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Assessment of natural background radiation levels in Ranipokhari, Kathmandu, Nepal, following the 2015 earthquake and during reconstruction

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Hari Adhikari[1, 2], Roshan Chalise[3*], Himali Kalakhety[4], and Raju Khanal[3]

1 Amrit Campus, Tribhuvan University, Thamel, Kathmandu 44600, Nepal
2 Department of Physics, Northern Illinois University, Illinois, USA (Current)
3 Central Department of Physics, Tribhuvan University, Kirtipur, Kathmandu 44613, Nepal
4 Department of Physics and Geosciences, Texas A & M University-Kingsville, Texas, USA

Abstract: Natural background radiation is present in the environment, and its level can vary depending on the location, occurring radioactive elements in soil, water, and air. Measuring natural background radiation in Ranipokhari, a historic pond in Kathmandu, is important, considering its significance as a public space and its reconstruction after the 2015 earthquake. We used a Professional Digital Geiger Counter (GCA 07W) to measure the radiation dose at 50 different locations, 31 on the outer corner of the pond and 19 inside the pond. The minimum and maximum radiation exposure levels were found to be 49.80 μR/h and 147.48 μR/h, respectively, with an overall average exposure rate of (108.06 ± 3.47) μR/h. We observed that the count and exposure rates were higher on sunny days compared to rainy days. Hypothesis testing suggested that the average background exposure rate in Ranipokhari is higher than the world average external background radiation levels reported by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Our study provides crucial information on the natural background radiation levels in Ranipokhari, which can assist in safely reconstructing this historic pond after the earthquake.

Keywords: Radiation • Natural background radiation • GM counter • Count rate • Exposed rate

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I. Introduction

Natural background radiation is present all around us, originating from naturally occurring radioactive elements in soil, water, and air. This radiation varies by location and changes over time [1]. The world is naturally radioactive, and about 82% of the excessive radiation doses that humans are exposed to come from natural sources, including cosmic and terrestrial radiation and radiation exposure via inhalation or consumption sources. Several studies have been conducted in recent years, and the results have

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[*] *Corresponding Author: plasma.roshan@gmail.com*

provided varying estimates of the impact of background radiation on human health. The local geology of each world area determines the concentration of rocks, sand, and soil [2]. Radiation dose measures how much energy is deposited into a material from a radiation source. The measurement of absorbed dose in tissue is of fundamental importance in radiobiology as it measures the amount of energy the incident radiation imparts to the target tissue [3, 4]. The dose limit is referred for both equivalent and effective doses and is prescribed by Radiation Protection Regulation. The dose limit may help to be aware of the deterministic effect in almost all tissues [5, 6].

The natural background radiation dose level is compared in Taiwan using their measured data and published dose conservation factors. The indoor gamma dose rate in Taiwanese houses is 72 nSv/h, which is high compared with other countries, but the indoor radon level is much lower than in most other countries [6]. Among the 32 locations of Kathmandu Valley, the lowest value of the average dose rate is $(22.3 \pm 3.9) \times 10^{-3}$ mR/h at Sundhara, and the greatest value of the average dose rate is $(37.7 \pm 7) \times 10^{-3}$ mR/h at Budhanilkantha. As per the annual effective dose, the lowest value was 0.391 mSv/yr at Sundhara, and the greatest was 0.661 mSv/yr at Budhanilkantha. The average annual effective dose of Kathmandu Valley was 0.475 mSv/yr, ranging from 0.391 to 0.661 mSv/yr [7]. Using a high-pressure ion chamber with various shielding configurations, the natural background dose rate from cosmic, terrestrial, and sky shine components in the Abu Dhabi City region is measured. Two offshore measurements provided dose rate information attributed to the various background radiation components. The dosage rates for the various shielding configurations of the cosmic, terrestrial, and sky shine contributions were 33.0 ± 1.7, 15.7 ± 2.5, and 2.4 ± 2.1 nSv/h, respectively [8].

Figure 1. Professional GM counter (GCA-07W) [9], used for measuring the radiation levels.

The lack of information on natural background radiation levels in Ranipokhari, Kathmandu, Nepal, especially during and after the 2015 earthquake, motivated us to do this work. Studies on radiation levels in this area have yet to be reported, making it difficult to assess the potential radiation risks associated with the reconstruction activities following the earthquake. Additionally, this study aims to compare the natural background radiation levels in Ranipokhari with the world average external background radiation levels reported by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). This study investigates the natural background radiation levels in Ranipokhari, Nepal, and compares them with world averages reported by the UNSCEAR. The findings from this research will provide crucial information for risk assessment, public health planning, and preservation efforts concerning this significant cultural and historical landmark. By providing crucial data on radiation levels in this area, the study can inform risk assessment and public health planning and aid in preserving this important site amidst the challenges of its location in a seismically active region.

II. Material and Method

For radiation measurement, we have used the Professional Digital Geiger Counter (GCA 07W) shown in Fig. 1, available in the Central Department of Physics, Tribhuvan University, Kathmandu, Nepal. The radiation detector developed by Geiger and Muller in 1928 is sometimes known as the GM counter or just the Geiger tube. However, these detectors have remained in use up to this point due to their affordability, simplicity, and ease of use. A Geiger-Muller tube in a Geiger counter is used to detect radiation or an ionizing event. The output pulse count represents the count rate. The GM counter is a tool for identifying and gauging the dose rate and count per minute. On this device, a 2-character LCD screen displays the count and dosage rates concurrently. It gives the count rate in count per second (CPS) or counts per minute (CPM) and dose rate on the units of mR/h or mSv/h. It detects the radiation range from 0.001 μR/h resolution to 1000 μR/h, and here we used Z-test for statistical data calculation and analysis.

III. Overview of Ranipokhari

The artificial square-shaped pond known as Ranipokhari or “Queen’s Pond”, has a Shiva temple in the center. Ranipokhari is located in the center of Kathmandu, Nepal, at a latitude of $27°37'57.72''$ and a longitude of $84°19'41.8''$ (see Fig. 2(b) and Fig. 2(c)). The temple was built by King Pratap Malla in 1667 to console his queen over the death of their son (who was trampled by an elephant). It was a token of comfort for his wife, who was overcome with grief over the loss of their son. The pond is enclosed by iron bars and only opens once a year on Bhai Tika — the fifth and one of the most important days of the Tihar festival. The pond, one of Kathmandu’s most well-known monuments, is famous for its aesthetic and religious significance. Its dimensions are 180 x 140 m. It was damaged by the earthquake of 2015 A.D. and is currently under construction [10].

Fifty different locations in Ranipokhari are chosen for measurement. Five data sets are taken at each location, and then their average is taken. The locations are selected to cover the maximum possible area of study. Out of 50 locations, numbers 1 to 31 are outside the pond, and 32 to 50 are inside. The Z-test hypothesis test is carried out to test whether the dose rate in Ranipokhari exceeds the dose limit estimated by the International Commission on Radiological Protection (ICRP).

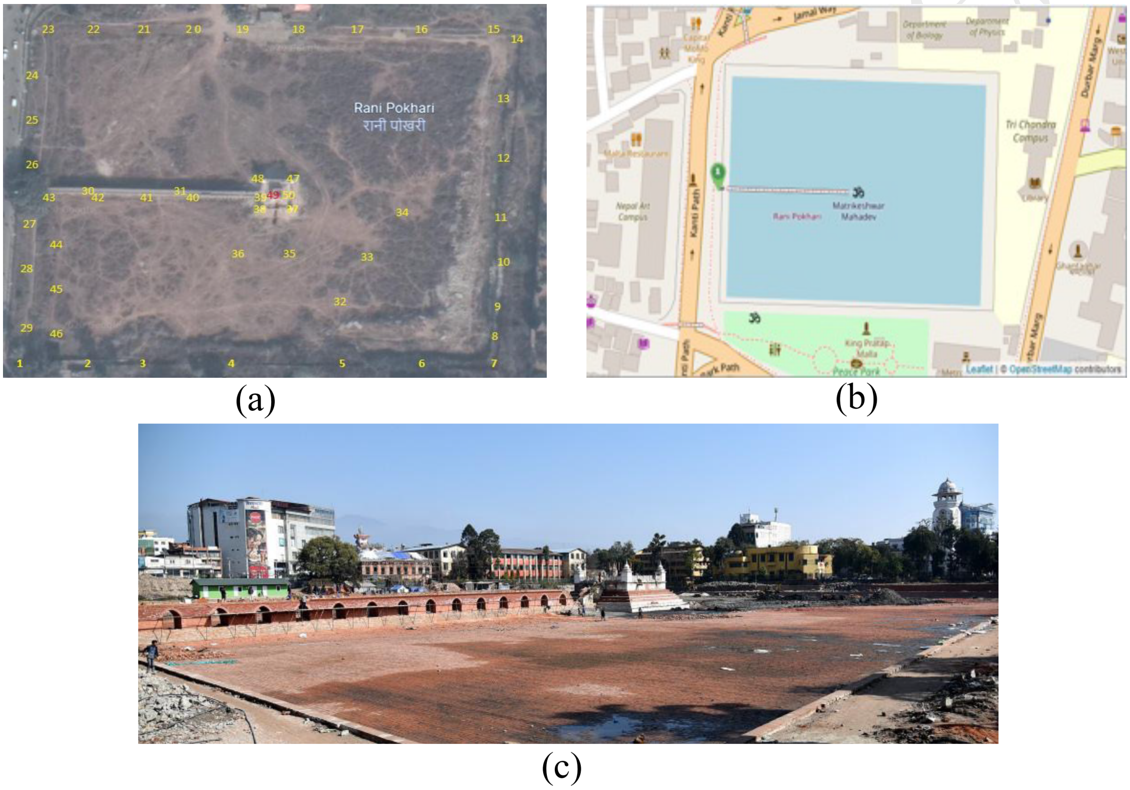
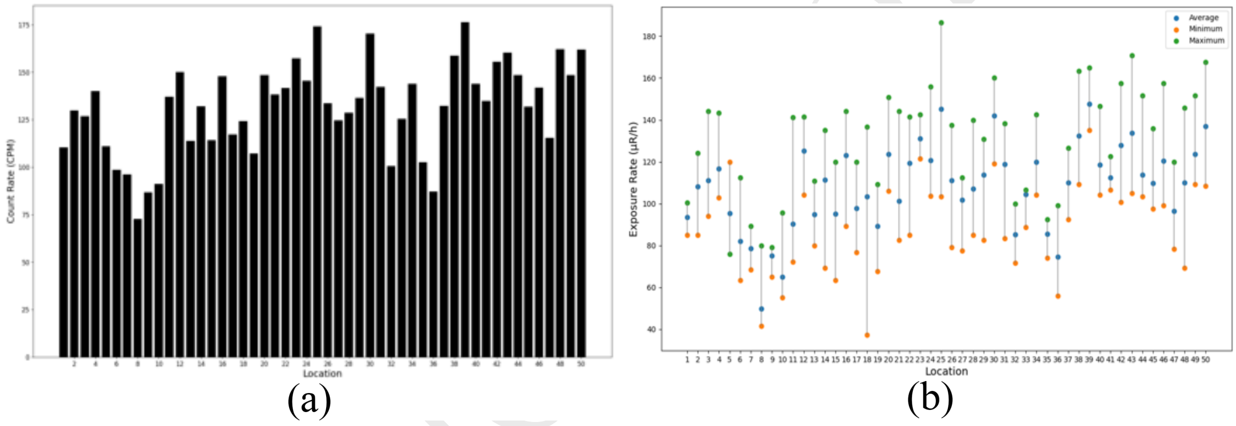


Figure 2. (a) Graphical representation of 50 locations in Ranipokhari, Kathmandu, Nepal, (b) Location map of Ranipokhari, and (c) Photo of Ranipokhari, showing the location of the measurements.

IV. Results and Discussion

Count Rate and Radiation Exposure Rate

Natural background counts at 50 different locations in Ranipokhari are measured using a GM Counter, as shown in Fig. 2(a). From the observation, it is found that the count rate lies between 72.80 CPM - 176.40 CPM at location 8 on the outer corner of the pond and at location no 39 inside the pond (Fig. 3(a)). The reason behind the high count rate on location no 39 inside the pond is expected to be radiation coming from the fossil, black mud used for soling, minerals and digging for construction, etc. Location 8 seems clear from extra materials like reconstruction and other waste materials. One of the strong reasons for the higher count rate on the other outer location is the storage of construction material and not cleaning after construction near it. The average exposure rate, along with the lowest and highest value of exposure rate at the respective 50 locations in Ranipokhari, is shown in Table 1 and Fig. 3(b). The maximum and minimum average exposure rate found at location no 39 is 147.48 μR/h, and at location no 8 is 49.80 μR/h, respectively. The average dose rate of these 50 locations was found (108.06 $\pm$ 3.47) μR/h. Only this average value of exposure rate is not a convenient way to decide on the dose limit because there is wide variation in data from 49.80 mR/h - 147.48 μR/h. We applied the Z-test to determine the mean distribution of data.



(a) (b)

Figure 3. (a) Counts per minute at 50 different locations in Ranipokhari, and (b) Average exposure rate of each of 50 different locations, with the respective location's maximum and minimum dose rate.

Statistical test

Here, the sample size ($n > 30$) and standard deviation ($s = 24.64$) satisfy the conditions required to apply the Z-test. The hypothesis testing follows the procedure outlined below.

Step I: Hypothesis Testing

Null hypothesis (H_0) : $\mu \leq \mu_0$(73.28 μR/h)

Alternative hypothesis (H_1) : $\mu > \mu_0$(73.28 μR/h) [Right-tailed test]

where population means $\mu_0 = 73.28$ μR/h represents the world average external background radiation level as reported by UNSCEAR [4].

Step II: Test Statistics

Under the null hypothesis, the test statistics are calculated using $Z = \frac{\bar{x}-\mu_0}{s/\sqrt{n}}$

where

$\bar{x} =$ mean of the sample

$\mu_0 =$ mean of the population

$s =$ standard deviation of the population (for large value of $n, \sigma = s$)

$n =$ number of observations.

Step III: Level of Significance

Take $\alpha = 0.01$ [for critical decisions, the significance level is set at 1%].

Step IV: Critical Value

The tabulated value at $\alpha = 1\% = 0.01$ is $\mathrm{Z}_\alpha = \mathrm{Z}_{0.01} = 2.33$ [from the Z-table].

Step V: Decision

If $|Z| > Z_a$ at $\alpha = 0.01$, the null hypothesis (H_0) is rejected, and the alternative hypothesis is accepted. Here, the required parameters for the Z-value calculation are as follows: $\bar{x} = 108.06$ μR/h, $\mu_0 = 73.28$ μR/h, $\sigma = 24.64, n = 50$.

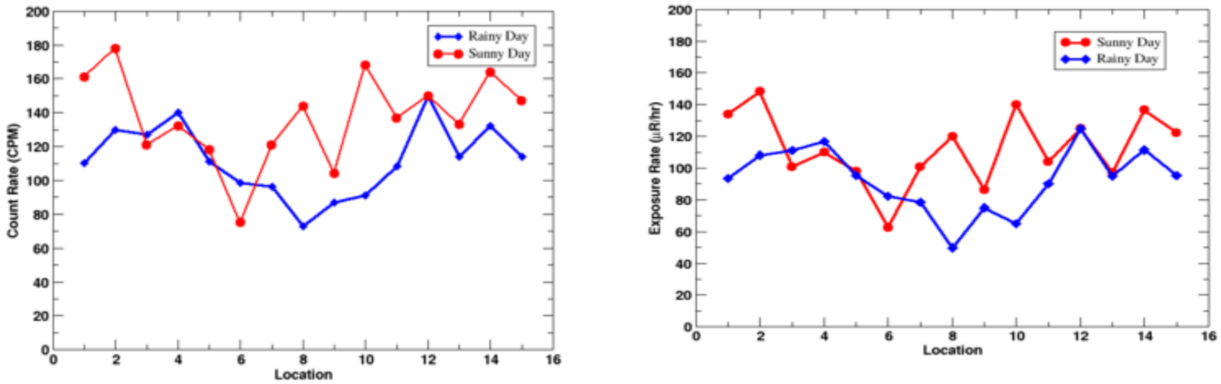
Step VI: Result

Applying the Z-test formula, we obtained $Z = 9.98$.

Step VII: Conclusion

As $|Z| > Z_\alpha (9.98 > 2.33)$, the null hypothesis is rejected.

We performed a Z-test for the data collected from Ranipokhari and found $|Z| > Z_\alpha$. This implies that the null hypothesis is rejected and the alternative hypothesis is accepted. It suggests that the average background exposure rate in Ranipokhari is higher than the world average external background radiation, as the United Nations Scientific Committee reported on the Effect of Atomic Radiation [4].



(a) (b)

Figure 4. Comparison of (a) count rates and (b) average exposure rate between rainy and sunny days at 50 different locations in Ranipokhari demonstrating weather conditions' impact on the respective parameter.

For a better understanding, data from 15 locations in Ranipokhari are re-observed. Background radiation is a statistical value, so it varies with the change in weather. Here, the first data is taken during a rainy day on 18 July 2020, and the re-observed data are taken on a sunny day on 21 July 2020. The data for these different days is shown in Fig. 4. We observed that counts per minute and exposure rate are higher on a sunny day than on a rainy day. The difference is mainly due to the factors related to atmospheric conditions, cosmic ray flux, instrument sensitivity, etc. Atmospheric conditions, such as humidity and temperature, can influence the behavior of radioactive gases like radon. Radon significantly contributes to background radiation, and its concentration can vary with weather conditions. Cosmic rays from outer space contribute significantly to background radiation. On sunny days, atmospheric moisture and clouds are less, allowing more cosmic rays to penetrate the atmosphere and reach the Earth's surface. In contrast, during rainy days, clouds partially block cosmic rays and reduce their ground-level flux. Higher counts and exposure rates on sunny days than rainy days may be attributed to increased solar radiation, reduced atmospheric attenuation, and ground reflection.

Table 1. Average, maximum, and minimum exposure rates at 50 different locations

Location	Exposure Rate (μR/h)			Location	Exposure Rate (μR/h)		
	Maximum	Minimum	Average		Maximum	Minimum	Average
1	100.00	85.00	93.36	26	137.50	79.10	111.20
2	124.10	85.00	108.14	27	112.50	76.60	101.80
3	144.10	94.10	111.13	28	140.00	85.00	107.10
4	143.30	102.50	116.64	29	130.80	82.50	113.64
5	75.80	120.00	95.45	30	160.00	119.10	141.96
6	112.50	63.30	82.14	31	138.30	83.30	118.80
7	89.10	68.30	78.44	32	100.00	71.60	85.30
8	80.00	41.60	49.80	33	106.60	88.60	104.46
9	79.10	65.00	74.98	34	142.50	104.10	119.82
10	95.50	55.00	65.00	35	92.50	74.10	85.48
11	141.10	72.20	90.16	36	99.10	55.80	74.62
12	141.60	104.10	125.10	37	126.60	92.50	110.14
13	110.80	80.00	94.76	38	163.30	109.10	132.30
14	135.00	69.10	111.46	39	165.00	135.00	147.48
15	120.00	83.30	95.16	40	146.60	104.10	118.58
16	144.10	89.10	123.13	41	122.50	106.60	112.30
17	120.00	73.80	97.64	42	157.50	100.80	127.80
18	136.60	37.30	103.40	43	170.80	105.00	133.64
19	109.10	67.50	89.30	44	151.60	103.30	113.62
20	150.80	105.00	123.64	45	135.80	97.50	109.80
21	144.10	82.50	101.14	46	157.50	99.10	120.40
22	141.60	85.00	119.30	47	120.00	78.30	96.42
23	142.50	121.60	131.14	48	145.80	69.10	109.96
24	155.80	102.50	120.64	49	151.60	109.10	123.60
25	186.60	160.00	145.12	50	167.50	108.30	136.98

V. Conclusion

In this study, we utilized a professional GM counter to measure natural background radiation dose in Ranipokhari, Kathmandu, Nepal, on July 18, 2020, providing crucial data for risk assessment, public health planning, and the preservation of this historically significant site, particularly in light of its reconstruction following the 2015 earthquake. The highest average dose rate recorded was 147.48 μR/h, while the lowest dose rate measured was 49.80 μR/h. The overall average dose rate for all 50 locations was calculated to be 108.06 ± 3.47 μR/h. The count rate ranged from a minimum of 72.80 μR/h (located at the outer corner of the pond) to 176.40 μR/h (located inside the pond). Furthermore, we observed that counts per minute and exposure rates were higher on sunny days than on rainy days. Our hypothesis testing suggests that the average natural background radiation exposure level in Ranipokhari (108.06 ± 3.47 μR/h) exceeds the world average external background radiation reported by the United Nations Scientific Committee on the Effects of Atomic Radiation; however, no immediate health risks are associated with it. These findings underscore the importance of continued monitoring and assessing radiation levels in the area, informing risk management strategies and public health planning efforts.

VI. Acknowledgements

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