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Assessment of Radon Concentrations and Annual Effective Dose in Potable Water of Al-Khidhir District, Southern Iraq: A Radiological Risk Evaluation

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Abstract

This study examines the levels of radon gas (^{222}Rn) and the associated annual effective dose (AED) in potable water supplies utilized for domestic purposes in the Al-Khidhir District, Al-Muthanna Governorate, southern Iraq. In the study area, which included both the eastern and western regions of Al-Khidhir City, 230 water samples were gathered from 23 residential areas. A calibrated RAD7 radon in air detector from the Durridge Company in USA was used to take the measurements. Water aeration and humidity control were done according to standard protocols. The average radon concentration in the water samples was 10.30 Bq/L, with a range of 0.29 to 33.01 Bq/L. the average annual effective doses from inaling radon were 0.0074 mSv/y, with a range of 0.000328 t0 0.07587 mSv/y. According to the European Union (0.1 mSv/y) and the World Health Organization (100 Bq/L), all recorded values were significantly below the uppermost permitted limits. The local geology, soil texture, building age, and water distribution network integrity all contributed to the variations in radon levels in various locations. Long-term use of radon-contaminated water at homes, may raise the risk of radiation exposure even though the levels detected were low. This study provides vital baseline information for environmental radiation monitoring and public health protection in southern Iraq.

Keywords: Radon; Potable water; Annual effective dose; Al-Muthanna; Radiological assessment; Iraq; Public health

Introduction

One of the most prevalent environmental elements that has an impact on ecosystems and human health is natural radioactivity. Ionizing radiation comes in two primary forms: artificial radiation, which originates from nuclear, industrial, and medical applications, and natural radiation, which is generated by cosmic rays and naturally radioactive materials (NORM) [1]. A naturally occurring radionuclide that has attracted a lot of attention is radon-222, an inert noble gas that has no color or odor and contributes to human internal radiation exposure [2].

Radium-226 decays to produce radon, a byproduct of the (238U) decay series. Due to its relatively long half-life (3.82 days), radon can enter indoor spaces and groundwater systems through soil, rocks, and construction materials [3]. Since radon is a gas, it dissolves readily in groundwater. It can be released during routine tasks like cooking, cleaning, or taking a shower, which could increase the gas concentrations in the interior air [4].

Lung cancer risk increases with prolonged exposure to high radon levels. After tobacco use, it is the second most frequent cause of lung cancer worldwide [5, 6]. According to UNSCEAR (2010), radon and its offspring account for nearly half of the 2.4 mSv average annual effective dose from natural background radiation worldwide. Significant regional variations in radon levels have been found in studies carried out in Europe, North America, and Asia. These variations are influenced by local geology, soil porosity, uranium concentration, and water composition [7, 8, 9].

Numerous studies conducted in Iraq have evaluated the levels of radon in soil and groundwater, showing that the southern provinces have moderate to low levels [10, 11]. However, information about radon levels in drinking water in Al-Muthanna Province that is specifically intended for domestic use is limited. A systemic assessment of radiological safety is necessary because many people in the region rely on both fixed and mobile water distribution systems. The present investigation aims to (1) determine the levels of radon gas in drinking water sources in Al-Khidhir City, (2) calculate the corresponding yearly effective doses from inhalation exposure, and (3) compare the results with global radiological safety guidelines.

1. Study Area

The study took place in Al-Khidhir District, which is about 30 km south of Samawah City and along the Euphrates River in Al-Muthanna Governorate, southern Iraq. The area has dry weather, alluvial soil, and a mix of clay and sandy sediments that come from the Euphrates basin. The water supply network's primary treatment facilities receive their water directly from the river. The treated water is subsequently delivered to homes via secondary distribution networks. The city is divided into two main sections: Al-Kabir on the west side and Al-Sagher on the east. Al-Hussein, Al-Firdous, Al-Zahraa, Al-Askari, and Al-Baqir are among the more than 20 residential neighborhoods. Older homes and inadequate ventilation are prevalent in many areas, which may facilitate the accumulation of radon indoors.

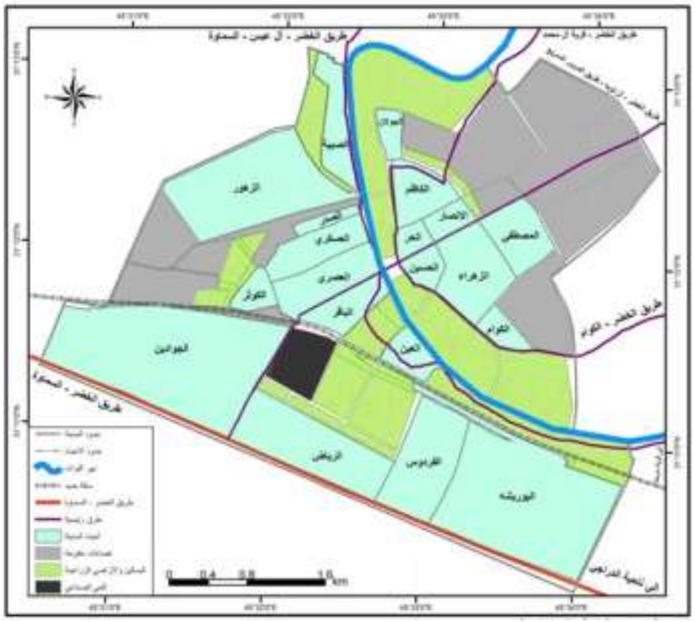

Figure 1: Administrative map of Al-Khader District Center

Materials and Methods

1.1. Samples Collection

Ten samples of drinkable water were collected from each of the 23 neighborhoods, totalling 230 samples. To get rid of any stagnant water, samples were taken straight from household taps after the water ran for ten minutes. We placed each sample in a 0.5 L pre-cleaned plastic bottle, filled it to the top to prevent air bubbles from forming, and then sealed it immediately with airtight caps to prevent radon from escaping.

A Global Positioning System (GPS) was used to georeference sampling sites and make a map of their spatial distribution. We moved all the samples to the lab on the same day and looked at them right away to stop the radon from breaking down.

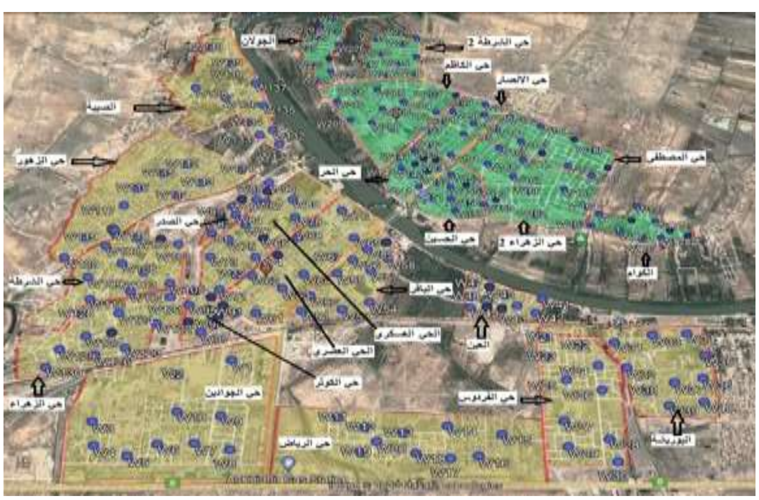

Figure 2: The locations of the collected samples.

1.2.Measurement Techniques

An active alpha-spectrometry system based on a solid-state silicon detector, the RAD7 Radon Detector (Durridge Company, USA), was used to measure the amount of radon in water. The RAD7 system picks up alpha particles that come from radon and its offspring. It turns the energy from the radiation into electrical pulses, which are then turned into radon concentration values (Bq/L).

We used the RAD H_2O accessory to measure water. It worked by moving radon from the water to the air in a closed-loop aeration process. The 250 mL water sample was put in a glass bubbler that was connected to the RAD7 unit by desiccant tubes filled with calcium carbonate to keep the humidity below 8%. The system was cleaned out and allowed to settle for 15 minutes, and then it was measured several times for five minutes each time.

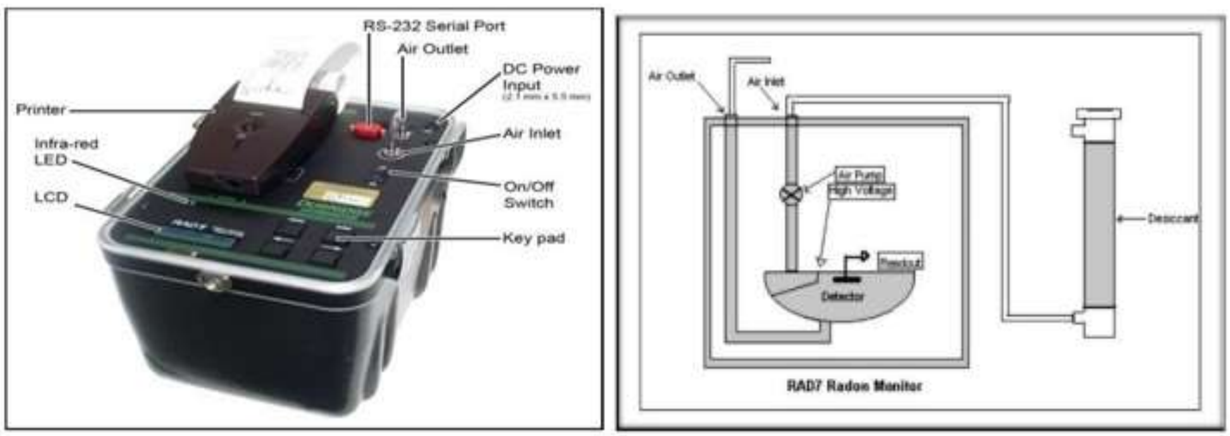

Figure 3: RAD7 external and external installation.

1.3. Calibration and Quality Assurance

The manufacturer pre-calibrated the instrument and checked it with reference water samples that had known radon activity. To make sure the samples were stable, background measurements were taken before and after each batch. We used Durridge CAPTURE software to collect and analyse data. It gave us real-time spectra and estimates of statistical errors.

1.4. Annual Effective Dose Calculation

The annual effective dose (AED) due to radon inhalation from domestic water use was calculated following the UNSCEAR (2000) and WHO (2008) recommendations, using the equation:

$$H_{inh}(mSv/y) = C_{Rn} \times F \times T \times D$$

Where C_{Rn} is “ concentration of radon in water (Bq/L)”, F is “equilibrium factor (0.4)”, T is “exposure time (7000 h/y)”, and D is “dose conversion factor (9×10^{-6} mSv/Bq.h/m^3)”.

Results and Discussion

1.5.Radon Concentrations in Potable Water

The average radon concentration across all samples was 10.30 Bq/L, with a range of 0.29 to 33.01 Bq/L. The Al-Hussein neighbourhood had the highest concentration, while the Al-Ain area had the lowest. The differences in radon levels across space were due to differences in geology, soil texture, and the age of the water infrastructure.

The observed range is much lower than the World Health Organization's [12] limit of 100 Bq/L and is similar to measurements from similar studies in Iraq and nearby countries. For example, Kirkuk (mean 18 Bq/L) [11], Basra (mean 12 Bq/L) [13], and Iran (mean 9 Bq/L) [14]. In older areas like Al-Hussein, slightly higher levels of radon may be due to leaky underground pipes that let soil-gas in or high levels of natural uranium in the local sediments [15]. Also, poorly ventilated homes and the presence of basements (saradeeb) may make radon levels rise inside when water is used.

1.6.Annual Effective Dose Assessment

The annual effective dose (AED) that was calculated ranged from 0.000328 to 0.07587 mSv/y, with a mean of 0.0074 mSv/y. WHO (2008) and the European Commission Directive 2013/51/Euratom set a limit of 0.1 mSv/y, which is ten times higher than these numbers. So, the risk of radiation from radon in Al-Khidhir's drinking water is very low.

Italy (0.006 mSv/y) [7], India (0.009 mSv/y) [4], and Egypt (0.007 mSv/y) [16] all reported similar low doses. Even though the exposure is low, long-term effects could be bad for health, especially for kids and people who live in homes with poor ventilation.

1.7.Environmental and Health Implications

Even though the current levels are safe, it is still advisable to monitor them because new construction, geological changes, and water pipe corrosion can all alter the way radon travels. Campaigns to raise public awareness should encourage routine ventilation and water system inspections.

Inhaling radon exposes the body to alpha radiation from the inside, which can hurt lung tissue. According to epidemiological models, a 100 Bq/m^3 rise in indoor radon levels raises the risk of lung cancer by about 16% [17]. So, keeping radon levels in water low is very important for protecting the health of the community in the long term.

Conclusions

The current study evaluated radon levels and yearly effective doses in drinking water from the Al-Khidhir District, Al-Muthanna Governorate, Iraq. The results show that the measured radon levels (0.29–33.01 Bq/L) and the annual effective doses (0.000328–0.07587 mSv/y) are both well below the levels that international organisations say are safe. The differences seen between neighbourhoods are mostly due to geological and infrastructure factors.

Even though the current radiological risk is very low, it is still a good idea to keep an eye on things and improve how water is managed to keep people safe in the long term. This baseline study is an important reference for future environmental monitoring and health assessments of radiation in southern Iraq.

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