زانـکۆی سەڵاحەدین-هەولێر

Salaheddin University-Erbil

Measurement of Radon Activity Concentration in Water Samples from Qasre Region Using RAD7 Radon Detector

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

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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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Date: 5 / 4 / 2023

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Date 5 / 4 / 2023

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 Salaheddin 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.

ACKNOWLEDGEMENS

Abstract

The Radon activity concentration has been measured in waters used for some villages in Qasre region in Erbil city from Iraqi Kurdistan region using RAD7 semi-conductor detector. The measured values of radon activity concentrations ranged from 0.15 to 4.3 Bq. L^{-1} with the mean value of 1.2 ± 0.46 Bq. L^{-1}. The values of Radon activity concentration in water samples under study were less than the recommended values of 11.1 Bq.L^{-1}.

The calculated annual effective doses from ingestion of radon with water and inhalation of this radionuclide escaping from water were values ranged from 0.5 to 7.53 $\mu Sv.y^{-1}$ and from 0 to 0.11 μ Sv. y^{-1}, respectively.

Therefore, it should be underlined that, generally, inhalation of the radon escaping from water which is a substantial part of the radiological hazard due to the presence of the natural radionuclides from the uranium and thorium series in the water.

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Chapter one

Introduction

1-1 Natural Radioactivity in Environment

Radon is a noble gas with the mass number of 222 and an atomic number of 86 in a periodic table (Stumper and Johnson, 1987). Radon is a radioactive element with a half-life of about 3.824 days; it's colorless, tasteless, odorless, chemically inert, and 7.5 times denser than air. It is naturally emitted from rocks and soil as a product of the decay of radium(^{226}Ra) in the ^{238}U decay chain from Earth's crust (Abojassim et al., 2015). When ^{226}Ra decay to ^{222}Rn in the soil, nearly 10% of the produced radon reaches the atmosphere (Vo Giannis and Nikolopoulos, 2015). The radon emanation depends mainly on ^{226}Ra content and mineral grain size, its transport in the earth governed by geophysical and geochemical parameters, while exhalation is controlled by hydro meteorological conditions. (Ismail, 2004, Abdullah et al., 2015). Radon is present in trace amount almost everywhere on earth being distributed in the soil, groundwater and in the lower levels of the atmosphere. Radon which is present everywhere on the earth surface reaches by different processes and accumulates in the houses and underground mines. Radon contributes more than 60 % of the total annual effective dose for the human body (Kad him and Malayali, 2014). The radiological importance of Radon (^{222}Rn) cannot be overemphasized. ^{222}Rn is found in the ^{238}U decay chain and poses a direct health risk when present in high concentrations in water due to its solubility (Duggal, et al., 2013). Granite rocks are mostly rich in ^{238}U and consequently are responsible for ushering of the decay daughter radium (^{226}Ra) which in turn characterizes the associated groundwater (Szabo, et al., 2012). Natural radioactivity in drinking water causes internal human exposure caused by the decay of radionuclides taken into the body through ingestion and/or

inhalation indirectly when they are incorporated into the human food chain (Kasić ,et al).
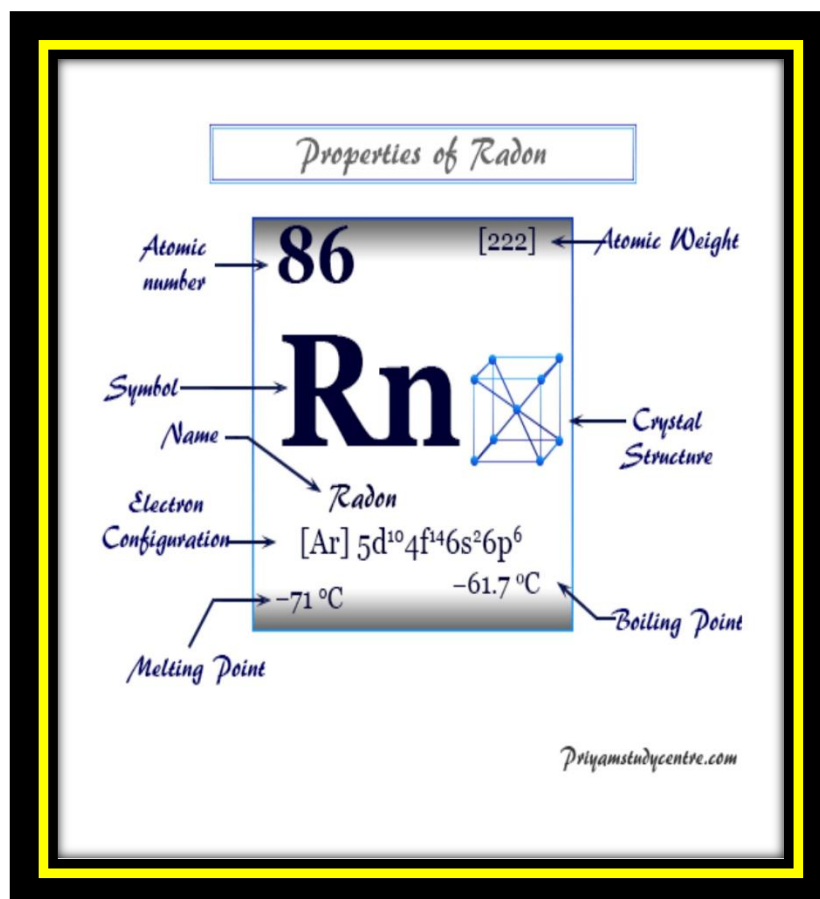
Figure 1-1: some properties of radon

1-2 Aim of this Research

Monitoring drinking water quality is an important aspect of public health studies, radon and radium estimations are one among the public health studies, as it describes the extent of population exposure to radiation as well as the influencing source water. While on the other hand, the objectives of this research are:

1- To determine the radon activity concentration measurements in well, spring, and river water samples collected from Qasre Region environment and to calculate the radiological risks derived from the radon concentrations.

2- To establish the distribution pattern of the radon activities measured in the area so as to certain the safety of the usage the water.

3- To find the annual effective dose due to ingestion and inhalation of radon gas and its progenies from drinking water samples.

Chapter two

Theory and Methodology

2-1 Source of Radon

2-1-1 Radon in Soil

Certain types of rock, including granites, dark shale, light-colored volcanic rocks, sedimentary rocks containing The main source of radon in the atmosphere as a minimum 80% is emanations phosphate and metamorphic rocks (Virk and Singh, 1993).

Radon is a gas; it has much greater mobility than uranium and radium, which are fixed in the solid matter in rocks and soils (Hararah, 2007). Certain rocks and soils that contain high levels of uranium also store natural deposits of radon, among which are Granite, shale and Phosphate (mineral), radon can more easily leave the rocks and soils by escaping from the soil that derived from rocks. These rocks contain several uranium, into fractures and openings in rocks and into the pore spaces between grains of soil (GARBA, 2012).

2-1-2 Radon in Water

Usually, ^{226}Ra and ^{222}Rn are not in radioactive equilibrium with each other in water, ^{226}Ra is rather insoluble element and the concentration of radon in water is larger than radium. The radionuclides in drinking water are members of three natural radioactive series (Nelson, Rachiele and Smith, 1983). Radon is identified as a public health concern when present in drinking water. The (WHO) suggests that radon causes up to 15% of lung cancers worldwide. In 2012, (EPA) proposed a Maximum Contaminant Level (MCL) 11.1Bq/l (about 300 pci/L) for radon in drinking water(USEPA , 2012).Water is the most important source of life and makes up 70 - 75% of total body weight. While 70% of the earth plant surface is

covered by water, only 0.3 % of the total water resources on earth are drinkable and suitable for daily use. Human race provides their water from surface water and ground water. Ground water is more radioactive than surface water since it passes through rock and soil formations, dissolves many compounds, minerals and radioactive substances (Duenas *et al.*, 1999). Radon concentrations in water depend much on source of radon emanation which may be as a result of natural processes, industrial or agricultural activities and increase in human activities in the area where the wells are located. As well as being ingested through drinking water, radon is also released from water when the temperature is increased, the pressure is decreased and when water is aerated (Garba *et al.*, 2008).Radon has a high solubility in water and solubility decrease with increasing temperature. There are two different sources of radon derivation in water: due to radioactivity decay of dissolved ^{226}Ra and direct release of radon from the mineral's matrix containing member of uranium decay series. Due to difference in mobilization from rock and water chemistry, usually ^{226}Ra and ^{222}Rn are not in radioactive equilibrium with each other in water, ^{226}Ra is
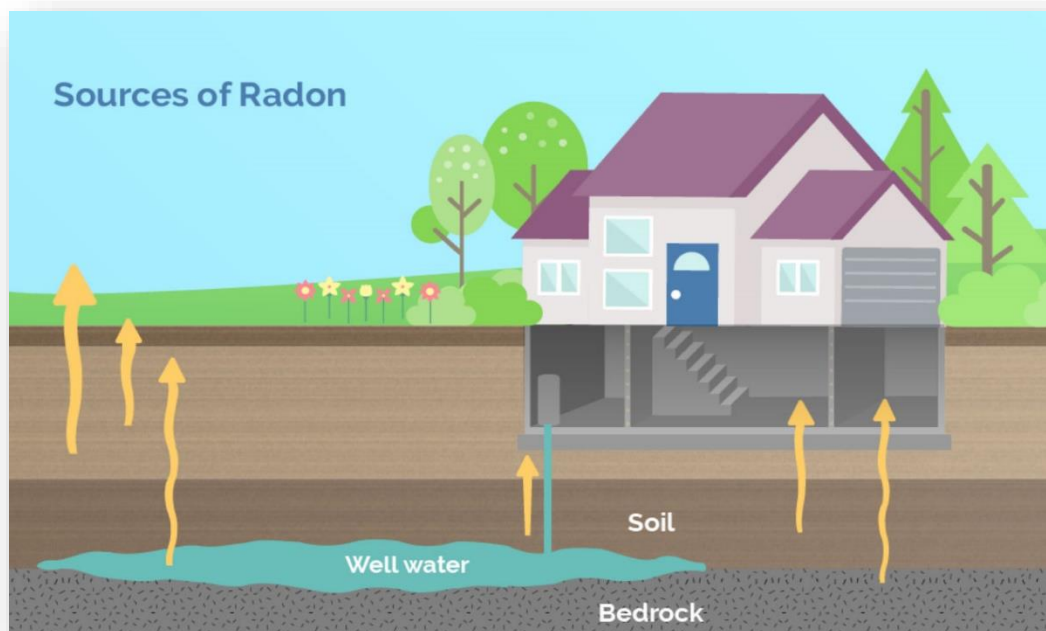
Figure 2-1: Ionizing radiation exposure to the public
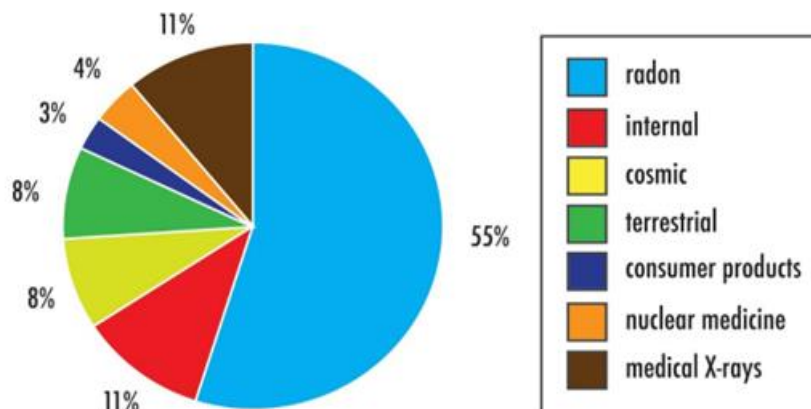
Figure 2-**2**: Radon sources

2-2 Radon and radium health hazards

Some of the radon that you swallow with drinking water passes through the walls of your stomach and intestine. After radon enters your blood stream most (greater than 90%) of the radon goes to the lungs where you breathe most of it out. This occurs very shortly after it is taken in. Any remaining radon undergoes decay. Radon that does not go to the lungs goes to other organs and fat where it may remain and undergo decay. There is very limited information on whether radon gas can penetrate the skin, but some radon may be able to pass through the skin when you bathe in water containing radon. Radon is the second leading cause of lung cancer after smoking, which is responsible for 87% of the lung cancer cases, radon is estimated to be the second leading cause (12%) of lung cancer in the USA today and a serious public health problem, it causes about 20,000 lung cancer deaths each year(International Atomic Energy Agency, 2010).The (USEPA) considered the bone cancer and different kinds of soft tissue cancers as the main health effects associated with intake of ^{226}Ra. (Nelson, Rachiele and Smith, 1983).
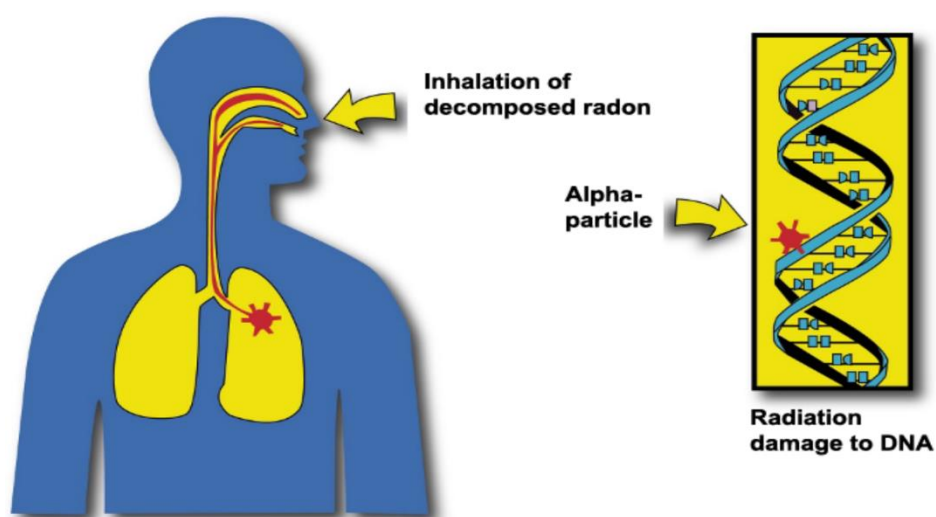
Figure 2-**3:** Radon Is Inhaled Into The Lung And Make Hazard On Human Health.

2-3 Experimental Work

2-3-1 Study of the area

Qasre consists of 25 villages and has a population of 8913 people. Qasre is 18 kilometers away from the center of Choman town. There are two different opinions about the name of Qasre. The second is that two brothers settled in this area named (Khusraw) and (Sakot) according to the time the name became Qasre and Makosan, which are now both places and prosperous and the remains of the hill (Sakot) still remains. In 1914, Qasre had only five households and was a village belonging to Balak district and Ruandz township. After the spring uprising (1991) the area was rebuilt again and due to the expansion of the area during the fifth cabinet of the Kurdistan Regional Government and by the decree of the Kurdistan Regional Government No. (130) on 05-11-2007 The total population of the region is (8913) eight thousand nine hundred and thirteen people, of which (5708) five thousand seven hundred and eight people live in the center of the township and (3205) three thousand two hundred and five people live in villages. Qasre is an agricultural and tourism area and most of the population is engaged

in agriculture and breeding animals and bees. This is in addition to the existence of several tourist areas that a large number of tourists visit in summer, such as the resorts (Balayan Valley, Kani Bast, Walash, Rezhdoor).
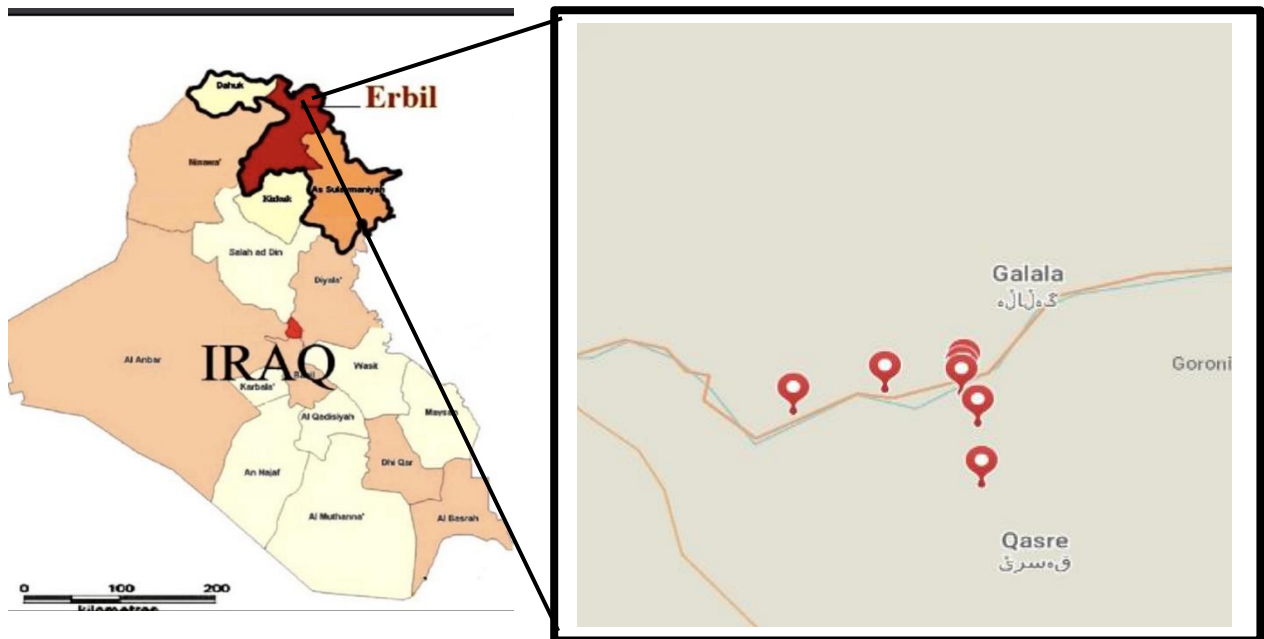
Figure 2-4: The location of receiving samples on the Iraq map.

2-3-2 Sample collection and preparation

A add up to of 8 well water was collected for some quarters in Qasre region from Iraqi Kurdistan region, we chose inspecting destinations whose waters are ceaselessly utilized for human utilization as well as in creatures and trim generation. For RAD-H_2O strong state finder investigation, an aliquant of each sample, The RAD-H_2O radon analyzer made by Durridge Company Inc. has been utilized for radon concentration estimation within the water tests. The water tests were taken in 250 ml vials planned for the RAD-H_2O gadget and given by the producer. And the climate conditions amid the examining period were reasonably steady. Water examining is complicated for the reality that the gas effectively gets away from water, and so must be done without any air circulation, which

might lead to outgassing. Measurement of radon concentration in the collected samples was performed by RAD7 device. RAD7 device works according to alpha particles energy emitted by Radon. The RAD7 method employs a closed loop aeration design in which the air volume and water volume are constant and independent of the ¬low rate. The air recirculates through the water and continuously extracts the radon until a state of equilibrium develops. The RAD7 system reaches this state of equilibrium.

2-3-3 Radon detection device (RAD7)

Alpha particles emitted from the different isotopes of polonium have different energies, and produce different strength signals in the detector. Detector used by The DURRIDGE RAD7 is a truly versatile radon research scientists and professionals worldwide. It's mature and yet still state-of-the-art design matches or exceeds those of the most expensive radon measurement devices in the world. At the same time, it incorporates a number of exclusive features that are found in no other radon detector, regardless of price. Incredibly, the RAD7 is affordable. The RAD7 is a sophisticated measuring instrument widely used in laboratories and research work around the globe. It is used by professional radon testers, mitigators and home inspectors, as well as by research scientists studying groundwater, mines, deserts, the ocean and volcanoes at extreme temperature. A rugged carrying case encloses the instrument, ensuring reliability in the field. The RAD7 is the easiest electronic radon detector to use, with preprogrammed setups for common tasks.

The RAD7 radon detector is a solid state α particle detecting electronic system. The internal sample chamber of RAD7 is a 0.7-liter hemisphere, encrusted on the inside with an electrical conductor. A solid state, ion implanted, planar Silicon alpha detector is at the center of the hemisphere as shown in Figure 2-2. The high voltage power circuit charges the inside conductor to a potential of 2,000–2,500 V relative to the detector, creating an electric field throughout the

volume of the cell. The electric field drives the positively charged particles onto the detector. Nucleus of ^{222}Rn that decays within the chamber of RAD7 leaves its transformed nucleus, ^{218}Po, as a positively charged ion. The prevailing electric field within the chamber drives this positively charged ion to the detector, to which it fuses. When the short-lived ^{218}Po nucleus decays upon the detector's active surface, it's emitted α particle has a 50% probability of entering the detector and producing an electrical signal proportional in strength to the energy of the α particle. Subsequent decays of the samhich are then recorded in different energy windows. During analysis of a water sample in Watt 250 protocol and sniff mode after about 30 min, the average radon concentration is determined from the activity of ^{218}Po without bringing the radon in the air loop to equilibrium with its daughters. In addition to 218Po, there are other daughters of radon also like ^{214}Po and ^{210}Pb, which emit α particle.

A novelty of RAD7 electronic detector is that in sniff mode, it uses only the α particles emitted from ^{218}Po to determine the ^{222}Rn concentration of a sample, and does not take into account The α particles emitted from ^{214}Po and other subsequently formed decay products left over from previous tests. The ^{218}Po has a half-life of about 3 min, so the RAD7, in sniff mode, has a 15 min response time to either sudden increase or decrease in the level of ^{222}Rn.

With this technique one is capable of conducting several independent onsite tests for measuring radon concentration in shortest possible time and, therefore, can cover an extensive area for the survey purpose in less time. ^{216}Po has a half-life of only 150 msec, so the instrument response to thoron (^{220}Rn) is virtually instantaneous. The only delay is the time required to put the air sample into the measurement chamber, which is about 45 s. The sensitivity of the instrument is 0.2 CPM/pci.L^{-1} in the sniff mode, and 0.4 CPM/ pci.L^{-1} in the normal mode. The instrument has a dynamic range of 4–400,000 Bq.m^{-3} (0.1–10,000 pci.L^{-1}). The data l   storage capacity of the instrument is 1,000 radon concentration

measurements, including time, date, temperature, humidity, battery voltage, thoron and statistical uncertainties(Khattak *et al.*, 2011).
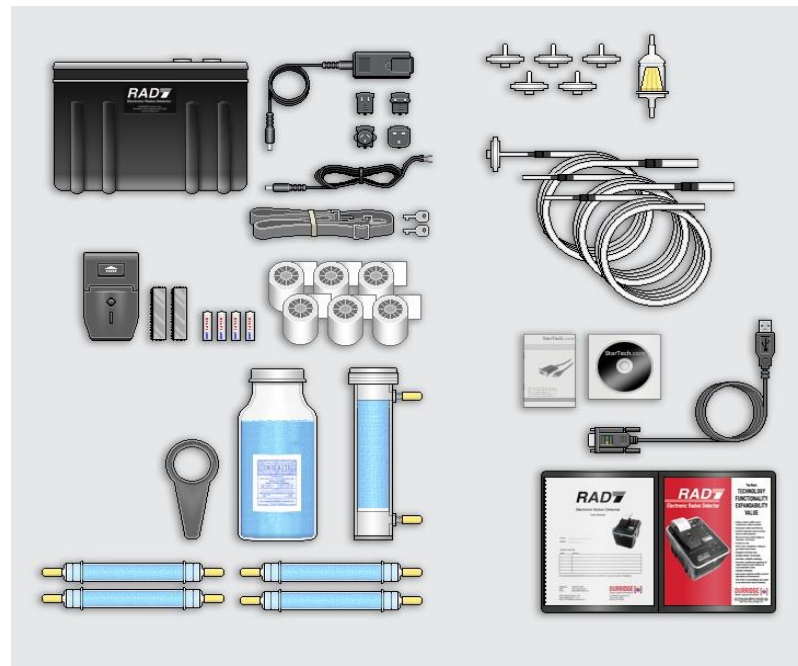
Figure 2-5: Contents of Rad 7
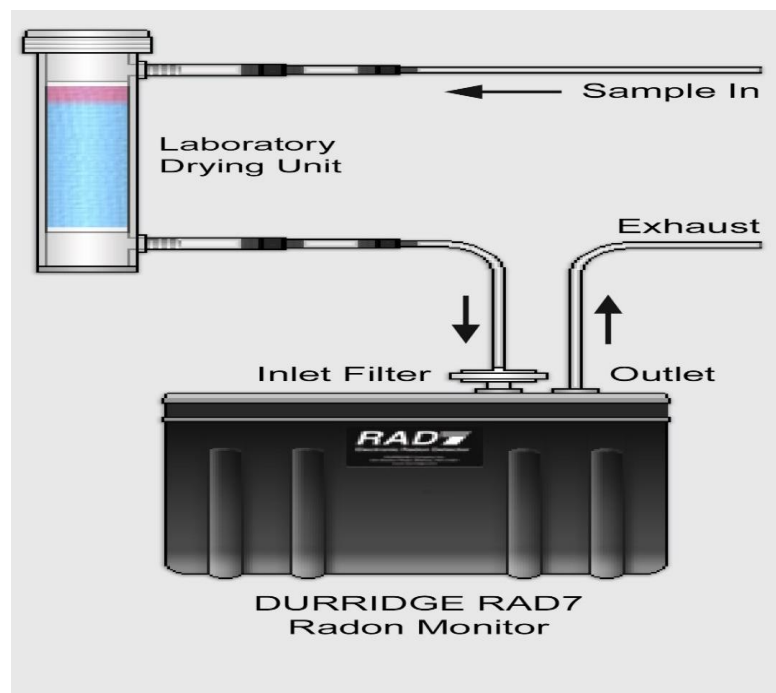
Figure 2-6: Schematic representation of RAD7 experimental setup
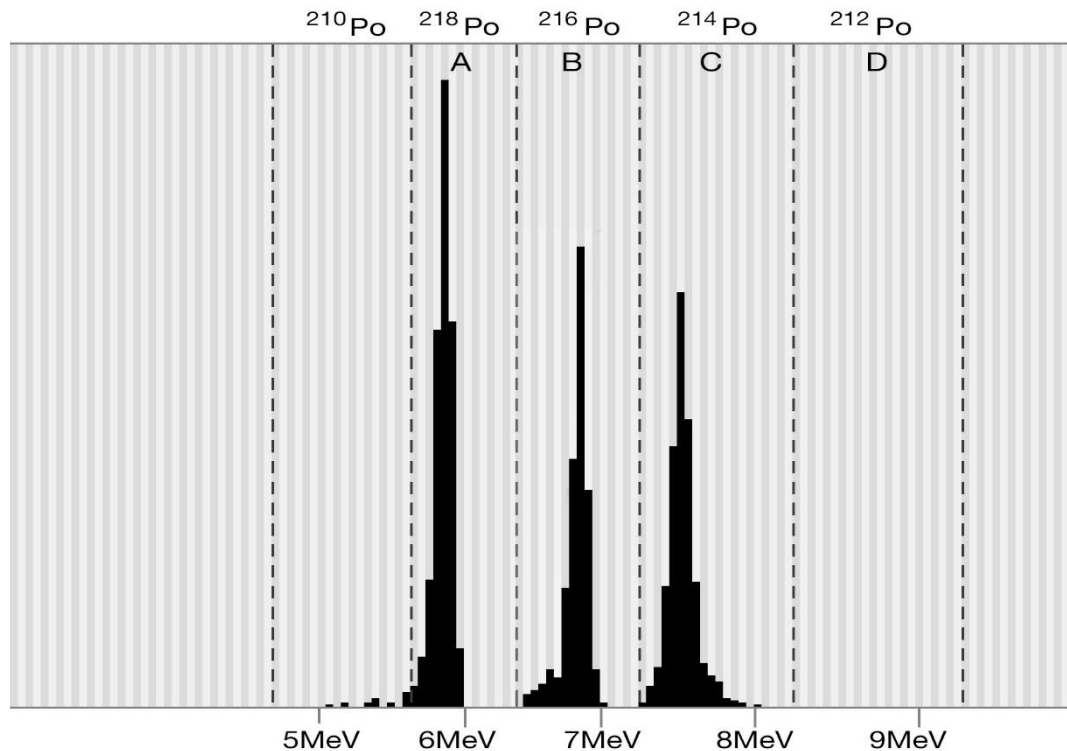
Figure 2-7: Rad7 detector output spectrum

2-3-4 Equation of health effect

The radiation dosage gotten from radon show in drinking water can be partitioned into two components, to be specific, (a) the dosage gotten from radon ingested and (b) the measurements gotten from radon breathed in. In case of ingestion, radon and its progenies show within the drinking water can give a radiation dose basically to the stomach. However, radon gas display within the drinking water can moreover elude into the indoor discuss amid showering and other domestic uses and can cause a critical increment within the hazard of lung cancer due to the radon inhaled.

Radon concentrations can be measured either in terms of a volume of air (Bq.m^{-3}) or a volume of water (Bq.l^{-1}). As well as the amount of radon in air or water commonly is reported in terms of activity with units of (pci.l^{-1}) of air or water (Council and others, 1999)**.**

The yearly compelling measurements ($\mu Sv.y^{-1}$) due to ingestion of the drinking water were calculated by taking under consideration the action concentration of radon ($Bq.l^{-1}$). ,the measurements change figure DCF ($Sv.Bq^{-1}$) and the yearly water consumption (l/y) agreeing to condition (UNSCEAR, 2000).

$$A.E.Ding = CRnW \times CW \times DCF \qquad (2.1)$$

Where CRnW is the concentration of radon in drinking water, CW is the Annual water intake equal to (150, 350, 500) l/year for (infant, children, adult) respectively and DCF is equal to (23, 5.9, 3.5) svbq^{-1} for (infant, Children, adult), respectively.

The annual effect dose due to inhalation of the drinking water was calculated by using the following equation:

$$A.E.Dinh = crnw \times F \times O \times DCF \qquad (2.2)$$

F is the equilibrium factor between radon and its progeny (0.4), O is the average indoor occupancy time per individual (7,000 h. Y-1) and DCF is the dose conversion factor for radon exposure [9 nsv/ (Bq h m^{-3})] (UNSCEAR, 2000).

Chapter Three
Results and discussion

The Radon monitoring detector RAD-H$_2$O an electronic radon detector was used to determine the activity concentration of radon gas in water samples were collected in Qasre region in Erbil city from Iraqi Kurdistan Region. The Radon monitoring detector RAD-H$_2$O an electronic radon detector was used to determine the activity concentration of radon gas in well- water samples were collected in Qasre region from Iraqi Kurdistan Region. The obtained results of these parameters were arranged in **Table 3-1**.

The activity concentration of ^{222}Rn gas in water samples was measured to be ranging from (0.15 to 4.3) Bq.m^{-1}, with the average value (1.2 ± 0.46) Bq.m^{-1}. As shown in Figure 3.1, the highest value of ^{222}Rn activity concentration was founded in water samples in Rezhdur Spring water, while the lowest value of ^{222}Rn activity concentration was founded in water samples in Rezhdur River water. The variation in values of ^{222}Rn activity concentration in water samples is due to the differences in the content of ^{226}Ra in water samples, the rocks in this location, the geological and geographical conditions in the studied area, as well as the depth of well.

The radon concentrations in the water in studied area are low and blow the maximum contaminant level of 11.1 Bq.L^{-1} in water (USEPA , 2012).

Table 3-1 Radon activity concentration (in Bq. L^{-1}) in water samples from Qasre region.

Code of Samples	Location	Longitude	Latitude	Radon Activity Concentration (Bq. L^{-1})
W1	Rezhdur well water	36.589876	44.808531	0.42 ± 0.12
W2	Rezhdur well water	36.588377	44.808441	2.57 ± 0.76
W3	Rezhdur Spring water	36.582238	44.812052	4.3± 0.63
W4	Saya Spring water	36.56992	44.812845	1.36 ± 1.44
W5	Saya River water	36.56992	44.812845	0.29 ± 0.32
W6	Rezhdur River waterr	36.591327	44.808926	0.15 ± 0.17
W7	Razan Spring water	36.588944	44.791644	0.18 ± 0.07
W8	Omerawa well water	36.584606	44.771824	0.36± 0.15
Average				1.2 ± 0.46
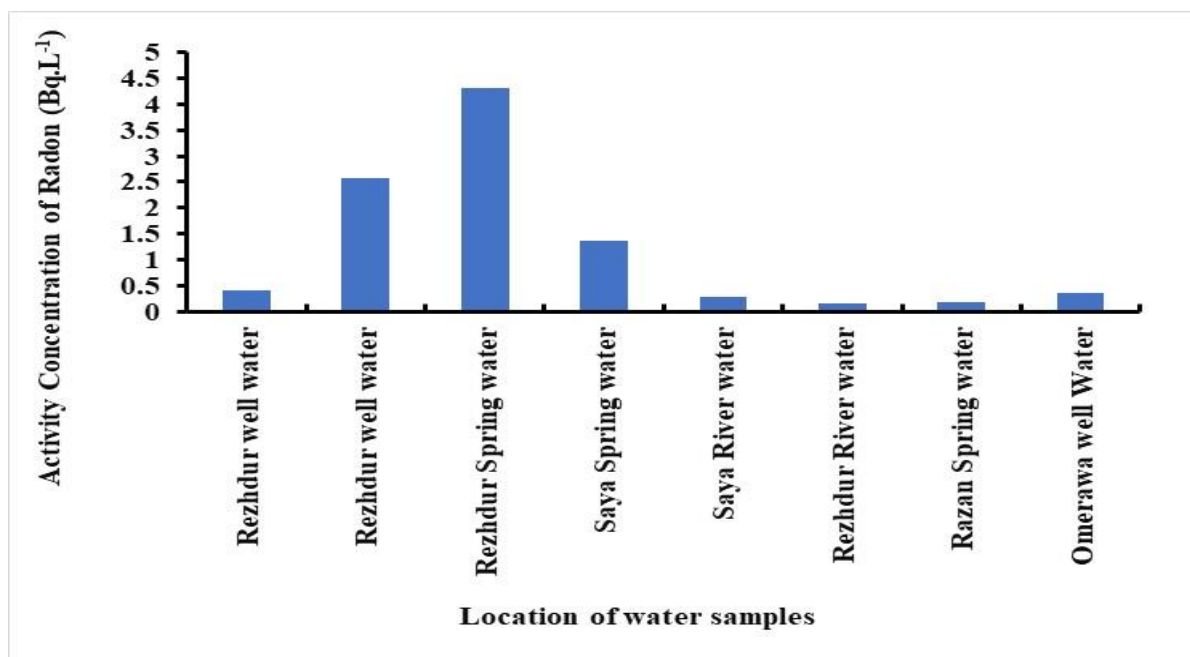
Figure 3.1: Radon activity concentration (in Bq. L^{-1}) in water samples from Qasre region.

Table 3-2 Comparison radon activity concentration (in Bq. L^{-1}) in water samples to the other researches.

Country	Range	References
Iraq (Erbil)	0.73 to 6	Present study
Iraq *(Erbil)*	4-12:18	(Qadir,2021)
Iraq (Sulaymaniyah)	7:589 -11:184	(Yousuf & Abullah, 2011)
Iraq (Baghdad)	0:289-0:072	(Kadhim, 2015))
Iraq (Mosul)	17:4 ± 0:8-36:1 ± 1:2	(Najam, 2014)
Iraq (Najaf)	0:0432 ± 0:0039- 8:876 ± 0:226	(Abojassim et al., 2015)
Turkey	1.44-27.45	(Erdogan,2013)
Saudi Arabia	0.89-35.44	(Alabdula'Aly, 1999)
Lebanon	0.91-49.6	(Abdullah,2007)

Table (3-3) shows the calculated value of annual effective doses due to ingestion of radon in water samples for three different age groups: infants, children and adults. The obtained values ranged from (0.5 to 14.84) $\mu Sv.y^{-1}$, (0.3

to 8.88) μSv.y^{-1}and (0.5 to 7.53) μSv.y^{-1}respectively. As shown in Figure (3-2), the maximum values of annual effective doses due to ingestion of radon in water samples for three different age groups were found at (W3), and minimum reported at (W6 and W7). The obtained values of annual effective doses due to inhalation of radon in water samples ranged from (0 to 0.11) μSv.y^{-1}. As shown in Figure (3-2), the maximum values of annual effective doses due to ingestion of radon in water samples for three different age groups were found at (W3), and minimum reported at (W6 and W7).

Table 3-3 Annual effective dose due to ingestion and inhalation of radon gas by water in (μSv.y^{-1}) for various ages.

| Code of Samples	Location	AED Due to ingestion of Radon gas by water (μSv.y^{-1})			AED Due to Inhalation of Radon gas by water in homes (μSv.y^{-1})
		Infants	Children	Adults	
W1	Rezhdur well water	1.45 ± 0.42	0.87 ± 0.25	0.74± 0.21	0.01± 0.001
W2	Rezhdur well water	8.85 ± 2.62	5.3 ± 1.57	4.49 ± 1.33	0.06 ± 0.02
W3	Rezhdur Spring water	14.84± 2.17	8.88 ± 1.3	7.53 ± 1.1	0.11 ± 0.02
W4	Saya Spring water	4.68 ± 4.97	2.8 ± 2.98	2.38 ± 2.52	0.03± 0.04
W5	Saya River water	0.99 ± 1.11	0.59 ± 0.67	0.5 ± 0.57	0.01 ± 0.01
W6	Rezhdur River water	0.5 ± 0.58	0.3 ± 0.35	0.25 ± 0.29	0
W7	Razan Spring water	0.63± 0.25	0.38 ± 0.15	0.32 ± 0.13	0
W8	Omerawa well water	1.26 ± 0.5	0.75 ± 0.3	0.64 ± 0.25	0.01 ± 0.001
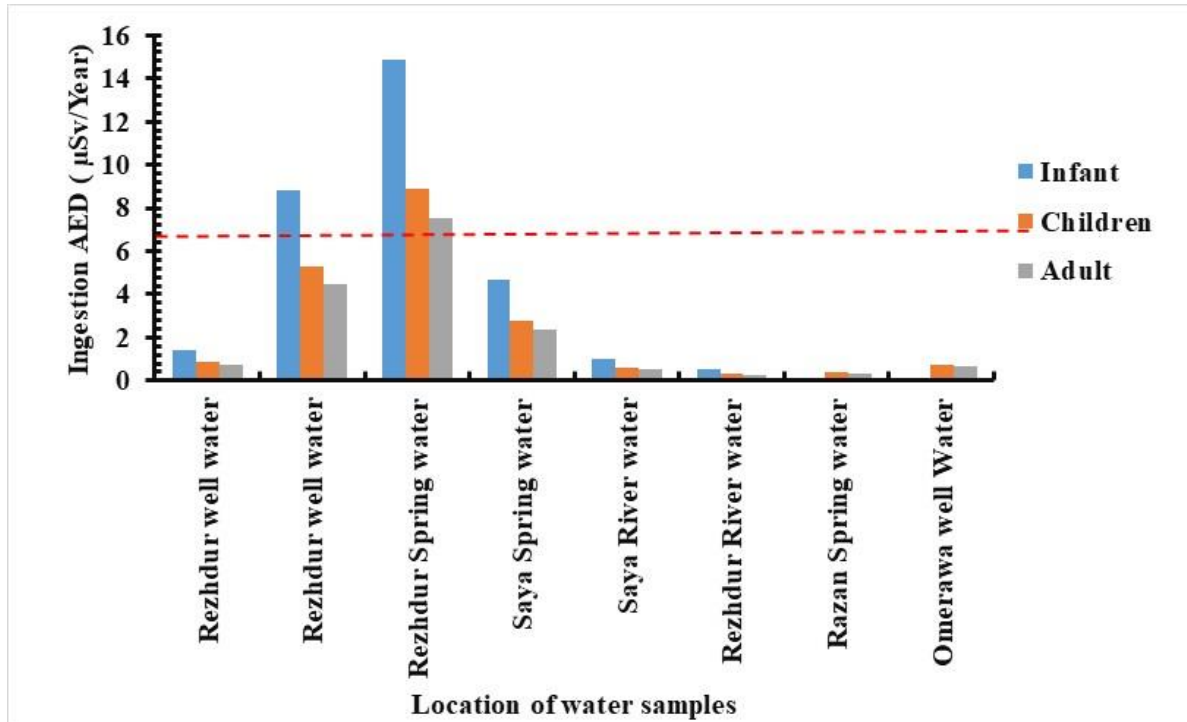
Figure 3-2: Annual effective dose due to ingestion of radon gas by water in ($\mu Sv.y^{-1}$) for various ages.

Table (3-4) shows the calculated value of total annual effective doses due to ingestion and inhalation of radon in water samples for three different age groups: infants, children and adults. The obtained values ranged from (0.51 to 14.95) $\mu Sv.y^{-1}$, (0.3 to 8.99) $\mu Sv.y^{-1}$ and (0.26 to 7.64) $\mu Sv.y^{-1}$ respectively. As shown in Figure (3-3), the maximum values of annual effective doses due to ingestion of radon in water samples for three different age groups were found at (W3), and minimum reported at (W6 and W7).

Table 3-4 Total annual effective dose due to ingestion and inhalation of radon gas by water in (μSv. y^{-1}) for various ages.

Code of Samples	Location	Total AED Due to ingestion of Radon gas by water (μSv.y^{-1})		
		Infants	Children	Adults
W1	Rezhdur well water	1.46 ± 0.42	0.88± 0.25	0.75± 0.21
W2	Rezhdur well water	8.91 ± 2.64	5.36 ± 1.58	4.55 ± 1.35
W3	Rezhdur Spring water	14.95± 2.18	8.99 ± 1.31	7.64 ± 1.11
W4	Saya Spring water	4.72 ± 5.01	2.84± 3.01	2.41 ± 2.56
W5	Saya River water	1 ± 1.12	0.6 ± 0.68	0.51± 0.57
W6	Rezhdur River water	0.51 ± 0.58	0.3 ± 0.35	0.26 ± 0.3
W7	Razan Spring water	0.63± 0.25	0.38 ± 0.15	0.32 ± 0.13
W8	Oerawa well water	1.27 ± 0.51	0.76 ± 0.3	0.65 ± 0.26
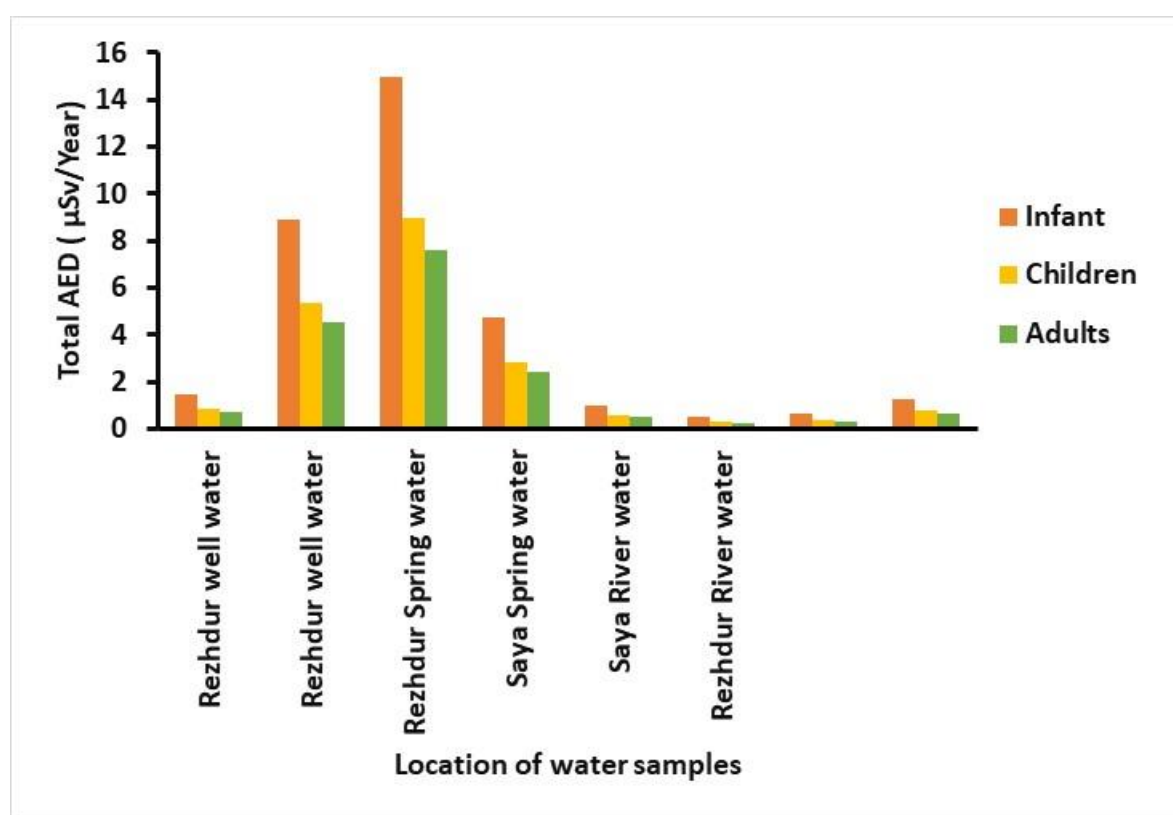
Figure 3-3: Total annual effective dose due to inhalation of radon gas by water in (μSv.y^{-1}) for various ages.

Chapter Four
Conclusion

The measurements of the radon concentration levels of waters in Qasre region have been carried out. These measurements are considered highly important for public health as these waters are used for supplying tap water to the households. Based on the RAD-H$_2$O radon monitoring detector, The activity concentration of ^{222}Rn gas in water samples was measured to be ranging from (0.15 to 4.3) Bq.L^{-1}, with the average value (1.2 $\pm$ 0.46) Bq.L^{-1}. The results were below the action level recommended by WHO of 11.1 Bq.L^{-1}. The annual effective doses due to ingestion of radon in water samples for three different age groups: infants, children and adult values ranged from (0.5 to 14.84) μSv.y^{-1}, (0.3 to 8.88) μSv.y^{-1} and (0.5 to 7.53) μSv.y^{-1} respectively.On the basis of the current results, we may conclude that the levels of radon gas in water samples were collected from Qasre region Governorate from Iraqi Kurdistan Region are well within acceptable values.

Reference

1-STRUEMPLER, A. W. & JOHNSON, S. E. 1987. Radon and radon daughters: Characteristics, health effects and occurrences in dwellings in Chadron, Nebraska.

2-ABOJASSIM, A. A., GAZALY, H. H. A., AL-TAWEEL, M. H. & KADHIM, S. H. 2015. Radon concentrations in selected samples of tap water in Baghdad Government/Iraq. Research Journal of Applied Sciences, Engineering and Technology, 11, 1358-1364.

3-VOGIANNIS, E. G. & NIKOLOPOULOS, D. 2015. Radon sources and associated risk in terms of exposure and dose. Frontiers in public health, 2, 207.

4-ISMAIL A. H., Measurement of Radon Activity concentration in Iraqi Kurdistan Soil by Using CR39 Nuclear Track Detectors", M.Sc.Thesis, Univ. of Salahaddin, Erbil-Iraq, (2004).

5-ABDULLAH, K. O., MUHAMMED, S. Z. & HUSSEIN, A. M. 2015. Assessment of Rn and U concentrations in the soil of Qadafery, Kalar and Zarayan located in Sulaimani governorate of Kurdistan region-Iraq. American Journal of Environmental Protection, 4, 40-44.

6-KADHIM, I. H. & ALMAYYALI, A. O. M. 2014. Measurement of radon concentrations and their annual effective dose exposure in water from AlShomaly District of Babylon, Iraq. General Health and Medical Sciences, 1, 34-37.

7- Duggal,V., Mehra, R. And Rani,A.,2013.Determination of 222Rn level in groundwater using aRAD7 detector in the Bathinda district of Punjab ,India. Radiation Protection Dosimetry,156(2),pp.239-245.

8- Szabo, Z., Vincent, T.. Fischer. J.M., Kraemer,T.F.andJacobsen,E.2012Occurrenceand

9- Kasic, A., Kasumovic, A., Adrovic, F. And Hodzic, M.2016. Radon measurements in well and spring water of the Tuzla area. Bosnia and Herzegovina. Arhiv za higijenu rada i toksikologiju, 67(4), pp.332-339.

10-Virk, H. S. And Singh, B. (1993) 'Radon anomalies in soil-gas andgroundwater as earthquake precursor phenomena', Tectonophysics, 227(1-4), pp. 215-224.

11- Hararah,S.M. A. I. (2007)'Investigation of radon pollution in groundwater in the southern part of Gaza strip-Palestine 'AL Zabadi, H. Et al. (2012)*Exposure assessment of radon in the drinking water supplies: a descriptive study in Palestine', BMC research notes, 5(1), pp. 1-8.

12- GARBA.N.N. (2012) Determination of radon concentration in water sources of Zaria and environs using liquid scintillation counter.

13- Nelson,P.H. Rachiele,R and Smith,A. (1983)"Transport of radon in flowing boreholes at Stripa,Sweden', Journal of Geophysical Research: Solid Earth, 88 (B3), pp. 2395-2405.

14- USEPA (United States Environmental Protection Agency)(2012)*Drinking waterstandards and health advisories.Washington DC, U.S.A.,. EPA 822-S-12-001'. Available

15- Duenas, C. Et al. (1999) '226Ra and 222Rn concentrations and doses in bottled waters in Spain', Journal of environmental radioactivity, 45(3), pp. 283-290.

16- Garba, N. N. Et al. (2008) Radon: Its consequences and

17- UNSCEAR (2000) Sourcesand Effects of IonizingRadiation,United Nations Scientific Committee on theEffects of Atomic Radiation UNSCEAR 2000Reportto theGeneralAssembly, with Scientific Annexes,UNSCEAR 2000 Report.

18-Council, N. R.and others (1999) Risk assessment of radon in drinking water'.d= 1 &tocrestrict-=n& Toc=&tocentry=&qfield=&qfieldyear

19- Khattak. N. U. Et al. (2011) Radon concentration in drinking water sources of the Main Campus of the University of Peshawar and surrounding areas, Khyber