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Determination of Radon Gas Concentration in the Water of Midelt Region, Morocco, Using a Nuclear Track Detector (LR-115) and Assessment of Radiological Health Risk

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ABSTRACT

The article aims to assess radon concentration in various water samples, revealing levels ranging from 0.53 Bq/L to 4.68 Bq/L. Radon, specifically the isotope 222Rn, is a naturally occurring radioactive gas formed during the decay of the 238U decay series, originating from the breakdown of 226Ra. This gas is commonly found in rocks, soil, natural gas, and groundwater. Exposure to airborne and waterborne radon can increase the risk of certain cancers due to human radiation exposure. The primary Aim of this study was to assess the concentration of radon in water samples collected from diverse regions of Morocco, particularly the Midelt province and the Draa-Tafilalt region located at coordinates 32° 40' 48″ North, 4° 44' 24″ West. For this purpose, Solid State Nuclear Track Detectors of the LR-115 variety were used. The evaluations of annual effective dose equivalents exhibited a range spanning from 11.51 to 1.30 µSv/y, showcasing a consistent pattern of decline. Correspondingly, projections of excess lifetime cancer risk encompassed a spectrum from 4.00 to 1.98. Significantly higher risks were associated with samples S1 and S2, while notably lower risks were tied to S14 and S15. It is worth noting that all the water samples subjected to analysis registered annual effective doses that fell within the global average level recommended for ingestion exposure dose values (0.23 mSv/y) by the United Nations Scientific Committee on the Effects of Atomic Radiation. Given these results, there seem to be no radiation risks from radon gas in the study area.

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INTRODUCTION

Radon (^{222}Rn) is a gas that occurs naturally through the radioactive decay of uranium-238. Its parent radionuclide is radium-226 (^{226}Ra), which is found in various natural sources such as rocks, soil, natural gas, and groundwater (Pourreza et al.,2010). Radon is a well-known non-chemical inert gas that is formed when 226Ra undergoes radioactive decay by emitting alpha particles, producing the short-lived daughter product Polonium 218. The half-life of Radon is 3.8 days (Changizi et al.,2012). Radon is soluble in water, and high concentrations in drinking water can be a significant exposure route. Biokinetic models suggest that after ingestion, short-lived daughter products remain in the stomach for a few minutes before being transferred to the

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bloodstream and quickly eliminated from the body (Alshahri et al.,2019). Testing for ^{222}Rn in water is crucial in reducing potential exposure. However, the use of water in residential areas can lead to increased internal concentrations of ^{222}Rn depending on the total amount of water used, the size of the area, and the level of ventilation (Khadour et al.,2023). Radon can pose a serious risk to people living in areas where it can spread beyond its conversion to polonium, which extracts alpha particles and can contaminate plants and homes. Radiation is a type of energy emitted by radioactive substances (Fadaei et al.,2023). Figure 1 Map showing the locations of the studied water samples from rivers, dams and wells in Midelt region (Morocco). The aim of the present work is to ascertain the level of radon present in water samples from different areas of Morocco (Midelt province, Daraa-Tafilalt region 32° 40’ 48″ North,4° 44’ 24″ West) using Solid State Nuclear Track Detectors (LR-115 type) and to assess the health burden on the local population as a result of radon intake and inhalation from drinking the water and also compare the results with industry norms and the findings of other studies.

MATERIALS AND METHODS

Water samples were collected from various sources in Midelt, including rivers, well water, irrigation canals, plantations, and ponds and stored in plastic containers. Each container held $1/4$ liter of water, and a 2×2 cm nuclear track detector (LR-115) was installed on the inner surface of the container lid. The container was then covered for one month to allow equilibrium between the radon gas in the water and the radon in the air in the water (Orosun et al.,2022).

Figure 2 showing Schematic diagram of radon detection in water.

After one month, the track detectors were chemically treated for two hours in a 2.5 M NaOH solution at a temperature of $60°C$. The treatment revealed that each alpha particle left a small hole in the red layer, ranging from 1 to 15μm in width (Rastogi et al.,2018).

· The track density recorded on each detector was calculated from the equation (Ali Bukhari et al.,2022):

$$\tilde{n} = \frac{\sum N_i}{nA} \tag{1}$$

where ρ is the track density,

Ni refers to the number of tracks counted in the first period of view,

$A =$ is the area of the field of view in, cm^2, and $n =$ is the total number of small holes in the

Fig. 1. Locations map of the studied samples in the Midelt region (Morocco).

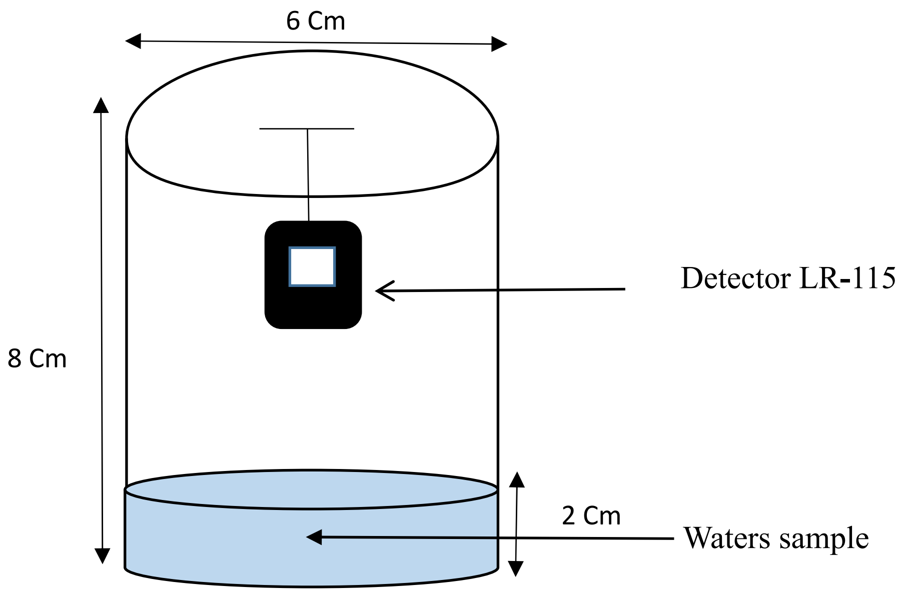

Fig. 2. Schematic diagram of radon detection in water

red layer.

· The Radon activity concentration C in the water can be estimated through the following empirical equation (El-Araby et al.,2019):

$$\boldsymbol{C = \frac{\tilde{n}}{K.t}} \tag{2}$$

where K is the calibration factor $\left(K = 0,201 \text{ tracks } cm^{-2} / \text{Bqm}^{-3} \text{ d}\right)$ of the LR-115 detector, t = is the exposure time in, days

Mean effective dose

The yearly amount of radiation exposure experienced by the residents was computed using the formula (1) provided by (UNSCEAR., 2000), based on the experimentally determined level of radon concentration (C_{Rn}).

$$\boldsymbol{H\left(mSv\, y^{-1}\right) = C_{Rn} \times \mathbf{F} \times \mathbf{O} \times \mathbf{DCF}} \tag{3}$$

Where, F is the global average (0.4) of equilibrium factor for radon and its progeny (UNSCEAR., 2000), O is the global average indoor occupancy factor (7000 hy^{-1}) (UNSCEAR., 2000) and DCF is the dose conversion factor (9 $nSvh^{-1}(Bqm^{-3})^{-1}$) for radon and its progeny (UNSCEAR., 2000).

Mean effective dose for ingestion and inhalation

When it comes to assessing ingestion and inhalation doses, the presence of radon in indoor water sources within homes is a more significant issue than potential contamination from other materials.

The yearly average effective doses for ingestion (E_{Wig}) and inhalation (E_{Wih}) were determined by utilizing the experimentally obtained radon concentration in water (C_{Rn}), and the calculations were based on expressions (4) and (5) provided in the UNSCEAR (2000) report, respectively :

$$E_{Wig}\left(mSv\, y^{-1}\right) = C_{Rn} \times C_w \times EDC \tag{4}$$

$$E_{Wih}\left(mSv\,y^{-1}\right)=C_{Rn}\times R_{Aw}\times F\times O\times DCF \quad (5)$$

Where, C_W is the weighted estimate of water consumption (60 ly^{-1}) and EDC is the effective dose coefficient for ingestion (3.5 $nSvBq^{-1}$). R_{Aw} is the ratio of radon in air to radon in tap water (10^{-4}) (Ajibola et al.,2021).

Estimating the Excess Lifetime Cancer Risk

Using equation 6, the increased lifetime cancer risk was calculated as follows:

$$ELCR=H\times DL\times RF \quad (6)$$

where $ELCR$ is the excess lifetime cancer risk, H is the annual effective dose equivalent $\left(mSv\,y^{-1}\right)$, DL is the average duration of life (estimated to $70\,years$) and RF is the Risk Factor (Sv^{-1}), i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for the public (Ramasamy et al.,2013).

RESULTS AND DISCUSSION

The table1 provides information on the radon concentration in water samples of different sources, including well water, dams water, and rivers water. Radon is a naturally occurring radioactive gas that can be found in soil, rocks, and water sources. It is a known carcinogen and can be harmful to human health when inhaled or ingested in high concentrations.

To determine the highest value of the lowest radon concentration in water using LR 115, we need to look at the minimum radon concentration recorded for each type of water sample. LR 115 is a type of solid-state nuclear track detector that is commonly used for measuring the concentration of radon in water. The tracks density in the table refers to the number of alpha particle tracks recorded on a piece of LR 115 material, which is used as an indirect method for detecting the presence of radon gas in the sample. The higher the tracks density, the higher the concentration of radon in the water sample.

Based on the table, the minimum radon concentration recorded for each type of water sample is as follows:

Well water: 3.30 Bq/L (sample S5)

Table 1. Radon concentrations in water for different areas Midelt region

Sample code	Type of water	Tracks density ($track.mm^{-2}$)	Concentration (Bq/L)
S1	Well water1	451.60	4.68
S2	Well water2	442.60	4.58
S3	Well water3	433.71	4.49
S4	Well water4	401.90	4.16
S5	Well water5	319.80	3.30
S6	Dams water1	199.33	2.06
S7	Dams water2	197.30	2.04
S8	Dams water3	177.60	1.84
S9	Dams water4	176.20	1.82
S10	Dams water5	171.32	1.77
S11	Rives water1	109.20	1.13
S12	Rives water2	98.10	1.01
S13	Rives water3	79.11	0.81
S14	Rives water4	71.35	0.73
S15	Rives water5	51.95	0.53
Average		225.40	2.33

Table 2. The activity concentration of ^{222}Rn in comparison with similar studies from other parts of the world

Location	Type of water	Concentration (Bq/L)	References
Shanono/Bagwai, Nigeria Ground	Groundwater	3.176–49.9328	(Bello et al.,2020)
Portugal	Drinking water	2–1690	(Inacio et al.,2017)
Vietnam	Well water	1.4	(Hao et al.,2015)
Stockholm/ Sweden	Wells water	4–63	(Skeppstorm et al.,2006).
Ijero, Ekiti, Nigeria	Groundwater	0.168–78.509	(Akinnagbe et al.,2018).
Virginia, USA	Well water	3.7–296	(Moses et al.,1990).
Baoji, China	Drinking water	12–127	(Xinwie et al.,2004).
Jammu, India	Boreholes	9.03	(Rani et al.,2012).
Midelt, Morocco	Well water	4.68–3.30	This study
Midelt, Morocco	Dams water	2.06–1.77	This study
Midelt, Morocco	Rivers water	1.13–0.53	This study

Dams water: 1.77 Bq/L (sample S10)

Rivers water: 0.53 Bq/L (sample S15)

Therefore, the highest value of the lowest radon concentration in water using LR 115 is 3.30 Bq/L, which is the minimum radon concentration recorded for the well water samples.

This information is important for evaluating potential health risks associated with radon exposure and for implementing appropriate measures to ensure safe drinking water. It is recommended to regularly monitor the radon concentration in water sources to ensure that they remain within safe levels. This can help to reduce the risk of exposure to radon for individuals who consume water from these sources

The data reveals significant differences in the concentration of a certain substance in various water sources in Midelt, Morocco. Well water has the highest concentration, ranging from 3.30 to 4.68 Bq/L, while dam water exhibits a lower concentration, with a range of 1.77 to 2.06 Bq/L. River water, on the other hand, displays the lowest concentration, ranging from 0.53 to 1.13 Bq/L. These concentration variations highlight the diversity in substance levels among these water sources in the Midelt region. To gain a deeper understanding of this substance, including its potential origins and its possible implications for the environment and public health, further investigation and analysis are required.

Table 3 provides information on the radiation doses and cancer risks associated with different concentrations of radon in water samples.To determine the maximum and minimum values for each column, we need to look at the values associated with each water sample.

The minimum values for each column are:

Effective dose by ingestion per year (mSv/y): 0.05 (sample S14)

Annual effective dose inhalation (mSv/y): 0.45 (sample S15)

Annual effective dose equivalent (µSv/y): 1.30 (sample S15)

Excess lifetime cancer risk (ELCR): 0.0062 (sample S15)

The maximum values for each column are:

Effective dose by ingestion per year (mSv/y): 0.48 (sample S1)

Annual effective dose inhalation (mSv/y): 0.0091 (sample S1)

Annual effective dose equivalent (µSv/y): 11.51 (sample S1)

Excess lifetime cancer risk (ELCR): 4.00 (sample S1)

This study provides important insights into the radon concentration in water in the Midelt region. The findings indicate that well water poses a significant radiological risk to individuals who consume it. Therefore, there is an urgent need for appropriate measures to be taken to reduce exposure to radon in well water.

The obtained results are consistent with previous studies that have demonstrated the potential

Table 3. Calculated Annual Effective Dose Equivalent H and Estimating the Excess Lifetime Cancer Risk (ELCR)

Sample code	Effective dose by ingestion per year mSv/y	Annual effective dose inhalation mSv/y	annual effective dose equivalent $\mu Sv/y$	Estimating the Excess Lifetime Cancer Risk ELCR $\times 10^{-3}$
S1	0.48	0.009	11.51	4.00
S2	0.46	0.009	11.26	3.90
S3	0.45	0.009	11.04	3.80
S4	0.42	0.008	10.23	3.50
S5	0.33	0.006	8.11	2.80
S6	0.21	0.004	5.06	1.77
S7	0.20	0.004	5.01	1.75
S8	0.19	0.004	4.52	1.58
S9	0.19	0.004	4.47	1.56
S10	0.18	0.003	4.35	1.52
S11	0.11	0.002	2.78	0.97
S12	0.10	0.002	2.48	0.86
S13	0.08	0.002	1.99	0.69
S14	0.07	0.001	1.79	0.62
S15	0.05	0.001	1.30	0.45
Average	0.23	0.005	5.73	1.98

risks associated with exposure to high levels of radon in water. Radon is a naturally occurring radioactive gas that can seep into groundwater, which can then contaminate well water. Ingesting high levels of radon can increase the risk of lung cancer, particularly in individuals who smoke. To address the issue of radon exposure in well water, it is necessary to take steps to reduce the levels of radon in groundwater. This may involve a combination of measures, including the use of radon removal systems, improved well construction and maintenance, and the implementation of regulations to reduce exposure to radon in drinking water.

CONCLUSION

In conclusion, this study aimed to assess the level of radon in water samples from different areas of the Midelt region in Morocco and evaluate the potential health burden on the local population. The results showed that radon concentrations varied across different water sources, with well water exhibiting the highest levels. The use of Solid State Nuclear Track Detectors (LR-115) proved effective in measuring radon concentration in the water samples.The study also estimated the radiation doses and cancer risks associated with radon exposure. The calculated effective doses by ingestion and inhalation, as well as the annual effective dose equivalent, provided valuable information on the potential health risks. The excess lifetime cancer risk was also estimated, highlighting the importance of reducing radon exposure to minimize the risk of developing cancer. Comparisons with other studies from different regions demonstrated that radon concentrations in the Midelt region were in line with findings from other parts of the world. However, it is crucial to implement measures to ensure safe drinking water and regularly monitor radon levels to mitigate the health risks associated with radon exposure. Overall, this study emphasizes the significance of understanding and addressing radon contamination in water sources. By raising awareness and implementing appropriate measures, such as water treatment or alternative water sources, the risk of radon-related health issues can be minimized for the local population in the Midelt region of Morocco.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy ha/s been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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