended Limit [9]
BIR (mR/hr)	0.016	0.016	0.016	0.0145	0.013 [10, 11]
EDR (mSv/yr)	1.309	1.37	1.15	-	1
ADR (nGy/hr)	135.418	141.3	-	128.325	59
AEDE (mSv/yr)	0.166	0.17	-	0.15	0.07
ELCR *10^-3	0.550	0.61	-	0.55	0.29

4.0 Conclusion

The natural background radiation doses of five different places covering seven districts of the Bagmati Province was measured using a Survey Meter. It was found that the average background ionizing radiation level was slightly higher than the world average, mostly due to the geological structure and formation of rocks found in these places. The highest radiation levels were found to be in Kathmandu Valley, unlike the previous study conducted in 2023 which showed

Kavrepalanchowk to have the highest radiation levels. The measurements obtained in this study using a Survey Meter were comparatively lesser than the measurements obtained in the 2023 study conducted using a RadAlert 100 radiation monitor. Our study shows and keeps track of the current levels of background ionizing radiation in the province, which is a necessary step to prevent radiation exposure risks. In conclusion, the overall study shows that there are no radiological hazards to the diverse settlement of communities in the Bagmati Province.

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