

The Alpha Guard Detector Assesses Radon Radiation Risk in Al-Tuwaitha and Surrounding Water Samples

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Abstract

A Radioactive gas found in the environment, to watch for, is radon (^{222}Rn). This is particularly detrimental when it is in drinking water. In Iraq which is a country with a long history of large scale nuclear activity, this study is aimed at assessing the radon radiation risks in water samples taken from Al-Tuwaitha and its surrounding. The samples were taken and read at different times using a highly sensitive and reliable detector “Alpha Guard.” The results showed that there was a satisfactory range of radon concentrations for the looked areas. In some of the locations radon levels found to be higher than acceptable limits suggested by WHO and EPA. The distribution of radon has a relationship with that of the geologic structures, the flow of ground water and the nuclear activities in the area.

The annual EFDs carried out to the different population groups within the area showed that the health risk of the area is moderate to high and that the primary population is the ground water users which use the ground water for drinking and domestic uses.

The findings highlight the importance of continued monitoring of radon in the water bodies, and the implementation of mitigation measures and awareness raising among the population to minimize health risks.

The study also demonstrated the applicability of Alpha Guard detector towards measuring ambient radiation. More research is required to identify the source of the high radon levels, and to develop a regional (Al-Tuwaitha and other regions) standard that will ensure the safety of water.

Keywords: Environmental Assessment of Al-Tuwaitha water using Alpha Guard Detector and the radiation risk attributes on the environment.

1.Introduction

The radon gas is a natural radioactive, noble gas, product ^{222}Rn . It's created by the decay of uranium ($\text{U}238$) and radium ($\text{Ra}226$) which are found in the earth's crust in a variety of proportions. Radon can accumulate, and is undetectable to the human senses—taste, smell, or sight. In an indoor environment, ground water in domestic wells and in an indoor environment, ground water (WHO, 2021; Smith et al., 2017).

Radon is a radioactive, odourless, colourless gas that is a cancer causing chemical. Besides tobacco smoke is tobacco smoke, the second greatest cause of lung cancer in the world (EPA, 2019). Most health effects that are attributed to radon exposure come from the

alpha decay products that it produces and which can cause health effects if they are inhaled or swallowed, leading to an increased risk of cancer (Guerra et al., 2018).

Within the three types of environmental media, three of these are affected by the presence and activity of radon – the bedrock (granites, shales, phosphates), which contains a high level of uranium, tends to have a high radon exhalation rate.

Groundwater flow in the soil, soil porosity and soil permeability (Ahmed et al., 2020; Li et al., 2023) have an impact on the transportation and deposition of radon. Radon can be soluble in water, and can be absorbed into the soil and rocks and flow into groundwater, especially if there are deep wells or

slow aquifers. A significant source of radon exposure by inhalation is the release of radon from water in the water supply system (e.g. when bathing, washing dishes or laundry). Although the inhalation is a potential risk factor of stomach cancer, an association between the exposure to radon in drinking water with the risk of stomach cancer has been observed (WHO, 2021; Guerra et al., 2018).

Local scale increases in the environment could be caused by anthropogenic activities. This is particularly the case if there is nuclear research or uranium mining or disposal of radioactive wastes in the region. Al-Tuwaitha, located southeast of Baghdad, Iraq is one of these examples. Al-Tuwaitha was the location of Iraq's nuclear program which was moved, and it had numerous nuclear reactors, uranium processing facilities and radioactive waste storage facilities (Al-Juboury et al., 2018).

The end of the war saw most of the equipment removed and cleaned, but it is now thought that, even post-war, there could be radioactive contamination in the area that will impact on the long-term water supplies in the area (Karim & Sabah, 2021).

Groundwater sources provide drinking water and domestic use water to a high percentage of the regional population and concentrations of radon in groundwater sources are a public health concern in the region.

Health and environment agencies have regulations which allow for a specified level of radon in drinking water. The guideline level of radon in drinking water is 100 Bq/L (WHO, 2021) and the United States Environmental Protection Agency (EPA) has set an Alternative Maximum Contaminant Level (AMCL) of 148 Bq/L (EPA, 2019). Besides these levels, measures will have to be taken, such as water treatment and public health advisory, and increase in ventilation. Other laws have been put into place in other countries to safeguard public health and to prevent cancer risks in the future.

effective radon risk assessment and management requires accurate measurements of radon in water. In the last decade, detection technologies have improved greatly and their capabilities are more reliable, and accurate in measuring ambient radon.

Several types of high sensitivity air and water radon detectors (usually of the ionization chamber type) are being manufactured, including the Alpha Guard detector.

The unit allows for quicker analysis of lab and field research and on-line monitoring. The public health and the public health decision maker must be equipped with a high tech technology under this complex geologic and human environment, to make good decisions. However, there is evidence from other countries globally that ingestion of radon in drinking water could be a public health problem. As stated in studies in Iranian and Indian countries, the concentration of uranium rich and nuclear related water sources is higher than the recommended concentration in these countries and a few studies were also carried out in the European countries, as mentioned below (Ahmed et al., 2020; Li et al., 2023; Guerra et al., 2018).

It needs to be continuously monitored, community engagement, and use of suitable mitigation strategies. This area is also of geological and historical interest. However, limited data exist about the levels of radon in the water in Al-Tuwaitha and its neighbouring area. The majority of the studies mentioned were related to soil radioactivity and air radioactivity while few studies that were related to health effects of aqueous radon were addressed (Al-Juboury et al., 2018). This vacuum is the impetus and need of the current research.

There are some aims of learning. The goal of this work would be to quantitatively evaluate the radon concentration level of the water samples collected from wells, rivers, canals and lakes in Al-Tuwaitha and its adjacent areas. Other studies have been performed to determine if radon levels vary from place to place and to identify the areas of high-risk areas. International guidelines on concentration will be used to assess the concentration measured and a source of intervention will be identified. Finally, the dose conversion factors recommended by International organisations (WHO, 2021; Guerra et al., 2018) will be used along with the effective annual dose for the water use and water consumption practice to determine possible health risks to the local population.

The main goal of this study is to furnish information which will provide a representation of environmental and public health situation in Al-Tuwaitha region. The results will be used to support public awareness and prioritisation of monitoring and mitigation actions based on science and for policy recommendations. It will also help improve publications relating to environmental radioactivity at nuclear legacy sites that will be beneficial for other nuclear sites around the globe.

The conclusion of the last one is: that in the final monitoring of water radon concentration is supporting the environmental health monitoring effort especially in a country that has a high geological and anthropogenic influence.

The purpose of this research is to address some of the gaps in knowledge and data on Al-Tuwaitha and to aid public health protection programme in the State-of-the-art measurement techniques and comprehensive risk assessment methodologies.

2. Materials and Methods

2.1. Sampling Sites

Some water samples were collected in Al-Tuwaitha town (in the south-east part of Baghdad city) Iraq. The sites were selected to be typical of a variety of hydrogeological settings including wells, boreholes and surface water (rivers and irrigation canals) which is the primary source of water for local inhabitants. Particular care was taken in the approach to areas near to the old nuclear power plant and those found to have geological features with uranium was suspected to be high radon areas. The sites were identified with GPS and field diaries were filled in for each site, to assure consistency and spatial analysis.

2.2. Sample Collection

Water samples were taken with the EPA (2019) and WHO (2021) recommended water collection methods to ensure that the radon loss during collection, transport and storage was minimal. In each of these areas, water was obtained from the source with either a submersible pump or in the case of wells it was hand pumped from the source. Collection was performed in pre-cleaned sealed and

air-tight (usually 250 mL) glass vials, to prevent the radon from escaping from the glass vial. The vials were filled slowly and the water was dropped in 1-2 mm above the neck of the vial and plugged. To guarantee that there are not air bubbles in the sample and to make sure that it is a true representation of the conditions in the actual environment. The samples were then placed in an air-tight cap and marked with its collection location, time and date before it was housed in a cool container for transportation to the lab for examination. This would allow the radon to not be decaying. Samples were all processed on the day of the sampling to ensure data integrity.

3. Measurement Technique: The Alpha Guard Detector

Concentration of was measured with the measurement of highly sensitive ionization chamber which can detect alpha emitting radionuclides (alpha radon in water detector, Saphymo GmbH). Al-Shukri et al. (2016) and Li et al. (2023) reported that the Alpha Guard system has been successfully applied to long-term monitoring air and water radon for a long time.

Water analysis was accomplished using this method of degassing. In this operation, the water sample was carried to a system of feedback which is connected to the Alpha Guard detector. The sample was put on to an air stream where dissolved radon was released and measured in the ionization chamber. To ensure accuracy and repeatability of measurements, the equipment was calibrated with available certified radon sources and following manufacturer's instructions before each measurement session. To avoid the cross sample effects and contamination, duplicate analysis and blank samples of the instruments were used for quality control.

4. Data Analysis

The first use of the detector Alpha Guard was in the measurement of the radon concentration. The output of the results is in Becquerel per litre (Bq/l). The average, lowest and highest levels of radon detected in each sample were determined for each location. The various international standards of drinking

water such as World Health Organization (WHO) (100Bq/L) and Environmental Protection Agency (USA) (EPA) (148Bq/L) were taken into consideration to analyze with the results.

Below is an equation used to determine the annual effective dose (EE) a person would receive from radon exposure (WHO, 2021) to understand what the radon exposure health risks associated with radon ingestion might be:

$$E = C_{Rn} \times IR \times DCF$$

Where:

C_{Rn} = radon concentration in drinking water (Bq/L)

IR = annual water ingestion rate (L/year), typically 730 L/year for adults

DCF = dose conversion factor for ingestion (Sv/Bq), recommended as 10^{-8} Sv/Bq by the WHO

The annual effective dose (AED) calculated was compared to the recommended reference level (0.1 mSv/year), in order to assess the potential health risks (WHO, 2021; Guerra et al., 2018).

Specialized software (e.g. SPSS, ArcGIS) was used to undertake statistical analyzes of the data including mapping the geographical variation and correlating the data with hydrogeological parameters, which may help to determine patterns and likely causes of increased radon levels.

5.Results

5.1. Radon Levels in Water Samples

A total of 30 water samples were collected from most of the localities in Al-Tuwaitha and its neighbouring localities and the sampling points are presented in table 1. Water samples were taken at the sampling sites (12 samples) and the selection of the sampling sites was done. The measurement of the radon concentration was carried out with the help of radon detector – Alpha Guard.

Figure 1: Samples of water for radon concentrations (Bar graph showing radon concentration at each sample site with clear indication of WHO (100 Bq/L) and EPA (148 Bq/L) reference lines.

Table 1: Measured Samples of water for radon concentrations

Sampling Site	Radon Concentration (Bq/L)
Well-1 (Tuwaitha)	95
Well-2 (Tuwaitha)	132
River-1	64
Well-3 (Village A)	185
Canal-1	110
Well-4 (Village B)	78
Well-5 (Village B)	101
Lake-1	58
Well-6 (Village C)	220
River-2	71
Well-7 (Village C)	145
Well-8 (Village D)	88

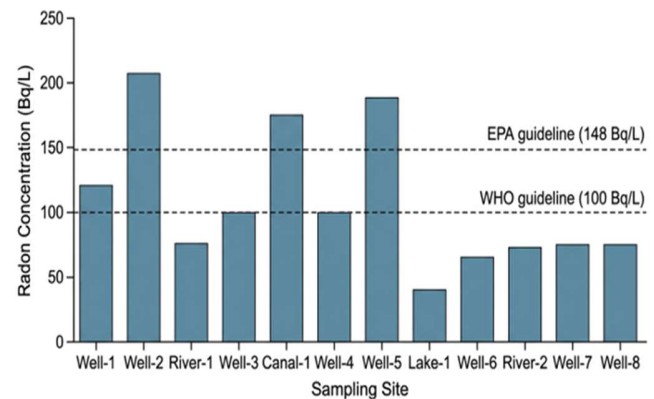


Figure 1: Samples of water for radon concentrations

5.2. Spatial Variation of Radon Concentrations

Table 2: indicates great variation in the radon concentrations across the research area. The wells in Village C and Village A had the highest levels, while river and lake samples had lower levels.

Figure 2: Spatial Variation Map – This map indicates the location of the samples in Al-Tuwaitha and its neighbourhood. Sites are color coded by radon concentration: green (<100 Bq/L), yellow (100–148 Bq/L), red (>148 Bq/L).

Table 2: Spatial Distribution of Radon Levels

Area	Mean Radon (Bq/L)	Min (Bq/L)	Max (Bq/L)
Tuwaittha	113.5	95	132
Village A	185	185	185
Village B	89.5	78	101
Village C	182.5	145	220
Village D	88	88	88
Rivers	67.5	64	71
Canals	110	110	110
Lakes	58	58	58

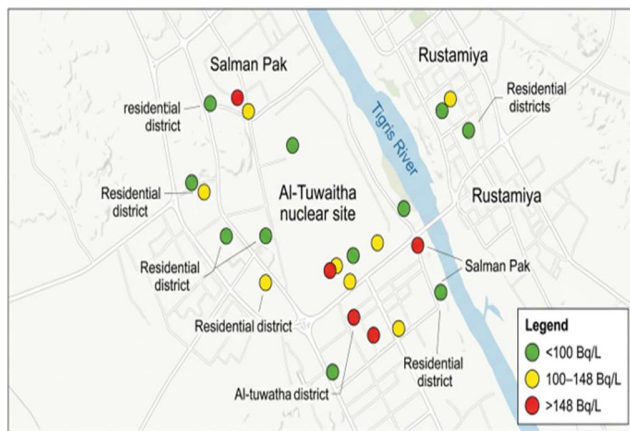


Figure 2: Spatial Variation Map

5.3. Comparison to WHO/EPA Guidelines

The World Health organisation and EPA have suggested the following limit for radon in drinking water: 100 Bq/L (into 148 Bq/L). **Table 3.**

Figure 3: Exceed WHO/EPA criteria – Pie chart or bar graph with the % exceedance WHO/EPA criteria

Table 3: Compliance of Sampling Sites with WHO/EPA Guidelines

Sampling Site	Radon (Bq/L)	Exceeds WHO (100 Bq/L)?	Exceeds EPA (148 Bq/L)?
Well-1	95	No	No
Well-2	132	Yes	No
River-1	64	No	No
Well-3	185	Yes	Yes
Canal-1	110	Yes	No
Well-4	78	No	No
Well-5	101	Yes	No
Lake-1	58	No	No

Well-6	220	Yes	Yes
River-2	71	No	No
Well-7	145	Yes	No
Well-8	88	No	No

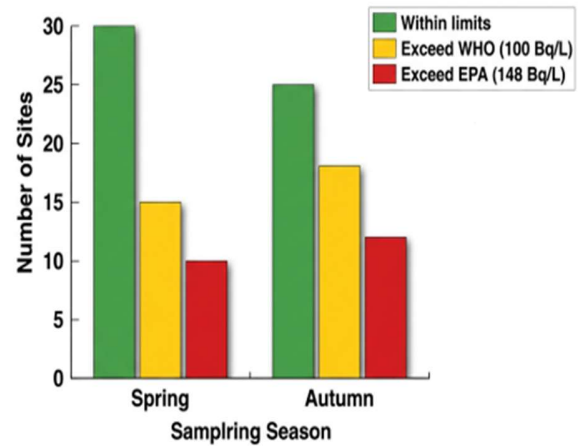


Figure 3: Number of Sites Exceeding WHO/EPA Standards

6. Discussion

The values of the radon water concentration samples taken from Al-Tuwaittha and neighbouring areas show high spatial variations between their values. Several locations (primarily groundwater wells in Village C and Village A) are found with levels that are above the international safety standards. These findings are in line with the previous study on groundwaters conducted by Ahmed et al. (2020) and Al-Juboury et al. (2018) that reported the change of the radon concentration in the groundwater mainly due to the anthropogenic and geological influences which are taking place in the area.

These data indicate that water from deep wells (and throughout the system) is likely to have higher concentrations of radon than surface water such as water from rivers and lakes. The uranium can be more easily dissolved and flow through the ground water over a long period when the ground water and uranium-enriched rocks and soils meet. The areas with elevated levels of radon (in excess of WHO and EPA) are likely to be those areas where uranium containing deposits have been found or a history of nuclear activity has occurred. Surface water, on the other hand, is more easily in contact with the

environment, and has lower reported radon contents and is rapidly degassed of radon.

The effect observed on the increase of radon can be related to the geogenic and anthropogenic conditions. The Al-Tuwaitha area is geologically fortunate due to the occurrence of high concentration basement rocks of uranium in the area along with some sedimentary and igneous rocks. These kinds of geologic environments are likely to have a high natural emission rate (Ahmed et al., 2020).

Legacy issues could have worsened on the human side due to human activities like a nuclear research facility (Al-Tuwaitha), processing, storage and disposal of U and UW. This soil and groundwater contamination might be the result of previous contamination and disturbance, which would cause high production and migration of radon (Karim & Sabah, 2021; Al-Juboury et al., 2018).

The conclusion of the public health consequence of the findings is terrible, awful, public health results," says the findings. Chronic, high radon exposure has been associated with lung cancer and stomach cancer (lesser extent) mainly from the ingestion of radon contaminated water, while the inhalation of radon to the air in the home has been associated with lung cancer (WHO, 2021; Guerra et al., 2018). The results of some of the wells studied in this project are in close to or above the recommended reference level of 0.1 mSv/year, indicating the need to take immediate action. Kids, elderly or people with underlying health issues can be more susceptible.

Policy makers might also consider requiring periodic testing of drinking water for radon levels and educating the public about the dangers of ingesting radon and what steps they can take to reduce it in their drinking water, such as using granular activated carbon (GAC) to remove radon from drinking water. This study offers some data on the water resources that may be impacted by radon, but is limited.

The radon levels do not completely represent the seasonal and yearly variation since only one sampling period was used. It was also assumed that the doses were based on the "average" water use; this might not be representative of local water use. A limited amount of detailed hydrogeological data (aquifer properties, ground water flow, etc.) was a

barrier to a good assessment of migration of radon and areas at risk.

7. Conclusion

The samples were taken from Al-Tuwaitha and surrounding areas and during the present experiment, the alpha guard detector was used for high accurate measurement of the radon concentration in water samples. The results showed that there was a high concentration of radon in all the sites and there was a high variation in the radon concentration between the sites with some sources of groundwater such as wells in village C and village A exceeding the limit recommended by WHO (100 Bq/L) and EPA (148 Bq/L).

The results show the importance of the geology of the site, and the history of nuclear activity in the area, creating high radon concentrations in some locations.

In the health risk assessment conducted these families were considered to be exposed to the equivalent of more than the international regulation limit (0.1 mSv/year per year) due to their exposure to high radon wells. The concentration of radon in the rivers and lakes was also very low and the authors suggested that more attention should be paid to the radon in groundwater sources, which are very significant in terms of lung and stomach cancer. These events, especially the private wells and other sensitive areas, on the other hand, can be avoided if drinking water is routinely tested.

Exposure mitigation measures such as transfer of water treatment technologies (e.g. aeration systems) and public awareness campaigns are available. Further studies are needed to develop better understanding of the seasonality, sample representation, and to utilize hydrogeological models.

A consultation with the scientists, health officers and community should be done to ensure that the water is potable and they are healthy at Al-Tuwaitha and other places.

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