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INVESTIGATION OF RADON CONCENTRATION AND TOXIC ELEMENTS IN WELL WATER AND SURFACE WATER IN MONYWA, MYANMAR

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Abstract

This study evaluates radon concentration and toxic element levels in water samples collected from various locations in Monywa, Myanmar. Samples were obtained from wells, rivers, and lakes, with radon concentrations measured using an LR-115 Type II detector and toxic elements quantified using an atomic absorption spectrophotometer (AA-7000, Shimadzu). The highest average radon concentration was recorded in well water used for drinking (30.02 Bq/m³), while surface water exhibited a maximum radon concentration of 13.94 Bq/m³. All measured radon concentrations were below the lower limit of the recommended action level. Additionally, the presence of toxic elements such as Cu, Zn, Pb, Cd, and As was detected in surface and well water. Radon levels in well water exceeded the EPA's recommended limit but remained below the WHO action level. Overall, the radon concentrations and toxic element levels observed in this study were within acceptable safety thresholds, providing valuable insights into water quality in the region.

Keywords: LR-115, radon, alpha track, well water, surface water and heavy metals

Introduction

Radon is a radioactive noble gas that does not chemically react with other elements. Radon emanation is a well understood phenomenon. It is a colorless, odorless and tasteless gas, which is 7.5 times heavier than air. Hence its presence in drinking water is not felt during consumption. The decay product of radon, i.e., its progeny is highly radioactive and gets absorbed to aerosol particles suspended in water. The range of recoil radon atom in water is about 0.1 μm but it emits alpha particle which has energy 5.5 MeV and can travel up to a few centimeters in air.

It has three isotopes, namely, ^{222}Rn (Radon), ^{220}Rn (Thoron) and ^{219}Rn (Actinon). All three are decay products (daughters) of ^{238}U, ^{232}Th and ^{235}U series, respectively. Thoron and Actinon have very short half-lives (in seconds) and Radon (222) represent the most essential isotope, with a half-life of 3.825 days which allows it to migrate over long distances and get accumulated into the indoor environment. Radon (^{222}Rn) and its short-lived decay products (^{218}Po, ^{214}Pb, ^{214}Bi and ^{214}Po) have been recognized globally as the main sources of exposure to the public in dwellings from the natural radioactivity, contributing to nearly 50% of the global mean effective dose to the public. In the United States of America, exposure to radon is the second cause of lung cancer after smoking. Scientists estimate that about 20,000 lung cancer deaths per year are related to radon (Seltenrich, N., 2019).

Radon is the most important source of naturally occurring radiation exposure for humans. For the world population, radon exposure represents 50% of the total exposure to natural background radiation, followed by earth gamma radiation at 20%, cosmic radiation at 18% and natural radiation from food and water at 12%. 95% of exposure to radon is from indoor air, with about 1% coming from drinking water (WHO, 2009).

Radon in domestic water supplies can cause human exposure to a radiation dose both through inhalation and ingestion. Radon is easily released from water into the atmosphere by agitation or heating. Many domestic uses of water result in such a release and can contribute to

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the total indoor air radon concentration. It has been estimated that 1000 Bq/L of radon in water will, on average, increase the radon concentration in indoor air by 100 Bq/m^3. It has been observed that the risk of lung cancer increases if the public is exposed to high concentrations of radon in indoor air. The organ at greatest risk from the ingestion of water containing radon and radon decay products is considered to be the stomach (Khursheed A., 2000).

Unfortunately, radon can lead to major health risks via two methods. The first method in which radon can be exposed to the human body is the inhalation of radon that escapes from groundwater to the air of homes. A second method is the ingestion of radon in drinking water. Long-term exposure to radon gas can result in lung cancer. In fact, approximately 16% of lung cancer deaths in Canada are due to long-term exposure to radon gas indoors. Furthermore, the studies reveal that radon gas is the primary cause of lung cancer in non-smokers and the second leading cause in smokers (Virk, J., & Virk, H. S. 2021).

The associated health risks due to inhalation and ingestion of radon and its progeny when present in enhanced levels in an indoor environment, water and soils surrounding a human dwelling have been well documented. There are many factors which influence the radon concentration in dwellings and environment, namely, radium content in the soil, meteorological parameters and the radon emanating from soils and rocks in the surroundings (Singh, M., *et al*, 1988).

Materials and Methods

The sources of water in the area under study are wells, river and lakes and water used for irrigation is wells, river and lakes water. Samples of water were collected from wells, river and lakes. Before the collection of water samples, bottles were rinsed with 15% HNO_3 and with distilled water in triplet. In order to insure sample quality, samples from wells were collected directly from well after purging for 10 min. Surface water was collected directly from river and lakes within 5 cm of the water surface. All samples were labeled with date, time and sample code.

Radon concentration in these samples was measured using LR-115 Type II detector.

Toxic elements (As, Pb, Cd, Cu and Zn) in water samples were measured by using atomic absorption spectrophotometer (AA-7000, Shimadzu).

Treatment of LR-115 Detector with Standard Source

LR-115 detectors were cut into small pieces of 1 cm × 1 cm. These detectors were irradiated with alpha from Am-241 source. The LR-115 was removed from the source and etched chemically in 10% NaOH solution at 60 °C for 90 minutes in an oven. The etched tracks on the detectors were scanned, using a microscope with magnification of 40X manually. It was also concerned with examining the composition of SSNTDs before and after irradiation by using FTIR method.

Detection of Radon via Alpha Particles in Water Samples

In this work, LR-115 detectors were used for measuring radon via alpha particles in the surface water and well water samples. 1000 mL of water was collected in an airtight plastic bottle with dimensions approximately 12 cm height ×6.5 cm length ×6.5 cm width. The LR 115 detector was putted on the inner side of the lid of the container with the active side facing the water. The active side will be the side that is curved in a concave manner. This container was sealed for 90 days to collect radon by emanation in water. During this time the alpha particles from radon and its daughter would leave tracks on the detector. The LR-115 was removed from the plastic bottle and etched chemically in the above procedure.

The track density of surface water and well water samples was calculated by dividing the number of tracks by the microscope view area (19.635 10^{-4} cm^2). The radon concentration in water was calculated using the track density (tracks/cm^2), a calibration factor (0.034 tracks.cm^{-2}.d^{-1}/Bq.m^{-3}) and exposure time (days). The track count was converted into a radon concentration level in Bq/m^3 using the formula: (Virk, J., & Virk, H. S., 2021).

$$C_{Rn} = \rho/k.t$$

Where, k is the calibration constant (0.034 track.cm^{-2}.d^{-1}/Bq.m^{-3}), ρ is track density (tracks/cm^2), t is exposure period (days).

Results and Discussion

Effect of Etching Parameters on LR-115 Detectors

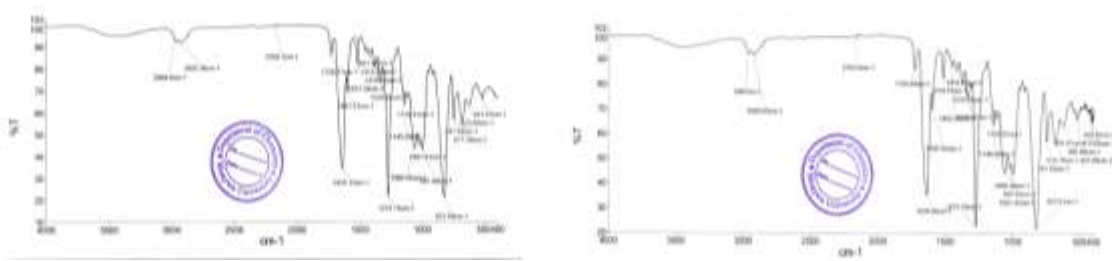
Six LR-115 detectors were irradiated with Am-241 alpha radiation for 20 min. These detectors were etched in 10 % NaOH solution with different etching times (50, 60, 70, 80, 90, and 100 min) at 60 °C. The etching time (90 min) was chosen optimum condition for this research.

Observation of Tracks with Standard Sources

The detection of LR-115 with alpha radiations was studied. LR-115 can detect especially for alpha. From the study on different alpha irradiation times (15, 30, 60, 90 min), the greater the irradiation times, the higher the track density on LR-115. But it will be damaged at irradiation time over 60 min. It was used for radon level measurement from the different water samples.

Examination of Effect of Radiation on LR-115 by Using FT IR Method

From the FT IR spectra of the alpha irradiated LR-115 detectors, it was found that the wavenumbers of functional groups in all irradiated detectors of different irradiation times do not differ before and after irradiation. The observations suggested that the potentiality of LR-115 can be used as dosimeters.



(a) (b)

Figure 1 FT IR spectra of (a) before irradiation and (b) after irradiation of LR-115 detectors with standard alpha source

Observation of Radon via Alpha Particles from the Water Samples

According to the experimental results, the LR-115 detector is more effective in alpha detection. Hence, it was used for observation of radon via alpha particles emitting from the surface water and well water.

Each LR-115 detector was fixed at the top of inside each plastic bottle according to facing the detector and α-emitted via radon in water samples. Radon gas, thoron gas and their progeny formed by decays inside the container irradiate the LR-115 detectors and form damaged trails. After the exposure period of three months, they were etched in 10 % NaOH at 60 °C for 90 min.

The experimental results revealed that the whole tracks were found in all the LR-115 detectors placed in water samples. The shape of the track observed agrees with the literature and it indicates that this is due to an interaction between detectors and alpha particles via radon present in it.

From Table 1, the track density was found to be between 45.27 and 84.88 track/cm^{2}d in all detectors in the well water (WW1) sample. The average value was found to be 63.38 track/cm^{2}d. According to the observed track density, the radon level was found to be between 21.45 and 40.21 Bq/m^3. Therefore, the radon concentration in well water sample was found to be 30.02 Bq/m^3.

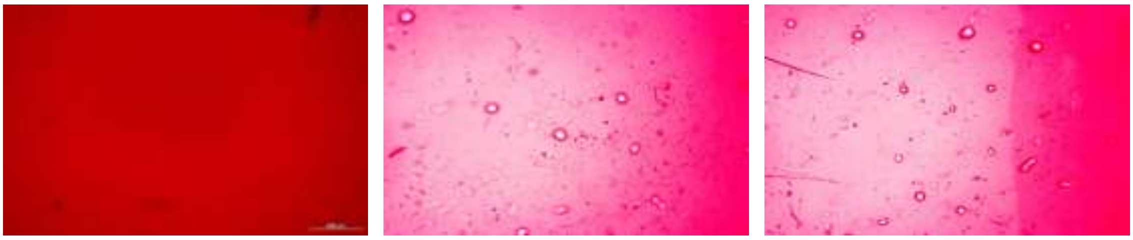
From Table 2, the track density was found to be between 39.61 and 67.91 track/cm^{2}d in all detectors in well water (WW2) sample. The average value was found to be 54.32 track/cm^{2}d. According to the observed track density, the radon concentration level was found to be between 18.76 and 29.49 Bq/m^3. The average was 25.73 Bq/m^3.

From Table 3, the track density was found to be between 39.61 and 96.20 track/cm^{2}d in all detectors in well water (WW3) sample. The average value was found to be 59.98 track/cm^{2}d. According to the observed track density, the radon level was found to be between 18.76 and 45.57 Bq/m^3. The average was 28.42 Bq/m^3.

From Table 4, the track density was found to be between 11.32 and 39.61 track/cm^{2}d in all detectors in surface water (SW1) sample. The average value was found to be 21.50 track/cm^{2}d. According to the observed track density, the radon level was found to be between 5.36 and 18.76 Bq/m^3. The average was 10.19 Bq/m^3.

From Table 5, the track density was found to be between 22.64 and 39.61 track/cm^{2}d in all detectors in surface water (SW2) sample. The average value was found to be 29.43 track/cm^{2}d. According to the observed track density, the radon level was found to be between 10.72 and 18.76 Bq/m^3. The average was 13.94 Bq/m^3.

From Table 6, the track density was found to be between 11.32 and 45.27 track/cm^{2}d in all detectors in surface water (SW3) sample. The average value was found to be 23.77 track/cm^{2}d. According to the observed track density, the radon concentration was found to be between 5.36 and 21.45 Bq/m^3. Therefore, the average radon concentration in the water was found to be 11.26 Bq/m^3.



un-irradiated (1) (2)

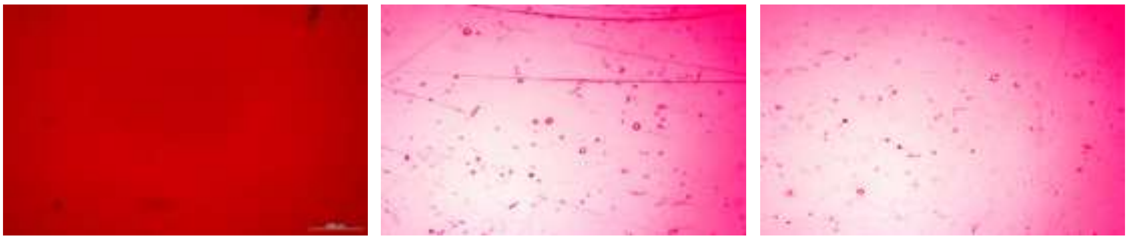
(3) (4) (5)

Figure 1. Photomicrographs of alpha tracks in LR-115 type II detectors for WW1

Table 1. Measurement of Track Density and Radon Concentration of WW1

LR-115	Track density (tracks/cm^{2}d)	Radon concentration (Bq/m^3)
1	56.59	26.81
2	84.88	40.21
3	67.91	32.17
4	45.27	21.45
5	62.25	29.49
Mean Value	63.38	30.02

* International reference level of radon concentration = 100 Bq/m^3



un-irradiated (1) (2)

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Figure 2. Photomicrographs of alpha tracks in LR-115 type II detectors for WW2

Table 2. Measurement of Track Density and Radon Concentration of WW2

LR-115	Track density (tracks/cm^{2}d)	Radon concentration (Bq/m^3)
1	45.27	21.45
2	56.59	26.81
3	67.91	32.17
4	39.61	18.76
5	62.25	29.49
Mean Value	54.32	25.73

* International reference level of radon concentration = 100 Bq/m^3

un-irradiated

(1)

(2)

(3)

(4)

(5)

Figure 3. Photomicrographs of alpha tracks in LR-115 type II detectors for WW3

Table 3. Measurement of Track Density and Radon Concentration of WW3

LR-115	Track density (tracks/cm^{2}d)	Radon concentration (Bq/m^3)
1	62.25	29.49
2	39.61	18.76
3	96.20	45.57
4	56.59	26.81
5	45.27	21.45
Mean Value	59.98	28.42

* International reference level of radon concentration = 100 Bq/m^3

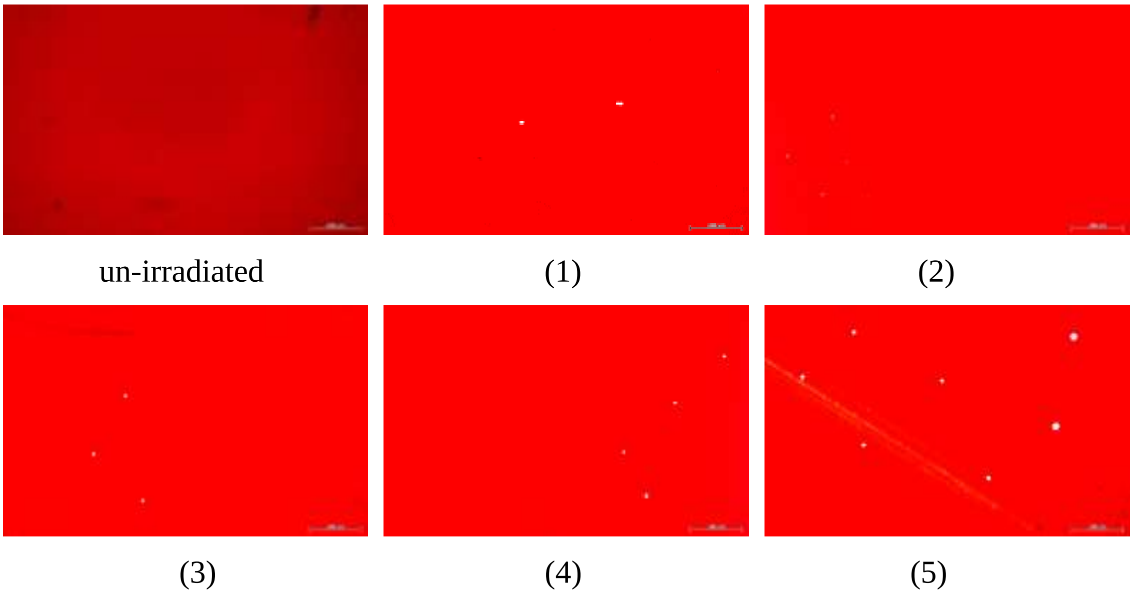


Figure 4. Photomicrographs of alpha tracks in LR-115 type II detectors for SW1

Table 4. Measurement of Track Density and Radon Concentration SW1

LR-115	Track density (tracks/cm^{2}d)	Radon concentration (Bq/m^3)
1	11.32	5.36
2	16.98	8.04
3	16.98	8.04
4	22.64	10.72
5	39.61	18.76
Mean Value	21.50	10.19

* International reference level of radon concentration = 100 Bq/m^3

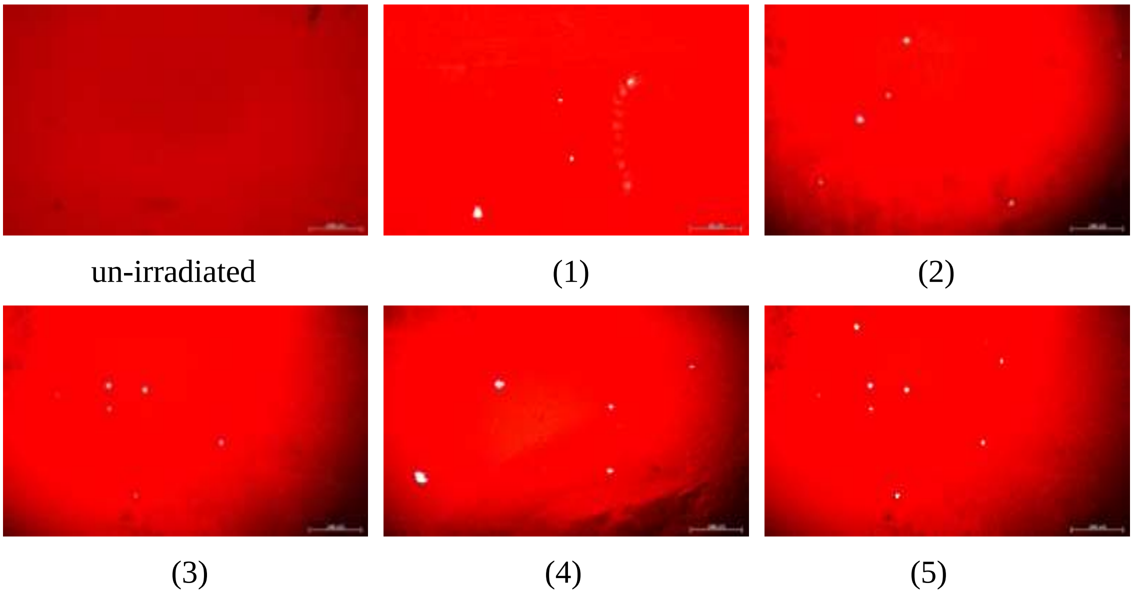
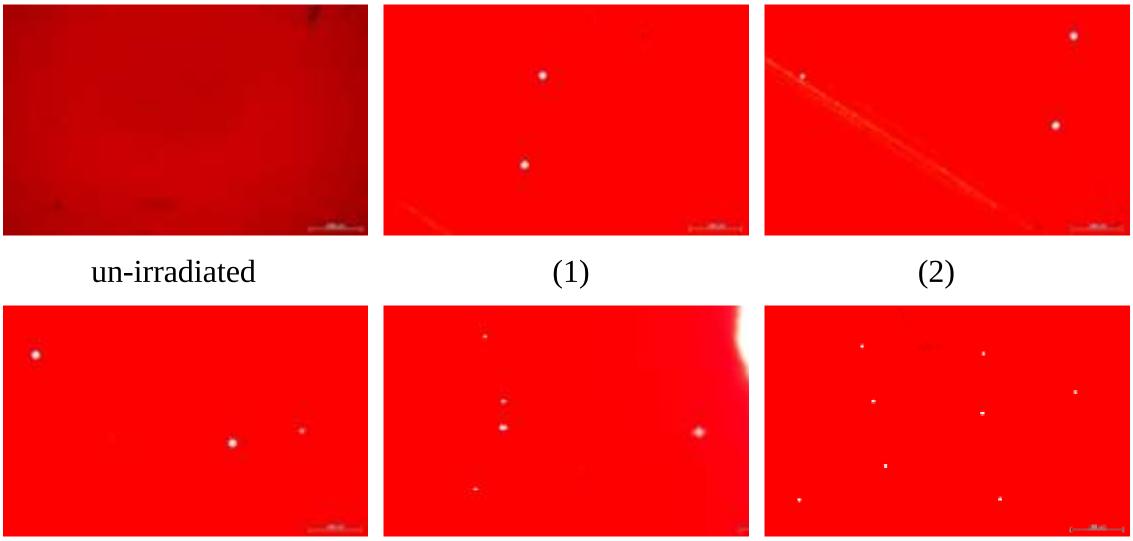


Figure 5. Photomicrographs of alpha tracks in LR-115 type II detectors for SW2

Table 5. Measurement of Track Density and Radon Concentration of SW2

LR-115	Track density (tracks/cm^{2}d)	Radon concentration (Bq/m^3)
1	22.64	10.72
2	28.29	13.40
3	28.29	13.40
4	28.29	13.40
5	39.61	18.76
Mean Value	29.43	13.94

* International reference level of radon concentration = 100 Bq/m^3



un-irradiated (1) (2)

(3) (4) (5)

Figure 6. Photomicrographs of alpha tracks in LR-115 type II detectors for SW3

Table 6. Measurement of Track Density and Radon Concentration of SW3

LR-115	Track density (tracks/cm^{2}d)	Radon concentration (Bq/m^3)
1	11.32	5.36
2	16.98	8.04
3	16.98	8.04
4	28.29	13.40
5	45.27	21.45
Mean Value	23.77	11.26

* International reference level of radon concentration = 100 Bq/m^3

Table 7. Comparison of Track Density and Radon Level of Each Water Source

Sr No.	Source of water	Sample Code	Track density (tracks/cm^{2}d)	Radon concentration (Bq/m^3)
1	Well	WW1	63.38	30.02
2	Well	WW2	54.32	25.73
3	Well	WW3	59.98	28.42
4	Chindwin River	SW1	21.50	10.19
5	Sarkyin Lake	SW2	29.43	13.94
6	Nyaungkine Lake	SW3	23.77	11.26

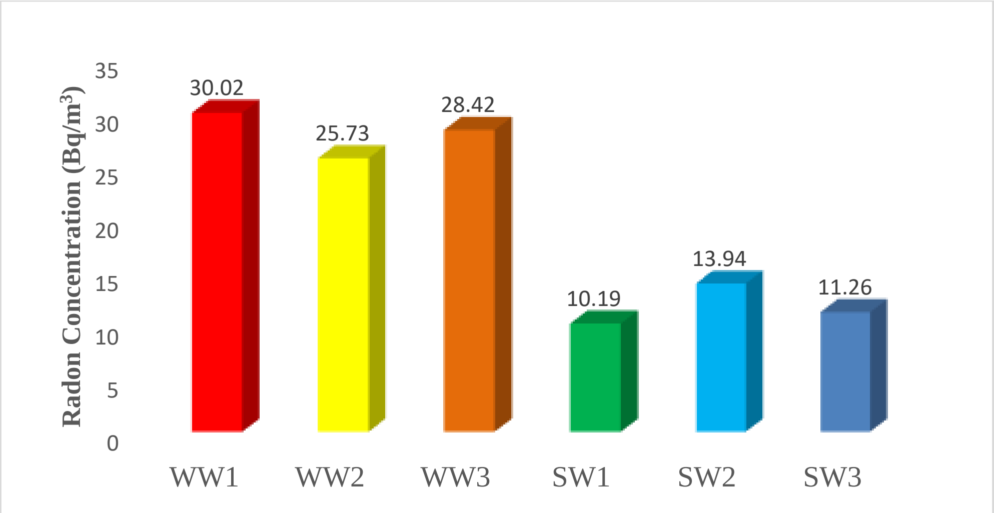


Figure 7. Track density recorded in different water samples using LR-115 Type II detectors

From this figure, radon was found to be present in all samples. Whether its concentration is low or high, it should be aware of the risk for people.

Table 8. Toxic Elements in Water and International Standard Limits

Sr No.	Sample Code	Source of water	As (mg/L)	Pb (mg/L)	Cd (mg/L)	Cu (mg/L)	Zn (mg/L)
1	WW1	Well	0.0010	0.0130	0.001	0.012	0.03
2	WW2	Well	0.0016	0.0170	0.001	0.014	0.02
3	WW3	Well	0.0018	0.0180	0.001	0.017	0.03
4	SW1	River	0.0228	0.2102	0.0153	0.0266	0.0050
5	SW2	Lake	0.0339	0.2570	0.0180	0.0266	0.0039
6	SW3	Lake	0.0359	0.3154	0.0187	0.0301	0.0044
WHO	mg/L		0.01	0.01	0.005	2	3
USEPA	mg/L		0.01	0.01	0.005	1.3	3

Conclusion

This study assessed the human health risks associated with radon concentrations and toxic elements in water collected from various locations in Monywa, Myanmar. Elevated radon levels were detected in well water, with the highest concentration recorded at 30.02 Bq/m³, while surface water showed lower radon levels, with a maximum of 13.94 Bq/m³. Radon concentrations in well water exceeded the EPA's recommended limit of 11 Bq/m³ but remained below the WHO's action level of 100 Bq/m³. In contrast, all surface water samples fell within acceptable limits set by both the USEPA and WHO. It is advised to boil well water before drinking to reduce radon levels. Results of heavy and hazardous metal concentrations in both well and surface water, As, Pb, Cd, Cu and Zn, were found to be less than the lower limit of the recommended action level of WHO/USEPA. But the concentrations of As, Pb, and Cd metals in surface water have a little exceeded the recommended limit.

It is recommended that drinking water is monitored by regular heavy metals to prevent excessive accumulation of heavy metals in the body.

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References

Ahmad, N., Jaafar, M. S., & Alsaffar, M. S. (2015). Study of radon concentration and toxic elements in drinking and irrigated water and its implications in Sungai Petani, Kedah, Malaysia. *Journal of Radiation Research and Applied Sciences*, 8(3), 294-299.

Al-Nafiey, M. S., Jaafar, M. S., & Bauk, S. A. B. A. R. (2014). Measuring radon concentration and toxic elements in the irrigation water of the agricultural areas in Cameron Highlands, Malaysia. *Sains Malaysiana*, 43(2), 227-231.

Ha, N. T. T., Van Giap, T., & Cuong, L. D. (2016). Technical Procedure Determination of Thoron Indoor Concentration by LR-115 Type II. *Journal of Environmental Science and Engineering B, 5*, 109-114.

Jidele, P. A., Dosunmu, O. G., Kolapo, A., Ajayi, K. F., & Ademola, K. A. (2021). Measurement of radon and potentially toxic elements concentrations in groundwater around Ota, Ogun State, Nigeria. *International Journal of Environmental Quality*, 42-49.

Khursheed, A. (2000). Doses to systemic tissues from radon gas. *Radiation Protection Dosimetry*, 88(2), 171-171.

Seltenrich, N. (2019). Radon risk: A global estimate of radon’s contribution to lung cancer. *Environmental health perspectives*, 127(2), 024001.

Singh, M. A. N. W. I. N. D. E. R., Ramola, R. C., Singh, S. U. R. I. N. D. E. R., & Virk, H. S. (1988). Influence of meteorological parameters on soil gas radon. *J. Assoc. Explor. Geophys. (India)*, 9(2).

Virk, J., & Virk, H. S. (2021). Radon estimation in water of surrey region of British Columbia, Canada using LR-115 type II nuclear track detector. *Earth*, 12, 50.

World Health Organization. (2009). *WHO handbook on indoor radon: a public health perspective*. World Health Organization.