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Research Article

Radon Radiological Risk Assessment Due to Tap Water Consumption in Abidjan, Côte d'Ivoire

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Abstract

Ensuring the potability of drinking water is an ongoing challenge for all worldwide nations. "In this study, we" evaluated dissolved "radon concentrations in" tap water consumed "in" Abidjan, Côte d'Ivoire. Samples of tap water were collected in vials throughout 13 communes of Abidjan District. After being exposed for 97 days to sheets of LR 115 detector, they were chemically etched and track onto their surfaces were optically counted. The results of the obtained dissolved radon concentrations ranged from (0.13 ±0.06) Bq/L to (2.12 ±0.87) Bq/L with an average of (0.81 ±0.34) Bq/L. The resulting total annual effective doses received by the public range from (1.3 ± 0.6) µSv/Y to (21 ± 9) µSv/Y with an average of (7.93 ± 3.25) µSv/Y. The obtained average dissolved radon concentration in tap water and corresponding total annual effective dose are larger and smaller than those obtained in Egypt, Pakistan, Palestine by some authors and in Libya, Saudi Arabia by others, respectively. But, these results are much lower than the threshold values of 100 Bq/L and 100 µSv/Y recommended by the World Health Organization (WHO) to States to take action. This preliminary study should be extended to other regions and drinking water sources across Côte d'Ivoire.

Keywords

Tap Water, LR 115 Detector, Radon Concentration, Radon Effective Dose, Abidjan

1. Introduction

The waters, particularly the deep ones, are in contact with plutonic rocks, such as granites, or metamorphic rocks. They thus become laden with radioactive elements, including radon gas [1]. This gas has been recognized as a definite human lung carcinogen, by the International Agency for Research on Cancer (IARC) of the World Health Organization (WHO), since 1988 [2]. Being water-soluble, radon is then transported via groundwater into the atmosphere [3].

Radon concentration values in water vary widely, ranging from a few Bq/L to several thousand Bq/L. The highest values are observed in groundwater and are generally associated with high uranium concentrations in the rocks constituting the aquifer [4].

Water from public supply networks that draw on groundwater, naturally contains radon.

The first WHO guidelines including radiological parameters for drinking water that dated back to the late 1950s have been updated [5].

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Regarding radon dissolved in drinking water, the danger stems primarily from the gas released into the indoor air of buildings, which increases the risk through inhalation rather than direct ingestion. Nevertheless, the WHO suggests threshold values of 100 Bq/L and 100 µSv/Y for dissolved radon concentration and radon annual effective dose from the ingestion and inhalation of such water, respectively; to trigger enhanced monitoring of the radiological quality of drinking water [6].

However, despite regulatory advances, data on radon levels in water, particularly drinking water, remains incomplete in several geographical regions of the world, including Côte d'Ivoire.

The present work falls within this framework and addresses the lack of data in Côte d'Ivoire.

Data exists regarding radiological risks of drinking water from different sources in Abidjan, including tap water and due to gross alpha and beta activities as well as natural radioactivity, but, due to radon this survey was the first to take place [7, 8].

Studies on dissolved radon in drinking water typically report global average dissolved radon concentrations remaining well below international reference levels such as the WHO and European Commission guidance value of 100 Bq L^{-1}. But, scientific curiosity requires that each specific situation be examined.

The objective of the present study was to measure dissolved radon concentrations in tap water in the city of Abidjan using the Solid- State Nuclear Track Detector (SSNTD) technique.

Several measurements of radon in drinking water have been performed, by researchers throughout the world using other techniques [9, 10].

But, the efficient and cost-effective SSNTD technique enables easy integrated measurements that are representative of annual averages; that is why we used it.

2. Materials and Methods

2.1. Location of the Sampling Sites

The study was conducted in the Abidjan District located in the southeast of Côte d'Ivoire, bordering the Atlantic Ocean and the Gulf of Guinea. Its geographical coordinates and area are 5° 20' 11'' latitude North, 4° 01' 36'' longitude West, and 2119 km^2, respectively. Its population is estimated at between 6 and 7 million inhabitants in 2026. The subsoil of Abidjan is essentially composed of sandy-clay formations.

Tap water samples were collected in vials, throughout 13 communes of Abidjan that are, Cocody, Adjame, Plateau, Abobo, Yopougon, Treichville, Marcory, Koumassi, Port-Bouet, Attecoube, Songon, Bingerville, and Anyama.

Figures 1 and 2 show the map of Côte d'Ivoire and the map of Abidjan, with the location of Abidjan and the sampling sites respectively.



Figure 1. *Map of Côte d'Ivoire [11].*

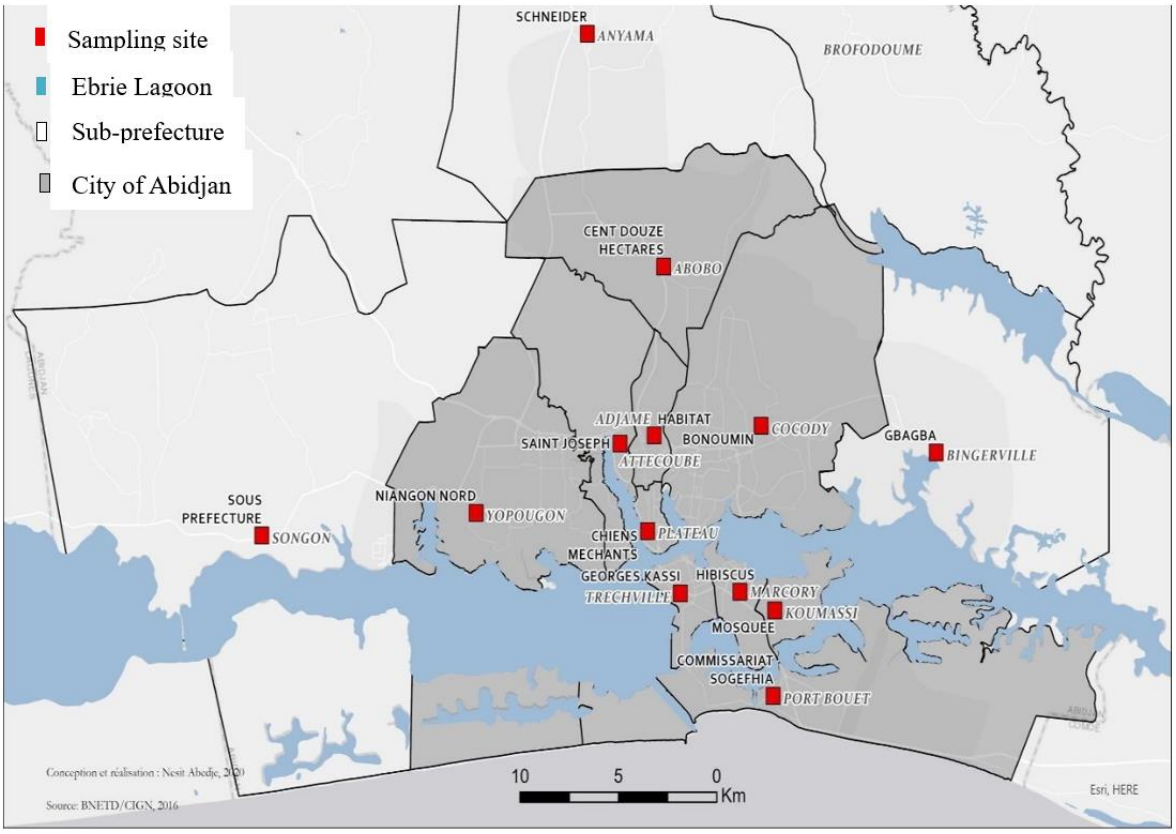


Figure 2. *Map of Abidjan District showing the location of the sampling sites [12].*

2.2. Experimental Procedures

2.2.1. Sampling Methods

At each sampling site, the level of ventilation at the location of the tap was recorded.

Identical volumes of water samples were collected while minimizing turbulence at the tap outlet and against the walls of the identical sampling vials, which could promote radon degassing. The vials were hermetically sealed immediately after sampling.

Subsequently, the samples were transported to the laboratory in sealed containers to prevent any exchange with the outside atmosphere.

A single sample was taken per site. So the absence of replicates is noted as a limitation.

2.2.2. Detector Exposure

Samples of LR 115 type 2 (manufactured by Dosirad-France) were previously affixed to the inner surfaces of identical closures to those of the sampling vials. They were wrapped in sheets of paper to minimize background noise. The initial closures of the vials containing the collected water samples were quickly replaced by the latter. Then, the start time and date of the exposure for each LR 115 sample were recorded.

Figure 3 shows the diagram of the exposure device.

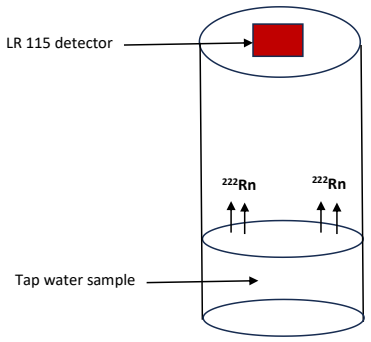


Figure 3. *Diagram of sampling device.*

2.2.3. Detector Analysis

After 97 days of exposure, the detectors were removed from the sampling vials. They were then chemically etched in a 2.5 mol/L sodium hydroxide solution heated to 60 ℃ for 90 minutes, and rinsed thoroughly with water before being air-dried. The revealed alpha -particle tracks on their surfaces were then counted using an optical microscope.

2.2.4. Concentration of Air-gap Emanated Radon

This concentration was calculated using the following formula [13]:

$$C_i = \frac{\rho - \rho_0}{k \times t} \quad (1)$$

where

C_i is the concentration of air-gap emanated radon from tap water (Bq/m^3);

ρ the track density (ranges from 17 to 258 tracks/cm^2);

k the calibration factor (k = 0.033 track/cm^2/day/Bq/m^3, determined in-house);

t the exposure time (t = 2328 h);

and ρ_0 the background (ρ_0 = 1 track/cm^2).

The geometry used is the Euclidean geometry.

The uncertainty in the concentration of air-gap emanated radon from tap water was computed using the following formula derived from (1):

$$\left(\frac{\Delta C_i}{C_i}\right)^2 = \left(\frac{\Delta \rho}{\rho}\right)^2 + \left(\frac{\Delta k}{k}\right)^2 \quad (2)$$

where

ΔC_i is the uncertainty in C_i;

$\Delta \rho$ the uncertainty in ρ;

and Δk the uncertainty in k.

2.2.5. Concentration of Dissolved Radon

This concentration was calculated using the following formula [14]:

$$C_d = \frac{C_i \times \lambda \times h \times t}{L} \quad (3)$$

where

C_d is the concentration of dissolved radon in tap water (Bq/L);

C_i the concentration of air-gap emanated radon from tap water (Bq/m^3);

λ the ^{222}Rn decay constant (λ = 0.00756 h^{-1});

h the distance between the water surface and the detector (h = 0.09 m);

t the exposure time (h);

and L the depth of the water sample (L = 0.06 m).

The uncertainty in the concentration of dissolved radon in tap water was computed using the following formula derived from (3):

$$\left(\frac{\Delta C_d}{C_d}\right)^2 = \left(\frac{\Delta C_i}{C_i}\right)^2 + \left(\frac{\Delta h}{h}\right)^2 + \left(\frac{\Delta L}{L}\right)^2 \quad (4)$$

with $\Delta\lambda = \Delta t = 0$

and where

Δh is the uncertainty and equal to h/(12)$^{1/2}$ [15];

and ΔL the uncertainty in L and equal to L/(12)$^{1/2}$ [15].

2.2.6. Annual Effective Dose from Ingestion of Radon

This dose was calculated using the following formula [16]:

$$D_{ing} = C_d \times D_w \times DCF \times t = 7.3 \times C_d \quad (5)$$

where

C_d is the concentration of dissolved radon in tap water (Bq/L);

D_w the daily water intake rate (2L/day);

DCF the dose conversion factor for the ingestion of radon and its progeny (10^{-8} Sv/Bq);

and t the annual drinking time (365 days) [17, 18].

The uncertainty in the annual effective dose from ingestion of radon in tap water was calculated using the following formula derived from (5):

$$\Delta D_{ing} = 7.3 \times \Delta C_d \quad (6)$$

2.2.7. Annual Effective Dose from Inhalation of Radon

This dose was calculated using the following formula [16]:

$$D_{inh} = C_d \times R \times D \times F \times t = 7.3 \times C_d \quad (7)$$

where

C_d is the concentration of dissolved radon in tap water (Bq/L);

R the ratio of radon concentrations in air and water (10^{-1} Bq.m^{-3}/Bq.L^{-1});

D the dose conversion factor (9 nSv/h per Bq/m^3);

F the indoor equilibrium factor between radon and its progeny (0.4);

and t the annual time spent residing at home (7000 h) [17, 18].

The uncertainty in the annual effective dose from inhalation of radon in tap water was calculated using the following formula derived from (7):

$$\Delta D_{inh} = 2.52 \times \Delta C_d \quad (8)$$

The total annual effective dose is the sum of the annual effective doses from ingestion and inhalation:

$$D_T = D_{ing} + D_{inh} \quad (9)$$

3. Results

The measurement results are summarized in Table 1. These are the dissolved radon concentrations in tap water, the effective doses, and the characterization of the ventilation at the sampling sites.

A histogram based on these results is presented in Figure 4.

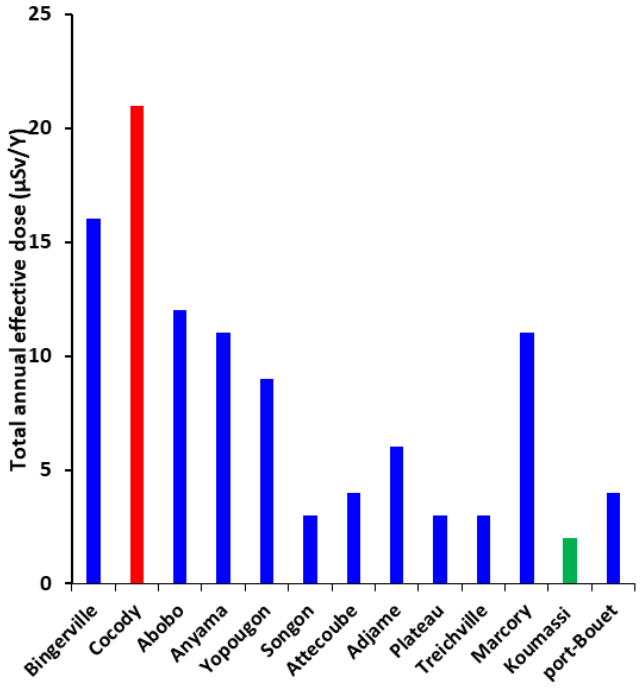


Figure 4. *Histogram of total annual effective dose versus sampling site.*

4. Discussion

We observed that the dissolved radon concentrations are higher at sites with poor ventilation (Bingerville, Cocody), while they are smaller at sites with good ventilation (Treichville, Koumassi, Plateau, Songon). It could seem that ventilating the area where a tap is located influence the concentration of radon dissolved in the water from that tap. But, the literature review does not confirm this. What has been established is that the reduction of radon in water once it leaves the tap is governed entirely by physical turbulence, water temperature, and pressure drops [19].

We also observed that, at each site, the annual effective dose from ingestion is higher than the annual effective dose from inhalation. Indeed, the annual effective dose from ingesting tap water is typically higher than the dose from inhaling radon because of how much more fluid we consume compared to the tiny fraction of gas that transfers from water into indoor air, combined with standard international dose conversion factors [20-22].

In Table 2, we compare the results of the current study with those obtained in other countries.

Table 1. *Radon concentrations and effective doses.*

Site Name	Ventilation	Cd (Bq/L)	D_{ing} (µSv/Y)	D_{inh} (µSv/Y)	D_T (µSv/Y)
Bingerville	Poor	1.61 ±0.66	12 ±5	4 ±2	16 ±7
Cocody	Poor	2.12 ±0.87	16 ±7	5 ±2	21 ±9
Abobo	Moderate	1.19 ±0.49	9 ±4	3 ±1	12 ±5
Anyama	Good	1.14 ±0.47	8 ±3	3 ±1	11 ±4
Yopougon	Good	0.99 ±0.41	7 ±3	2 ±1	9 ±4
Songon	Good	0.28 ±0.12	2.1 ±0.9	1.0 ±0.3	3.1 ±1.2
Attecoube	Good	0.44 ±0.18	3 ±1	1.1 ±0.5	4.1 ±1.5
Adjame	Good	0.62 ±0.26	4 ±2	2 ±1	6 ±3
Plateau	Good	0.31 ±0.13	2.3 ±0.9	1.0 ±0.3	3.3 ±1.2
Treichville	Moderate	0.13 ±0.06	1.0 ±0.4	0.3 ±0.2	1.3 ±0.6
Marcory	Good	1.06 ±0.44	8 ±3	3 ±1	11 ±4
Koumassi	Good	0.23 ±0.10	2 ±1	0.6 ±0.2	2.6 ±1.2
Port-Bouet	Good	0.39 ±0.16	3 ±1	1.0 ±0.4	4.0 ±1.4
Average		0.81 ±0.34			
Average					7.93 ±3.25

Table 2. Radon concentrations in drinking water for different countries.

Water type	Cd (Bq/L)	Reference	Country
Drinking water	1.65-3.82	Entesar et al, 2019 [13]	Saudi Arabia
Drinking water	0.27-5.40	Shilpa et al, 2017 [23]	India
Drinking water	0.20-1.23 (0.60)	Thabeyneh, 2015 [24]	Palestine
Drinking water	1.02-6.42 (3.46)	Rafat, 2014 [25]	Libya
Tap water	0.04-0.48 (0.14)	Hussein, 2014 [26]	Egypt
Drinking water	0.33-0.90 (0.60)	Nasir et al, 2012 [27]	Pakistan
Drinking water	0.39-0.47	Marques et al, 2004 [28]	Brazil
Tap water	0.13-2.12 (0.81)	Present study	Côte d'Ivoire

The range of dissolved radon concentrations in tap water obtained in the present study has a maximum value larger than those of Egypt, Brazil, Pakistan and Palestine and smaller than those of Saudi Arabia, India, and Libya. Its minimum value is larger than that of Egypt but smaller than those of Brazil, Pakistan, Libya, Palestine, India, and Saudi Arabia.

The current average dissolved radon concentration is slightly above those of Palestine and Pakistan, almost double of that of Brazil, and much greater and smaller than those of Egypt and Libya, respectively.

The average dissolved radon concentration [(0.81 ± 0.34) Bq/L] and total annual effective dose [(7.93 ± 3.25) µSv/Y] obtained in the current study are much smaller than the thresholds (100 Bq/L and 100 µSv/Y) recommended by the WHO to States to take action.

The results of this study are representative of annual averages, given the SSNTD technique employed. Indeed, this method enabled time-integrated measurements to be obtained [29].

5. Conclusions

In this study, the concentrations of dissolved radon in tap water consumed in Abidjan were measured and the corresponding annual effective doses by ingestion and inhalation and the total annual effective doses were computed. The technique of SSNTD used, allowed to perform integrated measurements representative of annual averages. The dissolved radon concentrations obtained are greater and smaller than those obtained in other countries by some authors and others, respectively. The annual averages of dissolved radon concentration and total effective dose are very much lower than the thresholds recommended by WHO to States to take action. Therefore, regarding the radiological risk due to radon, the tap waters studied at Abidjan are safe for consumption. But, the study should be extended to drinking water from all sources throughout Côte d'Ivoire.

Abbreviations

LR 115	Lexan Resin 115
WHO	World Health Organization
SSNTD	Solid State Nuclear Track Detector
DCF	Dose Conversion Factor

Author Contributions

Dabo Salif Ignace Agba: Conceptualization, Data curation, Formal Analysis, Writing – original draft

Tekpo Paul Amewe Dali: Supervision, Validation

Omer Kouakou: Software, Writing – review & editing

Data Availability Statement

The data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Phoka C. Rathebe, Mota Xavier Kholopo. Radon Detection in Drinking Water: Instruments and Measurement Techniques—A Comprehensive Review. *Applied Sciences.* 2026, *16*(18), 9147. https://doi.org/10.3390/app16189147

[2] IARC. Man-Made Mineral Fibres and Radon. Available from: https://publications.iarc.who.int/61 (accessed 13 October 2026).

[3] Joash N. Ongori, Robert Lindsay, Mashinga J. Mvelase. Radon transfer velocity at the water–air interface. Applied Radiation and Isotopes. 2015, Volume 105, Pages: 144-149. https://doi.org/10.1016/j.apradiso.2015.07.058

[4] Yehia Manawi, Arzoo Hassan, Muataz Ali Atieh, Jenny Lawler. Overview of radon gas in groundwater around the world: Health effects and treatment technologies. Journal of Environmental Management. 2024, Volume 368, 122176. https://doi.org/10.1016/j.jenvman.2024.122176

[5] WHO, (2022). Guidelines for drinking-water quality: fourth edition incorporating the first and second addenda. Available from: https://www.who.int/publications/i/item/9789240045064 (accessed 13 October 2026).

[6] Wau, M. K., Willie, H., Kolkoma, D. *et al.* Quantifying dissolved radon in drinking water using an augmented method. *Journal of Radioanalytical and Nuclear Chemistry. 2026,* 335, 5263–5269. https://doi.org/10.1007/s10967-026-11019-3

[7] Kezo, P. C., Konate, I. and Agba, D. S. I. Gross Alpha and Beta Activities and Related Life time Risks Assessment Due to Ingestion of Drinking Water from Different Sources in the District of Abidjan, Cote d'Ivoire. World Journal of Nuclear Science and Technology. 2024, 14, 86-96. https://doi.org/10.4236/wjnst.2024.141004

[8] Kezo P. C., Monnehan G. A., Faanu A., Gogon B. D. L. H., Koua A. A., Dali T. P. A., Djagouri K. Assessment of the Exposure to Natural Radioactivity to Public from the Consumption of Tap Drinking Water in the Six Most Populated Townships of the District of Abidjan. Research Journal of Environmental and Earth Sciences. 2016, 8(4), 56-62. https://doi.org/10.19026/rjees.8.3066

[9] Suresh S, Rangaswamy D R, Srinivasa E and Sannappa J. Measurement of radon concentration in drinking water and natural radioactivity in soil and their radiological hazards. JOURNAL OF RADIATION RESEARCH AND APPLIED SCIENCES. 2020, VOL. 13, NO. 1, 12–26. https://doi.org/10.1080/16878507.2019.1693175

[10] Habila Nuhu, Suhairul Hashima, Mohamad Syazwan Mohd Sanusi and Muneer Aziz Saleh. Radon activity concentration measurements in water sources from Perak state Malaysia. JOURNAL OF RADIATION RESEARCH AND APPLIED SCIENCES. 2020, VOL. 13, NO. 1, 665–671. https://doi.org/10.1080/16878507.2020.1820270

[11] Nations online project. Administrative Map of Côte d'Ivoire. Available from: https://www.nationsonline.org (accessed 14 October 2026).

[12] Nesit Abedje, (2020). Carte d'Abidjan, [Unpublished institutional document]. Bureau National d'Etudes Techniques et de Développement (BNETD), Côte d'Ivoire.

[13] Entesar H. El-Araby, H. A. Soliman and M. Abo-Elmagd. Measurement of radon levels in water and the associated health hazards in Jazan, Saudi Arabia. Journal of Radiation Research and Applied Sciences, 2019, Vol 12, N°1, 31-36. https://doi.org/10.1080/16878507.2019.1594134

[14] Liath Ahmed Najam, Hazim Louis Mansour, Nada Fadhil Tawfiq, Mahmood Salim Karim. Measurement of radon concentrations in tap water samples for Thi-Qar Governorate using nuclear track detector (CR-39). Detection. 2016, 4, 1-8. https://doi.org/10.4236/detection.2016.41001

[15] Stage PAF. Notion d'erreurs et d'incertitudes en sciences expérimentales. Académie de Toulouse.

[16] UNSCEAR. Report to the General Assembly, With Scientific Annexes, United Nations Sales Publication E.94.IX.2; United Nations: New York. Available from: https://www.unscear.org/unscear/publications/1993.html (accessed 16 October 2026).

[17] UNSCEAR. Report of the United Nations Scientific Committeeon the Effects of Atomic Radiation to the General Assembly. ANNEX B exposures from natural radiation sources. Available from: https://www.unscear.org/unscear/uploads/documents/unscear-reports/UNSCEAR_2000_Report_Vol.I.pdf (accessed 16 October 2026).

[18] WHO. Guidelines for drinking-water quality (3rd ed.). Available from: https://www.who.int/publications/i/item/9789241547611 (accessed 17 October 2026).

[19] Abdulkarim Abubakar, Mohammed Audu, Sama'ila Ibrahim and Magaji Musa Jawa. Determination of RADON-222 Concentration in Some Selected Drinking Water Sources at Geidam Town, Geidam Local Government Area of Yobe State, Nigeria. Journal of Emerging Technologies and Innovative Research (JETIR), 2021, Volume 8, Issue 2. https://www.jetir.org

[20] Pintilie-Nicolov, V., Georgescu, P. L., Iticescu, C. *et al.* The assessment of the annual effective dose due to ingestion of radionuclides from drinking water consumption: calculation methods. *Journal of Radioanalytical and Nuclear Chemistry. 2021,* 327, 49–58. https://doi.org/10.1007/s10967-020-07438-5

[21] Binesh, A. & Mowlavi, Ali & Mohammadi, S.. Estimation of the effective dose from radon ingestion and inhalation in drinking water sources of Mashhad, Iran. Iranian Journal of Radiation Research. 2012, 10. 37-41.

[22] Dosh, Rukia & Hasan, Ali & Abojassim, Ali. Effective dose (ingestion and inhalation) due to radon from tap water samples in children at primary schools in Najaf city, Iraq. Water Supply. 2023, 23. 1234-1249. https://doi.org/10.2166/ws.2023.046

[23] Shilpa, G. M., Anandaram, B. N., & Mohankumari, T. L. Measurement of ^{222}Rn concentration in drinking water in the environs of Thirthahalli taluk, Karnataka, India. Journal of Radiation Research and Applied Sciences. 2017, 10, 262–268.

[24] Thabayneh., K. M. Measurement of ^{222}Rn concentration levels in drinking water and the associated health effects in the Southern part of West bank – Palestine. Applied Radiation and Isotopes. 2015, 103, 48–53.

[25] Rafat M. Amin. Evaluation of radon gas concentration in the drinking water and dwellings of south-west Libya, using CR-39 detectors. International Journal of Environmental Sciences. 2014, 4. 484-490. https://doi.org/10.6088/ijes.20140400005

[26] A. S. Hussein. Radon measurements in water samples from western desert of Egypt using nuclear track detectors and estimation of corresponding doses. Radiation Protection and Environment. 2014, 37(3): p 165-168. https://doi.org/10.4103/0972-0464.154879

[27] Nasir, T., & Shah, M. Measurement of annual effective doses of radon from drinking water and dwellings by CR-39 track detectors in kulachi city of Pakistan. Journal of Basic &Applied Sciences. 2012, 8, 528–536.

[28] Marques, A. L., Dos Santos, W., & Geraldo, L. P. Direct measurements of radon activity in water from various natural sources using nuclear track detectors. Applied Radiation and Isotopes. 2004, 60, 801–804.

[29] Sahoo, B. K., & Sapra, B. K. Advances in Measurement of Indoor ^{222}Rn and ^{220}Rn Gas Concentrations Using Solid State Nuclear Track Detectors. Solid State Phenomena. 2015, 238, 116–126. https://doi.org/10.4028/www.scientific.net/ssp.238.116