زانکۆی سەلاحەدین - هەولێر

Salahaddin University-Erbil

Research Project Title

Tap Water Radon ^{222}Rn Activity Concentration Measurements at Salahaddin University Students' Accommodations.

Research Project

Submitted to the Department of Physics in partial fulfillment of the requirements for the degree of BSc. in Physics

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APRIL – 2023

بِسْمِ اللهِ الرَّحْمنِ الرَّحِيمِ

قَالُواْ سُبْحَانَكَ لاَ عِلْمَ لَنَا إِلاَّ مَا عَلَّمْتَنَا إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ

صدق الله العظيم

سورة البقرة الاية32

Supervisor Certificate

This research project has been written under my supervision and has been submitted for the award of the degree of BSc. in (Physics).

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I confirm that all requirements have been completed.

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Date / /

This project is dedicated to:

Allah Almighty, my Creator and my Master,

My great teacher and messenger, Mohammed (May Allah bless and grant him), who taught us the purpose of life,

My homeland Kurdistan, the warmest womb,

The Salahadin University, my second magnificent home;

My great parents, who never stop giving of themselves in countless ways,

My beloved brothers and sisters;

To all my family, the symbol of love and giving,

My friends who encourage and support me,

All the people in my life who touch my heart

ACKNOWLEDGEMENTS

First and foremost, I must acknowledge my limitless thanks to Allah, the Ever-Magnificent, the Ever-Thankful, for His help and blessing. I deeply thank the physics department and Salahaddin University for allowing us to complete this work. I am very appreciative of my colleagues in the physics department. I am grateful to some people, who worked hard with me from the beginning till the completion of the present research, particularly my supervisor **M. GOVAR MUAYAD ABDULLAH,** who has always been bringing abrin gusto to the study. I want to take this opportunity to say warm thanks to all my beloved friends, who have been so supportive of bowling my thesis. I also would like to express my wholehearted thanks to my family for their generous support throughout my life, particularly while pursuing the thesis. Last but not least, my deepest everyone who made his thesis real.

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Abstract

Water is essential to our environment; increased pollution, human activity, and a high concentration of naturally occurring radioactive elements can all harm its quality. Drinking water quality should be monitored regularly using precise scientific equipment. This research project aims to collect nineteen tap water samples from all Salahaddin University-Erbil students' accommodations, including those in the College of Education/Shaqlawa district. The RAD7-H2O solid state detector was used during this study to measure the radon activity concentration; the maximum value of radon activity concentration is from Shawkat Block B with 2.93± 0.04 Bq/L. The annual effective dosage of radon gas ingestion and inhalation was determined from water tap samples with a maximum value of (5.13 ± 0.07 μSv/y and 7.39 ± 0.117.39 ± 0.11 μSv/y) respectively. It is important to mention that all tap water source samples come from well water. As a result, all sample radon activity concentrations are safe to use and are below the recommended contamination level. According to the WHO and the Environmental Protection Agency (US-EPA), the recommended contamination threshold for radon activity in water is 11.1Bq/L; radon activity in water samples close to or above this range is hazardous to the student's life in their accommodation.

CHAPTER ONE

INTRODUCTION

1.1 Naturel Radioactivity

All human environments, including soil, water, food, and air, contain naturally occurring radioactive nuclides, and our bodies have naturally radioactive materials. The essential mechanism responsible for releasing radioactive nuclides into the soil, the primary source of natural background radiation, is weathering the earth's crust. Furthermore, radon is a naturally occurring radioactive inert gas with a thematic number of 86 (Azeez et al., 2019). There are "over twenty-six" radon isotopes, but the most important isotopes in terms of radiological significance are ^{222}Rn (radon) and ^{220}Rn (thoron) (Mustapha et al., 2002). Humans are exposed to radon in two ways: through inhalation or ingestion. Radon can enter our homes' indoor environments through cracks and openings in the floor and walls. Groundwater is another source of radon delivery to the indoor environment. Radon and its short-lived decay products, such as ^{218}Po, ^{214}Po, and ^{214}Bi, among others, have been identified as the major sources of public exposure from natural radioactivity, accounting for nearly 50% of the global mean effective dose to the community. Two of ^{222}Rn's emitting daughters, ^{218}Po and ^{214}Po, contribute more than 90% of the total radiation dose received from radon exposure. When radon decays after inhalation or ingestion, it releases energy that can damage DNA in sensitive organ cells such as the lungs and stomach(Khattak et al., 2011). Radon has been identified as the second leading cause of lung cancer after cigarette smoking, accounting for 21,000 lung cancer deaths in the United States each year. Epidemiological studies have revealed a clear link between high radon concentrations and the incidence of lung cancer(Akinnagbe et al., 2018).

1.2 Definition of Ra^{222}

1.2.a Radon Characteristics

Radon is a naturally occurring, chemically inert, radioactive gas that emits alpha particles. Natural radioactive decay produces this colorless, tasteless, and odorless gas. of uranium, radium, and thorium found in trace amounts throughout the Earth's crust's rocks and soils Radon (^{222}Rn), Thoron (^{220}Rn) and action are the three naturally occurring isotopes of radon (^{219}Rn). Radon (^{222}Rn), the most stable isotope, is produced by the decay of ^{238}U and has a natural abundance of approximately 99.3% of total uranium within the Earth's crust. Thoron (^{220}Rn) is formed in nature due to the decay of ^{232}Th; Radon’s most stable and abundant isotope is ^{222}Rn, which has a half-life of 3.8 days. It decays by emitting a 5.49 meV particle and producing radioactive daughters. Radon is found in nature in the air and is soluble in water in all water sources on Earth, including lakes, rivers, oceans, underground waters, springs, and even atmospheric precipitation (Khattak et al., 2011).

1.2.b Chemical Components and Properties

Friedrich Ernest Dorn discovered radon, an atomic number 86 chemical element, in 1900 while researching radium's decay process. From ^{193}Rn to ^{228}Rn, radon has 39 recognized isotopes. Since $radon^{222}$ is the most stable of all the isotopes that result from the radioactive decay chain of ^{226}Ra and ^{238}U, it was the main subject of this investigation. With a half-life of 3.82 days, $radon^{222}$ is a radioactive noble gas that is colorless, odorless, and tasteless. It is produced naturally when thorium and uranium undergo indirect decay. The presence of uranium in the earth's crust means that ^{226}Ra and ^{222}Rn can be found in practically all rocks, soil, and even water(Somashekar and Ravikumar, 2010).

1.3 Radon in environmental

1.3. a Radon in Air

This section provides a framework for the selected radon monitor devices used for radon and its decay product measurements, as well as the development of procedures to ensure the accuracy of radon measurements in mine air and water. Some methods have been developed and improved to produce more accurate and reliable results. Radon in the air measurement can be divided into past forms of active monitoring. In terms of measurement conditions, each method has advantages and disadvantages. Passive radon monitoring is an integrated measurement commonly referred to as a long-term measurement; in this method, a radon detector is placed on the measurement site for several days to several years). On the other hand, active radon monitoring is a real-time measurement method for short-time measurement. In this method, an active radon monitor instrument measures radon concentrations over time (from 1 minute to several hours) (SHAHROKHI, 2018).

1.3.b Radon in Soil

Radionuclides in soil and rock are not evenly distributed; hence natural radioactivity depends primarily on the geological formations and geographical conditions, giving rise to the various levels of radionuclides in such media. Mining and other industrial activities result in large volumes of materials containing naturally occurring radioactive materials Mining and processing of the ores generate waste that is richer in radionuclides and, as such, called technologically enhanced naturally occurring radioactive materials. The natural background radiation, which may increase significantly, is of great concern to radiation protection regulatory bodies. Formerly used for large-scale mining, abandoned mine sites are now used for small-scale artisanal mining (Olise et al., 2016).

1.3 c. Radon in water

Identifying the drained water underground as a radon entrance point into the atmosphere is possible. Water passing through soil and rocks can occasionally dissolve large amounts of radon, whiexhalingrough walls or the earth. Due to the significance of the Radon's pathways into the mine, a long (two and a half years, every month) dissolved radon concentration monitoring in the water was conducted to not only monitor the behavior of radon concentration in different seasons but also to estimate the contribution of the dissolved radon in the water to the radon concentration in the mine air(SHAHROKHI, 2018).

1.4 Health effects of radon

Exposure to radon and its byproducts may increase the risk of cancer. Radon inhalation is thought to be the second leading cause of lung cancer in the United States and possibly worldwide. Inhalation of the ^{222}Rn dissolved in and released from water for human consumption accounts for 89% of the estimated cancer risk, while radon in drinking water accounts for 11%. The ^{222}Rn can enter the home via well and river water, for example, when taking a shower or using water for household tasks. When radon and its radioactive decay products are absorbed into the bloodstream, sensitive cells in the stomach and other organs are exposed to its radiation(Oner et al., 2009). The main health hazards from radon in drinking water, according to USEPA (2010), are lung cancer from inhaling radon released from water used in the home and stomach cancer from consuming radon in drinking water. The alpha particles from radon's radioactive decay can interact with biological tissues when inhaled or ingested causiingestedamage. All across the world, evaluation studies of the radiation dosage from radon consumption and inhalation in drinking water are ongoing due to these and other factors. The understanding of the environmental factors that affect radon exposure is being improved by all of these investigations(Kurnaz and Çetiner, 2016).

1.5 Aim of the research

Drinking water quality should be monitored regularly using precise scientific equipment. This research project aims to collect nineteen tap water samples from all Salahaddin University-Erbil students' accommodations, including those in the College of Education/Shaqlawa district. By using the RAD7-H2O solid state detector to measure the radon activity concentration. As well as the annual effective dosage of radon gas ingestion and inhalation can be determine from tap water samples consumed by residents of Salahaddin University-Erbil students’ accommodations.

CHAPTER TWO

Material and Method

2.1 Geological information of study area

Erbil is one of the governorates of the Kurdistan region. The location of Erbil governorate is between latitudes 35˚30´ and 37˚15 N and longitudes 43˚22´ and 45˚05´ E. The Erbil border extends to Iran in the East and Turkey in the North. The city of Erbil is the capital of the Kurdistan region (Hameed, 2013). Erbil province is the capital of Kurdistan of, Iraq. The ad is situated in the northeast of Rag. Erbil covers about 8170 source kilometers. It is bounded northwest by the Circater Zab River and southeast by the Lesser Zab River(Toma et al., 2013).

The governorate of Erbil is situated in the northern part of the Kurdistan Region of Iraq, with an elevation of 139 to 3607 m above sea level. The study covers about 14600 km; it is divided into seven districts (Erbil, Makmur, Koyasnjaq, Shaqlawa, Soran, Mergasur, and Choman). The number of inhabitants of the governorate is 2,162,509, according to the latest census in 2018. The area is characterized as semi-arid, the kind of BSs conferring to Koppen classification. The summer season is hot and dry, while the winters are cold and wet. Rainfall is inadequate for October and November, averaging 543 mm (Ibrahim et al., 2021).

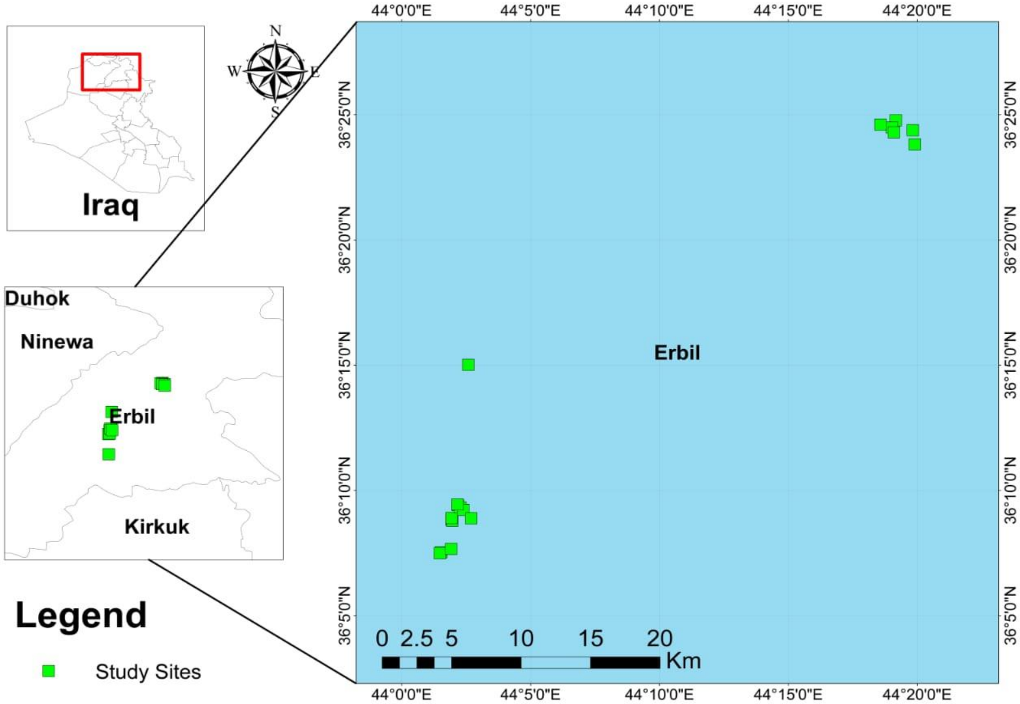

Fig 1. GIS locates spring water samples.

2.2 Experimental Procedure

2.2.1 Sample preparation

A total number of 19 water samples from Erbil and Shaqlawa students' accommodations were collected. I chose students' accommodations, whose water is continuously used for students' meals and bathing. The location of each spring was determined using a convenient global positioning framework and Arc-GIS program, as shown in Fig.1. Each sample was saved in a cool box before being exchanged to the research facility at the Laboratory of nuclear research in the Physics Department /College of Education/Salahaddin University- Erbil and kept at a room temperature of around 15 degrees Celsius for conservation. The RAD7 device operates on the energy of alpha particles emitted by radon and Thoron (Xinwei, 2006). The RAD-H2O system uses a closed-loop aeration design in which the air and water volumes are constant and independent of the low rate (Todorovic et al., 2012). The water samples were taken in 250 ml vials designed for the RAD-H2O system and provided by the manufacturer, and it was connected to the RAD-7. Also, the internal air pump of the radon monitor was used for re-circulating a closed air loop through the water sample, and the weather conditions during the testing period were reasonably consistent. The freshness of the water was ensured by pumping off an adequate amount of water for 30 min.

2.2.2 Radon detection device (RAD7)

Dredge Company's RAD7 is a radon-in-air monitor. The RAD H2O is an accessory for the RAD7 that measures radon in water with high accuracy over a wide range of concentrations, capable of obtaining a reading for radon concentration in water within an hour of taking the sample. The RAD H2O employs standard, pre-set protocols built into the RAD7, which provide a direct reading of the radon concentration in the water sample itself. The RAD7 detector can calculate the radon concentration in a water sample by multiplying the radon concentration in the air loop by a fixed conversion coefficient. The air loop volume, the model's importance, and the equilibrium radon distribution coefficient at room temperature was used to calculate a conversion coefficient of 4 for a 250 mL water sample vial. The method employs a closed-loop aeration design in which air and water volumes remain constant and independent of flow. The water sample must be collected carefully; it does not come into contact with the. In the RAD7 setup, a user can choose between two different protocols (Watt 40 and Watt 250), allowing him to calculate radon concentration in vials of two different sizes (40 or 250 mL) supplied with the equipment. In our case, we used vials with a capacity of 250 miles. When analyzing a sample to determine its radon concentration, an appropriate protocol was chosen each time in the setup. Extraction efficiency for a 40 mL sample vial is typically 99%, and 94% for a 250 mL sample vial. During a test, a sample bottle was connected to the RAD7. The radon-inbuilt monitor's internal air pump was used to re-circulate the air in a closed loop through the water sample, removing the dissolved radon from the water into the closed air loop. The air was continuously recirculated through the water to remove the dissolved radon until the RAD H2O system reached a state of equilibrium in about 5 minutes, after which no more radon could be recovered to the air loop from the water. A water test using the Watt 250 protocol takes about 30 minutes. At the start of a trial, the RAD7 inbuilt pump automatically starts running for 5 minutes, aerating the sample and delivering the degassed radon to the RAD7 measuring chamber. More than 94% of the available radon in the water is removed during the 5 minutes of aeration. After 5 minutes of operation, the pump shuts down automatically, and the system waits another 5 minutes. Following that, the system begins counting. After 5 minutes, the system generates a short-form report for a 5-minute cycle. The same happens 5 minutes later and again for two more five-minute periods. The RAD7 prints a summary at the end of the run (30 minutes after it begins).

It shows average radon concentration in four counted cycles of 5 minutes each, a bar chart of the four readings, and a cumulative spectrum. The radon concentration shown is the water concentration, which is calculated automatically by the RAD7(Khattak et al., 2011).   The Durridge RAD7 radon monitor is version 2.5f 991128, model 711, and serial # 01052. It is owned by the Department of Physics, University of Salahaddin-Erbil. For this purpose, a specific kit of accessories RAD-H2O has been used. This kit has a set of vials (bottles) of 250 mL, hoses for con-sections, diffusing aerator, and a small desiccant tube. Before making a measurement, the RAD7 must be clear of radon and dry. To achieve this, it should be purged for some time. To save the small drying tubes for the actual measurement, use the larger laboratory drying unit during the initial purging process. The activated charcoal filter was used to clean the air in the system before each size to reduce the background value (Ezzulddin and Mansour, 2020).

Fig 2. Radon detection device (RAD7)

Fig 3. Schematic representation of Radon on water concentration experimental setup.

2.2.3 Calculation

The radiation dose obtained from radon in drinking water can be divided into two parts to be specific (a) the annual effective dosage from radon ingested and (b) the annual effective dose measurements from radon breathed in. In case of ingestion, radon and its progenies show within the drinking water can give a radiation dose to the stomach. However, radon gas display within the drinking water can elude into the indoor discussion amid showering and other domestic uses. It can cause a critical increment within the hazard of lung cancer due to the radon breathed in. The compelling yearly measurements (μSv/y) due to ingestion of the drinking water were calculated by taking under consideration the activity concentration of radon (Bq/l), the dose conversion factor DCF (Sv/Bq) and the yearly water consumption (l/y) agreeing to condition 2.1(Ali et al., 2010).

$$AED_{ing}=CRn_W \times C_W \times DCF \qquad 2.1$$

Where CRn_W is the radon concentration in drinking water, C_W is the adult's annual water intake equal to (500) l/y, and DCF is equal to (3.5) Sv/Bq. The annual effective dose due to inhalation of the drinking water was calculated using equation 2.2 (Ezzulddin and Mansour, 2020).

$$AED_{inh} =CR_{nW} \times F \times O \times DCF \qquad 2.2$$

F is the equilibrium factor between radon and its progeny (0.4), O is the average indoor occupancy time per individual (7008 h. y^{-1}), and DCF is the dose conversion factor for radon exposure [9 nSv/ (Bq h m3)](Radiation, 2000).

CHAPTER THREE

Result and Discussion

3.1 Radon Activity Concentration

Radon activity concentration was determined for nineteen tap water samples collected from most Salahaddin University-Erbil accommodations, as reported in Table 1. The radon concentration varied from 2.93 ± 0.04 Bq/L in the Shawkat block B to 0.15 ± 0 in the Lenas, Mam Khidr, and Akar 4. The results exhibit that all tap water samples are safe and below the maximum contamination level (MCL); US-EPA has proposed it permitted radon concentration in water to be 11.1Bq\l (Radiation, 1982). The highest value of ^{222}Rn activity concentration was founded in water samples at the Shawkat block B location. In contrast, the lowest value of ^{222}Rn activity concentration blended in water samples from Lenas, Mam Khidr, and Akar 4 accommodations, as shown in Fig 4.

Table 1: ^{222}Rn activity concentration (Bq/L) of tap water samples in accommodations

Code of samples	Location	Longitude	Latitude	Radon Activity Concentration (Bq/L)
W1	Shawkat block A	44.025544	36.12552	2.61 ± 0.2
W2	Shawkat block B	44.026696	36.01251	2.93 ± 0.04
W3	Shawkat block C	44.024649	36.12492	2.09 ± 0.13
W4	18 Shubat Block A	44.03224	36.12492	0.44 ± 0.06
W5	18 Shubat block B	44.032717	36.14656	1.07 ± 0.02
W6	18 Shubat block C	44.032303	36.14837	0.47 ± 0.06
W7	18 Shubat canteen	44.032003	36.12776	1.65 ± 0.19
W8	Akar 1	44.036268	36.15691	0.51 ± 0.09
W9	Akar 2	44.037898	36.15539	0.22 ± 0.02
W10	Akar 3	44.03979	36.15369	0.37 ± 0.03
W11	Akar 4	44.036104	36.15737	0.15 ± 0
W12	Akar 5	44.043062	36.25023	0.36 ± 0.02
W13	Akar 6	44.044928	36.14815	0.58 ± 0.13
W14	Holiday	44.319524	36.41295	0.73 ± 0.15
W15	Mam abdullah	44.316989	36.40812	1.06 ± 0.25
W16	Mam khidr	44.309649	36.41008	0.15 ± 0
W17	Rozhi nwe	44.330526	36.40634	0.29 ± 0
W18	Yanai kuran	44.318251	36.405	0.88 ± 0.09
W19	Lenas	44.33176	36.39697	0.15 ± 0

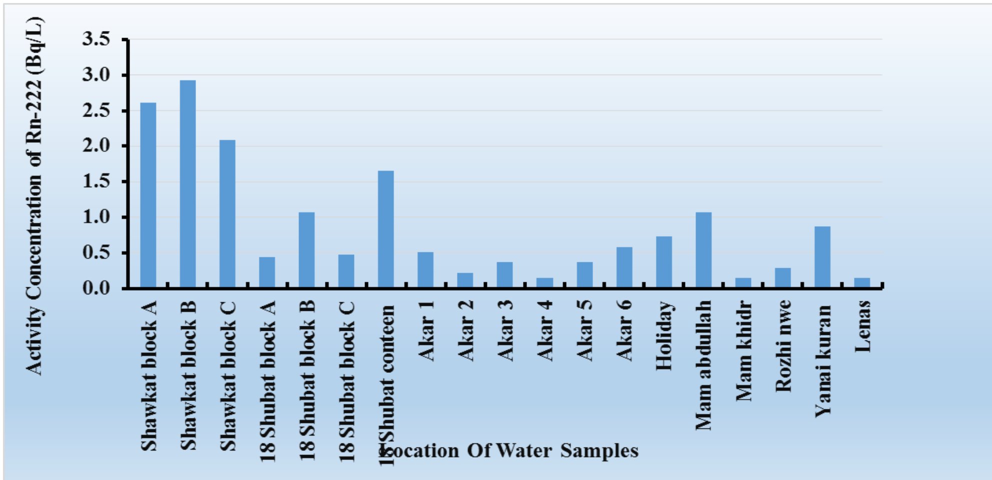

Fig 4. Radon activity concentration (in Bq/l) of tap water samples.

3.2 Annual Effective Dose Due to Ingestion and Inhalation

All of the dissolved radon is assumed to be absorbed by the stomach when calculating the absorbed dose from ingesting radon in drinking water. Some radon is lost to diffusion through the stomach wall before it can exit the body (Fonollosa et al., 2016). Because all students are adults. So, only adults have estimated annual effective doses from ingesting radon in tap water samples displayed in Table 2. The maximum value reported for water samples (W2) was (5.13 ± 0.07) µSv/y, and the minimum values found for water samples (W11, W16, and W19) was (0.26 ± 0) µSv/y as shown in Fig 5. As well as the annual effective doses from inhalation radon in tap water samples obtained in this study, as shown in Table 2. The maximum value was from (W2), and the lowest reported values were found at (W11, W16, and W19), as shown in Fig 6.

Table 2: The annual effective dose from ingestion and inhalation of ^{222}Rn in tap water samples.

Code of sample	location	Annual Effective Dose Due to ingestion of Radon gas by water (μSv/Year)	Annual Effective Dose Due to Inhalation of Radon Gas by Water in Homes (μSv/Year)
W1	Shawkat block	4.56 ± 0.35	6.57 ± 0.5
W2	Shawkat block B	5.13 ± 0.07	7.39 ± 0.11
W3	Shawkat block C	3.65 ± 0.23	5.26 ± 0.33
W4	18 Shubat Block A	0.77 ± 0.1	1.1 ± 0.15
W5	18 Shubat block B	1.87 ± 0.03	2.69 ± 0.04
W6	18 Shubat block C	0.83 ± 0.11	1.19 ± 0.16
W7	18 Shubat canteen	2.89 ± 0.33	4.16 ± 0.47
W8	Akar 1	0.89 ± 0.15	1.29 ± 0.22
W9	Akar 2	0.38 ± 0.04	0.55 ± 0.05
W10	Akar 3	0.64 ± 0.05	0.92 ± 0.07
W11	Akar 4	0.26 ± 0	0.37 ± 0
W12	Akar 5	0.64 ± 0.04	0.92 ± 0.05
W13	Akar 6	1.02 ± 0.22	1.47 ± 0.32
W14	Holiday	1.28 ± 0.26	1.84 ± 0.38
W15	Mam abdullah	1.86 ± 0.43	2.68 ± 0.62
W16	Mam khidr	0.26 ± 0	0.37 ± 0
W17	Rozhi nwe	0.51 ± 0	0.74 ± 0
W18	Yanai kuran	1.53 ± 0.16	2.21 ± 0.23
W19	Lenas	0.26 ± 0	0.37 ± 0

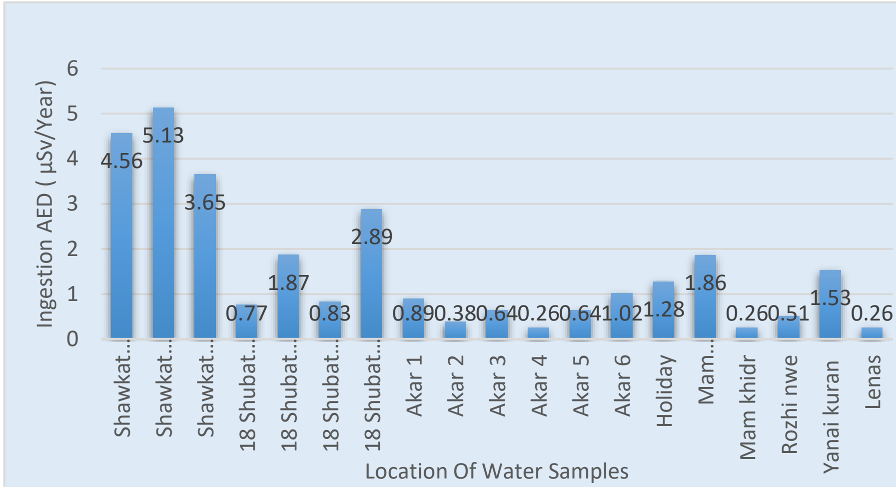

Fig 5. Annual effective dose due to ingestion of radon gas by water.

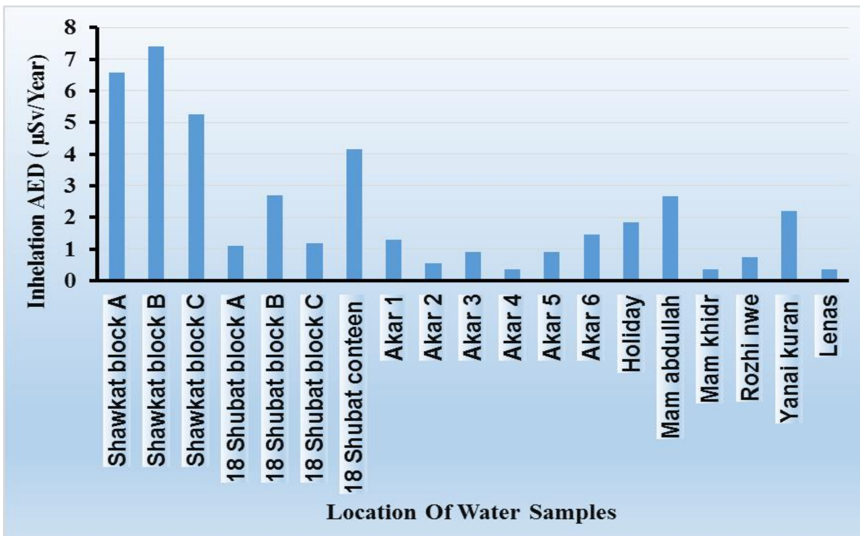

Fig 6. Annual effective dose due to radon Inhalation gas by water

3.3 Total Annual Effective Dose Due to Ingestion and Inhalation

Table 3 shows the calculation of the total annual effective dosages due to ingestion and inhalation of radon gas in tap water tested for adult students. The values between the lowest and highest tap water annual effective doses are Shawkat block B with (12.52 µSv/y) and (Akar 4, Mam khidr and Lenas) with (0.87 µSv/y), as shown in Fig 7.

Table 3: Total Annual Effective Dose Due to Ingestion and Inhalation

Location	Total Annual Effective Dose Due to ingestion and inhalation of Radon gas by water (µSv/Year)
Shawkat block A	11.13 ± 0.85
Shawkat block B	12.52 ± 0.18
Shawkat block C	8.91 ± 0.56
18 Shubat Block A	1.87 ± 0.25
18 Shubat block B	4.56 ± 0.07
18 Shubat block C	2.02 ± 0.27
18 Shubat canteen	7.05 ± 0.8
Akar 1	2.18 ± 0.37
Akar 2	0.93 ± 0.09
Akar 3	1.56 ± 0.12
Akar 4	0.63 ± 0
Akar 5	1.56 ± 0.09
Akar 6	2.49 ± 0.54
Holiday	3.12 ± 0.64
Mam abdullah	4.54 ± 1.05
Mam khidr	0.63 ± 0
Rozhi new	1.25 ± 0
Yanai kuran	3.74 ± 0.39
Lenas	0.63 ± 0

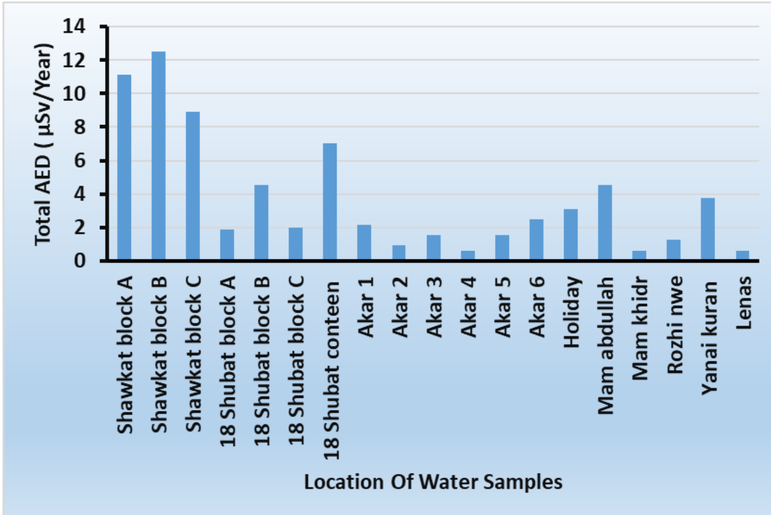

Fig 7. Total Annual effective dose due to ingestion and inhalation.

World Health Organization and EU Council recommended a 0.1 mSv/y annual Effective dose of drinking water to be safe (Organization, 2007). So, the total annual Effective dose from all the student accommodation tap water samples was below the permitted level, and all are within the safe limit.

CHAPTER FOUR

Conclusions

In this study, the radon concentration of nineteen samples of tap drinking water and the potential health risks that come with it were determined from Salahaddin University accommodations. Maximum sample concentrations of radon were lower than the USEPA action level, the 11.1 Bq/L contamination threshold established by the World Health Organization and the United States Environmental Protection Agency. The total annual effective doses of ^{222}Rn from drinking and bathing in all samples for adult students were below the WHO limit of $1 mSv.y^{-1}$ recommended by the WHO and the EU Council. As a result, all the tap water in the study area is safe for human consumption and shows no evidence of radon levels that would threaten human health.

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