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Study of Radon Gas Concentrations and Heavy Metals in Selected Samples of Water in Al-Zubair, Basra / Iraq

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

﴿يَهْدِي بِهِ اللَّهُ مَنِ اتَّبَعَ رِضْوَانَهُ سُبُلَ السَّلَامِ
وَيُخْرِجُهُمْ مِنَ الظُّلُمَاتِ إِلَى النُّورِ بِإِذْنِهِ وَيَهْدِيهِمْ
إِلَى صِرَاطٍ مُسْتَقِيمٍ﴾

[المائدة: ١٦]

Dedication

To my mother

Who provideds me with her continuous

love and support

To my brothers and sisters who supported me

To my friends and colleagues who have helped me

Muhammed

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In the name of Allah, praise be to Allah, and prayers and peace be upon the Messenger of Allah and the Seal of the Prophets, Muhammed, his good and pure family, and his chosen companions.

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Muhammed

Supervisors Certificate

We certify that the preparation of this thesis titled **(Measurement and Study of Radon Gas Concentrations and Heavy Metals in Selected Samples of Groundwater in Al-Zubair District-Basra Governorate / Iraq**) was done under our supervision in the department of physics, college of education for pure sciences, university of Babylon, as partial fulfilment of the requirements for the degree of master in education / physics.

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Abstract

This study included two parts, the first was measuring the concentration of radon gas in groundwater samples in the Zubair area with 56 samples, and also measuring radon in the water of the Shatt al-Arab with 20 samples from its first formation point. From the meeting of the Tigris and Euphrates rivers in the Qurna district to the second formation, where the Euphrates River empties again into the Shatt al-Arab in Karmat Ali in Basra Governorate, using the RAD7 electronic solid-state detector.

The results show that the concentration of radon gas in the groundwater samples ranged from 0.08 to 9.18 Bq/L with the mean 2.471 Bq/L and the annual effective dose for human exposure ranged from 0.0006 to 0.0643 μSv/y with the mean 0.0173 μSv/y. The lifetime incidence of cancer ranged from 0.0022 to 0.2474 with the mean 0.0665.

In the surface waters of the Shatt al-Arab, the rate of radon in the water 0.072 Bq/L, and the average of the annual effective dose 0.0005 μSv/y, while the lifetime cancer risk average was 0.0019. So, it been found that the concentration of radon gas in ground and surface water samples falls within the natural limits set by specialized organizations. The maximum allowable concentration of radon in water is 11.1 Bq/L, and the maximum annual effective dose is 1 mSv/year, as set by the EPA.

The second part of this study includes the determination of heavy metals in 52 groundwater samples of the studied samples for both lead and cadmium using the atomic absorption device AAS, the results showed that the rate of lead ranged from (0.0 to 0.537) at the mean 0.166 mg/L as well as the cadmium concentration ranged from (0.0 to 0.054) at the mean 0.015 mg/L. The results indicated that the concentrations levels of dissolved lead and cadmium in the investigated water

sources are within the normal limits set by the specialized organizations, and did not pose any significant health risks.

Contents

List of Symbols and Abbreviations

Symbol	The meaning
Bq/m^3	Becquerel per cubic meter Radon concentration unit per cubic meter of water
Bq/L	Becquerel per liter Radon concentration unit per liter of water
µSv/y	The unit of measure for the annual effective dose is (Micro sieverts per year)
mSv/y	Milli sieverts per year
Z	Atomic number
a.u	Atomic mass unit
MeV	Energy measurement unit
mg/L	unit of measurement for the concentration of heavy metals per liter of water
EPA	Environmental Protection Agency
SSNTD	Solid State Nuclear Track Detector
AAS	Atomic Absorption Spectrophotometer
AED	Annual Effective Dose
ICP-MS	Inductively coupled plasma mass spectrometry
ICP-OES	inductively coupled plasma optical emission spectrometry

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Chapter One

General Introduction

1.1 Introduction

Radiation has advantages, including that it is emitted in all directions. it is emitted from the floors and walls of our homes, from the food and drink that we consume, from the air that we breathe, and from rocks and soil. Alpha particles, beta particles, and gamma rays are the most common ionizing radiation. Radiation can come from different sources, including natural radionuclides as well as man-made ones. The water immense benefits cannot be limited except that it receives pollutants in the environment and then obtains pollution, which is described as any change in the characteristics or basic components of the environmental element and causes many health problems. [1]. Incorporating radioactive materials, whether liquid, solid, or gas, with the environmental elements of water, air, and soil leads to the rapid spread of intrusive materials in the air, with more of them becoming liquid or solid, resulting in air pollution and soil and water contamination [2]. As a result of rainfall, leaks of radioactive materials in liquid form entered the soil and spilled into rivers and groundwater. The geological and topographical features of the location determine the ordinary radioactive isotopes in rivers' water. The amount of uranium in water is hundreds of times lower than that found in soil and rocks [1]. The concentration of uranium in some natural water (save in specified regions) can be exceedingly high, and the isotope of radon must also be considered. Radon (^{222}Rn) levels in surface waters are lower than those in groundwater [3]. The other source of radioactivity in the water is radium (^{226}Ra) as one of the most important radioactive isotopes due to its lengthy half-life, it can be detected in water, especially drinking water.

Previous research on this subject has utilizeds various sampling and analytical techniques to measure the levels concentration of radon and heavy metals in water sources. Sampling methods typically involve collecting water samples from different artesian wells, rivers2, and springs at specific locations and depths. These samples are then analyzed in laboratories using specialized equipment and techniques [4].

For radon, commonly employed methods for measurement include liquid scintillation counting, alpha spectroscopy, and continuous radon monitoring. These techniques detect the radioactive decay of radon isotopes and provide information about its concentration in water. To determine the levels of toxic heavy metals, researchers often employ techniques such as inductively coupled plasma mass spectrometry (ICP-MS), atomic absorption spectrometry (AAS), or inductively coupled plasma optical emission spectrometry (ICP-OES). These techniques allow for the quantification of various heavy metals, including but not limited to lead, arsenic, mercury, cadmium, and chromium [5].

Studies are conducted in different regions, focusing on specific geological formations, industrial areas, or regions with potential contamination sources. The results of these studies can vary widely, depending on factors such as the local geology, anthropogenic activities, and natural background levels [6].

The findings of these investigations can inform policymakers, water resource managers, and health agencies about the potential risks associated with radon and heavy metal contamination. Based on the results, appropriate measures can be taken to mitigate risks, implement regulations, and ensure the safety of water supplies [7].

It's worth noting that scientific research on this topic is ongoing, and new studies continue to contribute to our understanding of radon and heavy metal concentrations in groundwater and surface water [8].

1.2 Literature Survey

Studying the concentration of radon and other toxic heavy metals in groundwater and surface water is crucial for assessing potential health risks and understanding the environmental impact of these contaminants. Among these studies related to the subject of the current study are the following:

Jumaa and Anbary (2010) [9] conducted a study to assess pollution with heavy elements in part of the water of the Diyala River and the soil and plants of the agricultural lands located on both sides of the river. Exceeds the World Health Organization's permissible limit for irrigation water.

Inaam, (2012) [10] Inam studied the concentration of radon gas in the water of the Hilla River. (41) samples were collected from different locations in the Babylon Governorate in central Iraq using a RAD-7 detector. Radioactive radon gas was also measured in drinking water samples in schools in the Abu Gharq district. In Babil Governorate, using (RAD7), the average radon concentration was calculated as (0.115 ± 0.048) Bq /L, and the annual effective dose was (0.413 mSv/y).

Nada, (2013) [11] determined the concentrations of radon gas and uranium in the groundwater in six locations in the city of Akash at, Iraq, using the CR-39 detection. (9.35 ±1.24 kBq/m^3) to (30.16 + 11.7 Bq / L), with an average of (31.24 + 9.35 Bq / L) and the annual effective dose for inhalation is (2.25 to 3.28) mSv/y and for the whole body (3.09 to 4.51 mSv/y).

Rashid (2013) [12] conducted a study by collecting samples from some sites in the province of Sulaymaniyah, such as deep wells, rivers, and springs. The CR-39 nuclear track detector was used to measure radon and uranium concentrations, and the results showed that the radon concentration ranged from (7.589 Bq/L to 1.184 Bq/L) in Deep wells and the results were at higher levels compared to the global values.

Laith, *et al*. (2014) [13] conducted a study to measure radon gas concentrations in drinking water samples for eleven sites in Nineveh Governorate (Iraq) using the CR-39 detector using sealed cup technology. The radon concentrations in Mosul Dam ranged from (17.4 Bq/L to 36.1 Bq/L), with an average of (26.37 Bq/L), and the results were lower than the European classification, where the highest level set by the authority was (100 Bq/L), and the annual effective dose ranged from (64 µSv/y to 132 µSv/y) and the total annual effective dose was in The locations of the studied area (45.45%) and it was found to be within the safe limit set by the competent associations.

Aqil (2014) [14] studied the concentrations of heavy elements (Cu,Cd,Fe,Pb and Cr) in the water of Bani Hassan creek, Karbala Governorate - Iraq, using the atomic absorption device. The results of the examination showed that the levels of these metals in its soluble form (0.51, 0.06, 2.78, 2.45, 0.15) µg/L, respectively, and the results were within the allowable range within the Iraqi and World Health Organization specifications.

Laith *et al*. (2015) [15] measured radon concentrations in samples of tap water taken from drinking water at home sites in Dhi Qar Governorate using the CR-39 detector. The measurement results showed that the highest level of radon concentration was in the Rifai area (0.223 $\pm$ 0.03 Bq / L) and the lowest level was in Al-Fajr area (0.108 $\pm$ 0.01 Bq/L) with an average of (0.175 $\pm$ 0.03 Bq/L) and the annual effective dose in Al-Rifai (0.814 µSv/y) and Al-Fajr (0.394 µSv/year) with an average of (0.64 ± 0.1 μSv/y) and the results in the study area were less than the permissible limit.

Kadhim and Hassen (2016) [16] conducted a study to measure the concentration of radon gas in samples of liquefaction water and the river. It collected 18 samples from different areas in Al-Qasim district in Babil Governorate, using the electronic radon detector RAD7. The rate of radon gas concentration and the standard deviation rate (Bq/L 0.08 ± 0.17) and the annual effective dose is equal to mSv/y (0.009), so the radon concentration was within the normal limits set by the competent organizations because the upper limit allowed for the concentration of radon gas in water according to the EAP agency is (11.1Bq/L).

Al-Alawy and Hassan (2017) [17] conducted a study by measuring radon gas concentrations and its effects in groundwater samples in six regions of Karbala Governorate, Iraq, using the (SSNTD-CR-39) detector, and the results showed the highest level of gas concentration Radon in the heat region reached (2.2 ± 4.152 Bq/L) and the lowest concentration was in the Ramadan neighborhood (1.6 ± 2.165 Bq/L) and the maximum annual effective dose in the Al-Hawar region was (14.43 ± 3.5 μSv/year) and the minimum in the Ramadan neighborhood (8.66 ± 3.1 μSv/year) The radon concentration and annual effective dose were lower than the allowable limit set by the Environmental Protection Agency.

Wissam (2017) [18] measured the concentration of radon gas in samples of the waters of the Husseiniya River in Karbala Governorate, Iraq, using the nuclear trace detector CR-39, and the results showed that it ranged from (2.508 to 0.0901 Bq/L) at a rate of (1.068 Bq/L). The results were below limit.

Faten *et al*. (2018) [19] determined radon concentrations in groundwater in the island of Djerba, southeast of Tunisia, using the RAD-7 detector, and the results of the examination ranged from (0 to 2.86 Bq/L) with an average of (1.867 Bq/L).

Eman *et al.* (2018) [20] estimated the concentrations of four heavy elements (Zn, Cu, Cd, and Pb) in the water and bottom sediments of the Tigris River, and the examination was carried out using the atomic absorption spectrometer. The results showed a significant increase in the concentrations of the studied heavy elements in the water and the sediments of the Tigris River in the city center and the Al-Busif area compared with the Mushairfa area.

Rupak *et al.* (2019) [21] conducted a study showing the presence or absence of a relationship between the concentration of radon gas and the physical and chemical parameters in the groundwater of the city of Erbil, Iraq, where 24 groundwater samples were collected from wells in different regions, and the radioactivity of dissolved radon in the groundwater was measured using The RAD7 detector also measured various factors, namely pH, total dissolved solids, total hardness, sulfate and magnesium in groundwater samples.

Anurani *et al*. (2019) [22] study on the spatial and temporal variability of radon in the river Basin (VRB) in southern India and their collected 40 groundwater samples during three seasons of the 2019 using $RADH_2O$ and their results of radon concentration in three seasons range of 0.64 to 79.94 Bq/L in pre-monsoon, 0.25 to 36.95 Bq/L in monsoon and 0.42 to 59.79 Bq/L in post-monsoon season and 18% of samples exceeded the permissible limit of EPA (11 Bq/L).

Tamim *et al.* (2019) [23] measured the concentration of heavy metals (Pb, Cd, Cu, Fe and Zn) in groundwater samples in the Jableh Plain - Lattakia, Syria. The samples were collected from 11 sources using the atomic absorption device, and the results showed lead (1.51 to 13.56 µg/L). And cadmium (0.056 to 1.022 µg/L), and the concentration of the elements was within the permissible limits for only one site. The concentration of lead was higher than the permissible limit according to the Syrian standard specifications.

Mosttir (2020) [24] conducted a study in which he collected 52 samples taken from selected areas (rivers, groundwater) in Basra Governorate, Iraq, to determine the concentrations of radon and radium, using the CR-39, LR-115typell, RAD-7 detector, and the results showed that the lowest concentration was in The Karma River water was (0.312± 0.196 Bq/L) and the highest concentration was in the Al-Chora River water (16.217 ± 0.097 Bq/L). The concentration of radon gas appeared in the groundwater with the highest concentration (22.415 ± 0.143 Bq/L) in the poultry area and the lowest concentration (0.682 ± 0.682). 0.046 Bq/L).

Dunia and Ahmed (2020) [25] conducted to measure the concentrations of Pb, Cr, As in the Yaji area in Kirkuk, northern Iraq, by taking 5 samples of groundwater from wells using the ICP-MS device, and the results of these average concentration was(45.34 , 11.8 and 0.74) µg, and the results were within the permissible range set by the Environmental Protection Agency.

Abdel, (2021) [26] studied to determine Estimation of radon gas concentration and its effective dose in the Quaternary aquifer, Nag Hammadi, Qena, Egypt the concentration of radon gas in its results showed that the average radon concentration was 1.56 Bq/L , and the annual effective dose was 16.42 µSv/y which was within the limits set by the relevant organizations.

P. RaviKumar *et al*. (2021) [27] Radon concentrations were measured in the Yadagir region, India, by collecting 93 groundwater samples from wells spread in the region using the RAD7 detector, and the results showed varying concentrations (37.0, 20.75, and 9.98 Bq/L) and they were above the safe level.

Awsam *et al*. (2022) [28] conducted a study and measured radon gas concentrations in samples of groundwater collected from different regions in Dhi Qar Governorate, Iraq, using the RAD7 detector and the RAD-H_2O accessory. The results of the examination ranged from (0.032 $\pm$ 0.022 Bq / L) to (0.780 $\pm$ 0.110 Bq/L) with an average of (0.40 $\pm$ 0.205 Bq/L) and the annual effective dose ranged from (1.99 to 0.08 µSv/y) with an average of (0.52 $\pm$ 0.10 µSv/y). The test results were within the limit permitted by the Environmental Protection Agency.

G. Oluwaseun *et al*. (2022) [29] and measured the concentration of radon gas in 20 samples taken from groundwater used for drinking in southwestern Nigeria along Awaraga and Awara and examined by the RAD7 detector, and the results showed that the radon concentration ranged from (5.0 to 400.1 Bq/L) with an average of (45.78 $\pm$ 85.93 Bq/L), the annual effective dose (59.4 µSv/year), and the lifetime risk of cancer with an average of (692.9).

Rafael *et al*. (2022) [30] conducted a study to measure the level of radon concentration on 20 samples of thermal water in the Campen Flegrei volcanic caldera, (southern Italy) by using RAD7 detector equipped with the accurate accessory RADH_2O , with an average value of (0.152 Bq/L).

Al-Mamoon and Al-Azmi (2022) [31] measured the concentration of radon gas in samples of groundwater in the northeastern part of the Kingdom of Saudi Arabia using the electronic detector RAD7, and the results ranged from 0.03 to 3.20 Bq/L, with an average of 1.16 Bq/L. The annual effective dose ranged from

0.05 to 16.24 µSv/y, with an average of 5.89 µSv/y, and the results were within the limits set by the specialized associations.

Muhnaya *et al.* (2022) [32] conducted a study to measure the concentrations of heavy elements (Pb, Cd, Ni, Cr) by collecting 10 samples from the course of the Queiq River adjacent to the treatment plant in the city of Aleppo, Syria. The results of the concentration of Pb ranged between (0.1-0.6) mg/ kg in summer and (0.04 - 0.12) mg / kg in winter, and Cd ranged between (0.01 - 0.06) mg / kg in summer and (0.08 - 0.09) mg / kg in winter and was within the permissible range

Suha *et al*. (2022) [33] conducted a study to measure the concentration of radon gas for three types of water (ground, surface, healthy drinking water) in the city of Al-Haydaria, Al-Najaf Governorate, Iraq. The examination was carried out using the RAD7 detector, and the results showed that the average concentration of radon in groundwater was (0.276). Bq/L), surface water (0.182 Bq/L) and healthy drinking water (1.32 Bq/L), and the annual effective dose was (0.706 µSv/y), (0.46 µSv/y), (0.337 µSv/y), respectively, and the results were within the limits established by the competent authorities.

Kamal *et al*. (2022) [34] studied the evaluation of the concentration of radon gas in the tap of 22 samples in three areas of Haditha in Anbar Governorate, Iraq, which are (Haditha Center, Al-Haqlaniya, and Barwana) in addition to the Euphrates River. The results showed that the concentration of radon gas in Haditha city ranged from (0.0091 to 0.031 Bq/L) and the annual effective dose ranges from (0.033 to 0.113 µSv/y), so the results were less than the permissible limit set by the Environmental Protection Agency.

Israa, (2022) [35] conducted a study to examine the heavy toxic elements lead, nickel and cadmium to determine contamination in soil samples using the atomic absorption scale (AAS) technique. Samples were collected from different regions in Babel Governorate, Iraq. The results showed that the average concentration values of each of lead were (18.919 mg/ kg), nickel (81.043 mg/kg) and cadmium (0.202 mg/kg). The results showed higher than the permissible limit.

Hassan (2022) [36] measured the concentration of radon gas for ten groundwater samples from distinct sites in the Makkah region in Saudi Arabia using the RAD7 detector, and the results showed an average of (2.851 Bq/L) and the annual effective dose (7.783 µSv/y).

Mojtaba *et al*. (2022) [37] conducted a study to determine the concentration of radon gas in groundwater in the Zarand region of Iran. Forty-eight samples of groundwater were collected from deep agricultural wells. The samples were examined by the RAD7 detector, and the results of the examination ranged from (4,667 ± 2,077 to 31.55 ± 14.912 Bq/L), which is higher than the level set by the Environmental Protection Agency.

Mustafa *et al*. (2022) [38] measured the concentration of radon gas in groundwater samples collected from six different locations in Ojo district Nigeria using the RAD-7 detector and the results showed higher than the level set by the Environmental Protection Agency.

Romano *et al*. (2022) [39] conducted a study to measure the concentration of radon in groundwater samples taken from wells, Al-Yanabeg and Al-Tabighia in 70 different locations in northeastern Sicily (southern Italy) using the RAD-7 detector, the results ranged from (1.6 to 57.5 Bq/L) and the dose Annual effective (56.5 µSv/y).

Idowu *et al*. (2023) [40] conducted a measure of the radon concentration of 58 samples of groundwater used for drinking and other domestic uses taken from different locations in the Abeokuta region, using the RAD7 detector. The results showed that the average concentration of radon in drinking water samples is (18.8). Bq/L and the radon concentration appeared in the hand-dug wells (from 1.14 to 20.02 Bq/L with an average of (9.7 Bq/L) and 48% of the water samples from the hand-dug wells had concentrations higher than the permissible limit and the annual effective dose appeared with an average of (0.027) mSv/y.

1.3 The Aims of the Research

The research aims to find the relationship between the presence of high levels of radiation and the increase in cancer rates in the study area, through the use of the RAD7 device to measure the concentration of radon gas and the AAS of the heavy metals lead and cadmium.

Chapter Two

Theoretical Part

2.1 Introduction

Natural radiation is present all around us and has various sources. Rocks and soil contain radioactive elements such as uranium, thorium, and potassium, which undergo radioactive decay and emit radiation. This radiation is known as terrestrial radiation and contributes to the background radiation [41].

2.2 Sources of Radiation

Radiation sources can be broadly categorized into natural sources and industrial sources.

2.2.1 Natural Sources of Radiation

Natural radiation sources can be further classified into two categories based on the origin and composition of the radioactive elements [42]:

2.2.1.1 Terrestrial Sources

Terrestrial sources of natural radiation include radioactive elements that are present in the Earth's crust, rocks, soil, and minerals. These radioactive elements include:

Uranium-238 (^{238}U), uranium-235 (^{235}U), and uranium-234 (^{234}U) are naturally occurring radioactive isotopes found in varying concentrations in rocks and minerals.

Thorium-232 (^{232}Th) is another naturally occurring radioactive isotope found in rocks, soil, and minerals.

Potassium-40 (^{40}K) is a radioactive isotope present in potassium, which is an essential element found in rocks, soil, and plants.

These radioactive elements undergo radioactive decay, emitting various types of radiation such as alpha particles, beta particles, and gamma rays [43].

2.2.1.2 Cosmic Sources

Cosmic radiation originates from outside the Earth and includes high-energy particles that bombard the Earth's atmosphere. These cosmic rays primarily come from the sun, stars, and other celestial bodies. Cosmic radiation exposure increases with altitude, and it is influenced by factors such as solar activity and the Earth's magnetic field [44].

It's important to note that natural radiation sources comprise numerous radioactive nuclides, but not all of them are significant in terms of human exposure or health risks. The specific radionuclides present in an area depend on the geological composition and the presence of radioactive elements in that particular region [45].

Regulatory bodies and organizations establish safety guidelines and standards to ensure that human exposure to natural radiation is kept within acceptable limits, taking into account the specific characteristics of the radionuclides and their potential health effects.

2.2.1.3 Natural Radiation within the Human Body [46].

Natural radiation also exists within the human body, and it originates from the air we breathe, the water we drink, and the food we consume. This internal radiation exposure is mainly due to the presence of radioactive isotopes in the environment and the incorporation of these isotopes into our bodies. Here are a couple of examples:

Inhalation of Radon Gas: Radon gas is a radioactive gas that is generated from the decay of uranium in rocks and soil. It can seep into buildings and accumulate indoors. When we breathe, small amounts of radon gas may be inhaled, leading to internal radiation exposure [47].

Ingestion of Radioactive Elements: Radioactive isotopes, such as carbon-14 (^{14}C) and ^{40}K, are naturally present in our environment, including in the air, water, and food. When we consume food and water, our bodies may take in trace amounts of these radioactive isotopes, leading to internal radiation exposure [37].

It is important to note that the levels of internal radiation exposure from natural sources within the human body are generally low and considered to be within safe limits. The human body has evolved to tolerate and manage these naturally occurring radioactive isotopes. The radioactive elements present in our bodies, such as ^{14}C and ^{40}K, undergo natural radioactive decay processes over time [48].

2.2.2 Industrial Sources of Radiation

Industrial sources of radiation result from human activities and applications. Some examples include:

Medical Applications: X-rays, CT scans, nuclear medicine procedures, and radiation therapy in medical diagnostics and treatments.

Nuclear Power Stations: Nuclear reactors generate electricity by inducing controlled nuclear reactions. While these facilities have numerous safety measures in place, they do emit small amounts of radiation.

Industrial Applications: Various industries use radiation for purposes such as material analysis, quality control, and non-destructive testing. This includes radiography, gauging, and irradiation processes [49].

It is essential to regulate and monitor industrial sources of radiation to ensure the protection of workers, the public, and the environment. Strict safety protocols and regulations are implemented to mitigate potential risks associated with industrial radiation sources.

2.3 Radon

Radon is indeed one of the most prominent radioactive elements and is commonly found in nature. It is a chemical element with the symbol ^{222}Rn, atomic number 86, and mass number 222 in the periodic table. Radon is a noble gas and is chemically inert, which means it does not easily react with other substances [50].

Radon is a radioactive element, and it is produced by the decay of heavier radioactive elements such as uranium and thorium found in rocks, soil, and water. These radioactive isotopes undergo a series of decay processes, eventually leading to the formation of radon gas [51].

One of the unique characteristics of radon is that it is colorless, tasteless, and odorless, making it difficult to detect without specialized equipment. This property also makes it more dangerous, as it can accumulate in enclosed spaces without being noticed [46].

Radon is present in varying concentrations in the air we breathe and can also dissolve in water. It can enter homes and buildings through cracks in the foundation, gaps around pipes, and other openings. Therefore, it is important to monitor radon levels in indoor environments and take measures to reduce exposure if necessary [52].

Various techniques are available to test and mitigate radon in homes, such as using radon detectors, improving ventilation, sealing entry points, and installing radon mitigation systems. It's important to note that while radon is a significant contributor to radiation exposure, there are other sources of radiation as well, including natural background radiation from the sun, cosmic rays, and other radioactive elements present in the environment. Additionally, industrial and medical sources can also contribute to radiation exposure, although they are typically regulated and controlled to minimize risks to human health [53].

2-4 Heavy Metals in groundwater

In addition to radon gas, we mention some heavy metals found in groundwater, which are:

a. Lead (Pb) is found in rocks, igneous rocks, and above alkaline, and it is little in groundwater. It is considered one of the toxic elements for humans, and increasing its concentration may cause cancer. Lead inhibits many of the main enzymes involved in the overall process of blood formation [54].

b. Cadmium (Cd) The sources of cadmium are phosphate fertilizers, dirty domestic water, and the products of industrial activities. It is considered a toxic element and pollutant of the environment. It has no importance in life processes and does not enter into cell construction and causes high blood pressure and kidney damage [55].

c. Nickel (Ni) is a heavy element found in acidic, oxidizing environments. It is present in the earth's crust in the form of oxides. Its concentration increases in base rocks and is associated with cobalt minerals in hot springs [56].

d. Copper (Cu) is one of the basic elements for humans. It is widely found in minerals distributed in nature. It is present in the form of sulfates and oxides. It has a concentration of 1.5 mg / L in groundwater and appears in three forms, which are solubility, colloidal and particulate matter. When its concentration rises to 2 mg / L, it is toxic to humans and causes vomiting diseases. diarrhea and heart disease [57].

e. Zinc (Zn) is an important trace element that has a vital role in the physiological process and metabolism of living organisms, but in high concentrations it is toxic and the permissible limit in water is 0.5 mg / L [58]

f. Cobalt (Co) is present in the earth's crust at a concentration of 20 ppm and has a high concentration in suprabasal rocks and a little in sandy calcareous rocks [59].

2.5 Radon Decay

Uranium and thorium are abundant radioactive elements found in the Earth's crust. They undergo a series of radioactive decay processes, ultimately leading to the formation of radon gas. Radon itself has a relatively short half-life, with the most stable isotope, ^{222}Rn, having a half-life of approximately 3.8 days. As a result, radon is considered one of the rarest elements in terms of its stable isotopes [52].

However, despite its short half-life, radon remains present on Earth due to the continuous decay of its parent elements, uranium, and thorium. Uranium and thorium have long half-lives, with some isotopes having half-lives in the billions of years. As these elements decay over time, radon is continuously produced as an intermediate step in the decay chain [30].

The decay of radon itself leads to the formation of other radioactive isotopes known as radon daughters or decay products as figure (2.1). These radon daughters are also radioactive and decay until they reach stable elements, predominantly lead [10].

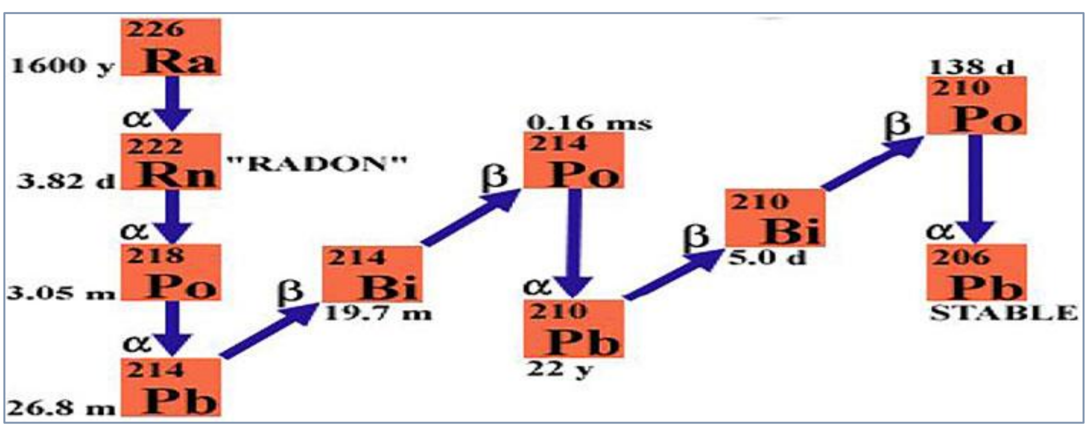


Figure 2.1: The schematic diagram of radium emission of alpha particles [48].

Radon is indeed a radioactive element that occurs naturally in the environment. It is a colorless and odorless gas that is formed from the decay of radium, which itself is a decay product of uranium or thorium. Radon undergoes a series of radioactive transformations through a process called radioactive decay [49].

During radioactive decay, radon produces several radioactive isotopes known as radon progeny or offspring. The primary radon progeny of concern are polonium-218 (^{218}Po), lead-214 (^{214}Pb), bismuth-214 (^{214}Bi), and polonium-214 (^{214}Po). These isotopes are also radioactive and undergo further decay, emitting various types of radiation [60].

The majority of the radiation dose resulting from radon exposure comes from the alpha particles emitted by ^{218}Po and ^{214}Pb. Alpha particles are relatively large and heavy particles that can cause significant damage to human tissues if inhaled or ingested. These particles can ionize atoms or molecules they interact with, leading to the disruption of biological processes and potentially increasing the risk of cancer development [61].

2.6 Radon Hazards on Health

Radon emits ionizing radiation, which can be harmful to human health. When radon gas is inhaled, its decay products release alpha particles that can damage the cells lining the lungs. Prolonged exposure to high levels of radon gas increases the risk of developing lung cancer, and it is considered the second leading cause of lung cancer after smoking [13].

While radon is the second most common cause of lung cancer overall, among non-smokers, it is the leading cause of the disease, according to estimates from policy-oriented organizations like the EPA. This underscores the importance of addressing radon exposure as a significant health concern, especially for individuals who do not smoke [62]. At higher levels of exposure, such as those experienced by uranium miners, there is strong evidence linking radon exposure to an increased risk of lung cancer [63].

There are uncertainties regarding the health effects of low-dose exposure to radon. The majority of the data and research on the health effects of radon come from studies conducted on individuals exposed to higher levels of radon, such as uranium miners or individuals living in areas with elevated radon concentrations [45].

Due to the widespread occurrence of uranium and thorium in the Earth's crust, radon will continue to be generated as a natural byproduct of their decay processes. This means that radon will persist on Earth for a significant period despite its short half-life [64].

The fact that radon is a gas and easily breathable does pose a health hazard. When radon gas is inhaled, its radioactive decay products can deposit in the lungs, emitting alpha particles that can damage the lung tissue. Prolonged exposure to high levels of radon gas increases the risk of developing lung cancer [49].

In terms of background radiation dose, radon is often a significant contributor to an individual's overall radiation exposure. The specific contribution of radon to background radiation can vary depending on local geological conditions. Radon is generated by the natural decay of uranium and thorium, which are present in varying concentrations in different types of rocks and soils. Areas with certain geological formations or high levels of uranium and thorium can have elevated radon levels in the surrounding environment [15].

It is important to note that local variations in geology can indeed affect radon levels. Some areas may have higher radon concentrations due to the specific geological composition, while others may have lower levels. Monitoring radon levels in homes and workplaces is crucial to identify and mitigate potential exposure risks in areas where radon concentrations are elevated [65].

The alpha particles emitted by the radon progeny can interact with the cells in the lungs and cause damage to their DNA. Prolonged exposure to high levels of radon gas and its progeny increases the risk of developing lung cancer. Radon-induced lung cancer is a significant health concern, especially for individuals who are exposed to high radon levels over long periods, such as in poorly ventilated buildings or underground mines [66].

To mitigate the risks associated with radon exposure, it is important to conduct radon testing in homes and workplaces and take appropriate measures to reduce radon levels if necessary, such as improving ventilation or implementing radon mitigation systems [67].

2.7 Alpha Particle

An alpha particle consists of two protons and two neutrons, which are held together by the strong nuclear force. This arrangement gives the alpha particle a positive charge of twice the charge of a proton and a mass that is slightly smaller than the combined mass of its four constituent particles [66].

Due to its relatively large mass compared to its components, an alpha particle moves at a slower velocity through matter. This slow velocity increases its chance of interacting with atoms along its path. When an alpha particle collides with matter, it transfers energy through collisions with the orbital electrons of atoms in the material [67].

The interaction between an alpha particle and the electrons in the material can lead to ionization. As the alpha particle collides with an atom, it can strip off one or more electrons from the atom, resulting in the release of the electron(s) from the atom and the formation of an ion. This ionization process requires a significant amount of energy, making the alpha particle highly ionizing [36].

Furthermore, the range of an alpha particle in a given medium is relatively short. As it moves through the material, the alpha particle loses energy due to multiple interactions and ionizations with atoms. Its short range is due to the large amount of energy transferred per collision and the subsequent ionization events [67].

These properties of alpha particles make them highly effective in causing ionization and damage to biological tissue. They have a limited penetration range and are easily stopped by a few centimeters of air or a thin layer of other materials. This characteristic makes alpha particles less penetrating but potentially more harmful if they enter living cells or tissues [54,66].

Unstable elements with heavy nuclei, specifically those with atomic numbers (Z) greater than 83, face challenges due to the large number of protons in the nucleus. These elements are known as the heavy or transuranic elements [67].

The protons in the nucleus carry positive charges, and due to their close proximity, there is a strong electrostatic repulsion between them. This repulsive force is directly proportional to the atomic number Z because an increase in Z leads to an increase in the number of protons and, consequently, an increase in the repulsion between them [68].

This strong repulsion between protons creates instability within the nucleus and makes it difficult for the nucleons (protons and neutrons) to stay together. To reduce the repulsive forces and achieve a more stable configuration, these heavy nuclei tend to release excess energy by undergoing radioactive decay [10].

The most common types of radioactive decay for heavy unstable nuclei are alpha decay and beta decay, which can be accompanied by the emission of gamma rays:

Alpha decay is a type of radioactive decay in which an atomic nucleus emits an alpha particle. An alpha particle consists of two protons and two neutrons, which is like a helium nucleus ($^{4}_{2}He$). During alpha decay the original nucleus, referred to as the parent nucleus, loses two protons and two neutrons, resulting in the formation of a new nucleus called the daughter nucleus, as the equation: [10].

$$^{A}_{Z}X \rightarrow \, ^{A-4}_{Z-2}X + \, ^{4}_{2}He \qquad (1\text{-}2)$$

Where: $^{A}_{Z}X$ represents the parent nucleus

$^{A-4}_{Z-2}X$: the daughter nucleus

$^{4}_{2}He$ represents the alpha particle emitted.

2.8 Heavy Metals

Heavy metals that are compounds are required by living organisms in certain amounts, but when present in excessive concentrations, they become toxic and have an adversely impact on the ecosystem, the heavy elements have a high atomic weight and a density greater than that of water, so the deposition of these elements requires a long biological half-life. Therefore, these elements accumulate in the organs of the human body [69]. Heavy element exposure has increased in humans and other organisms as a result of their recent use, particularly in industrial areas. These elements are communicated to humans through natural sources, such as the earth's crust, where they are naturally found and then transferred to water and air by erosion. Other human activities include industrial waste dumping, oil extraction, manufacturing, residential waste disposal, hospitals, Pb-containing fuel combustion, and mining. These components are difficult to decompose and accumulate in the human body, they cause many health problems [70] and these elements in the present study are included (Pb and Cd).

2.8.1 The Lead

Lead (Pb) is a dense, malleable, and soft metal with a bluish-white color when cut and forms a dull gray color when exposed to air. This oxidation process gives lead its characteristic opaque appearance [71]. It has been used by humans for thousands of years due to its various properties. It is included in the composition of numerous alloys, such as solder, pewter, and various types of bronze. Its soft and malleable nature makes it easy to shape and work with [3].

Lead has four stable isotopes: ^{204}Pb, ^{206}Pb, ^{207}Pb and ^{208}Pb. These isotopes are not radioactive and do not undergo decay. ^{204}Pb is a primordial isotope, meaning it has been present since the formation of the Earth [72].

It's important to note that while lead is a naturally occurring element, human activities, such as mining, industrial processes, and the use of lead-containing products, have resulted in increased environmental lead concentrations, posing health risks and environmental concerns [73].

Lead is a highly toxic element, and its harmful effects on human health have been extensively studied and recognized. Once its toxicity was discovered many countries-imposed restrictions and regulations on the use of lead in various applications to protect human health and the environment [1]. Lead's toxicity stems from its ability to interfere with biological processes, particularly affecting the nervous system. Lead can enter the body through ingestion, inhalation, or absorption through the skin. Once inside the body, it can be distributed to various organs, including the brain, where it can cause significant harm [71].

The neurological effects of lead poisoning are particularly concerning. Lead has the ability to disrupt the normal functioning of vital enzymes and proteins involved in nerve signal transmission, leading to neurological and motor disorders. It can impair cognitive function, learning abilities, and behavior, especially in children who are more vulnerable to lead exposure. Prolonged or high levels of lead exposure can result in permanent brain damage and developmental issues [63]. Additionally, lead can also affect other body systems, including the cardiovascular, renal, and reproductive systems. It can interfere with the production of red blood cells and cause anemia. Lead exposure during pregnancy can harm the developing fetus and lead to developmental abnormalities [74].

2.8.2 The Cadmium

Cadmium (Cd) atomic number 48 in the periodic table , is a toxic heavy metal white color. It was discovered by Friedrich Strohmeyer, a German chemist, in 1817. Strohmeyer identified cadmium as a distinct element while analyzing samples of zinc carbonate ore [73].

Cadmium is often found in association with other metals such as copper, zinc, and gold ores. It is primarily obtained as a byproduct of zinc production. Cadmium itself is not abundant in the Earth's crust, but its presence as a minor component in zinc ores makes it commercially viable to extract [74].

One important characteristic of cadmium is its toxicity. Cadmium and its compounds are considered hazardous to human health and the environment. Prolonged exposure to cadmium can lead to various health problems. The toxicity of cadmium arises from its ability to accumulate in the body over time, mainly in the kidneys and liver [75].

Cadmium exposure can occur through inhalation of fumes or dust, ingestion of contaminated food or water, or skin contact with cadmium-containing materials. It is primarily encountered in industrial settings, such as metal processing, battery manufacturing, and the production of pigments and plastics [76]. The toxic effects of cadmium can include damage to the kidneys, lungs, and liver. It can also disrupt various biological processes and has been classified as a carcinogen, meaning it can increase the risk of cancer development. The toxic element path in the human's bodies is shown in figure (2.2).

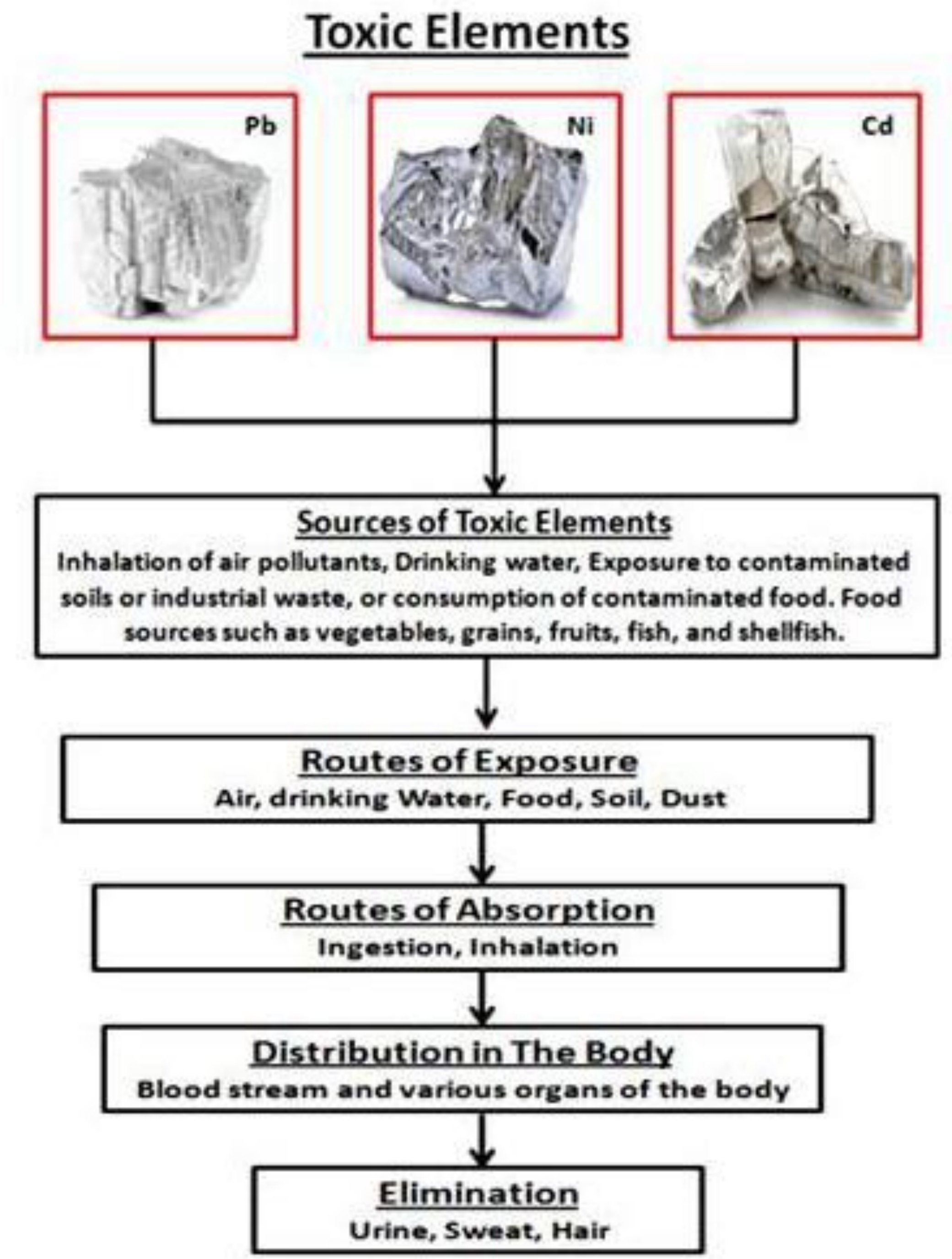


Figure 2.2: The routes of exposure of toxic elements [35].

Chapter Three

Experimental Part

3.1 Introduction

This chapter includes a description of the study area, sample collection and preparation, a description of the devices used to examine the samples, and the materials and methods used in the current study. Where samples were collected from two types of water (ground water in Al-Zubair region) and (surface water in Shatt Al-Arab) from Basra Governorate, southern Iraq.

3.2 Area of Study

Zubair district, located in southern Iraq. The district is situated to the southwest of the Basra Governorate. According to the 2018 estimates, the population of Zubair was approximately 511,224 people. Al-Zubair district is known for its agricultural activities, particularly the cultivation of palm trees and various vegetables. These agricultural practices rely on groundwater obtained from artesian wells in the region.as figure (3.1).

Figure 3.1 : Map of locations of groundwater samples in Al-Zubair and surface water samples of the Shatt Al-Arab River in Basra Governorate, southern Iraq.

The concentration of radioactive radon gas was measured in groundwater taken from artesian wells in the center and periphery of Al-Zubair district from various locations including houses, farms for tomatoes, vegetables, palm trees, water desalination plants, and areas where there are factories belonging to the Ministry of Industry, such as the iron and steel plant, the petrochemical plant, the private sector concrete plants, and car wash stations. And groups from the supermarket on the roads leading to those areas, training centers belonging to the Ministry of the Interior, and a military barracks belonging to the Naval Command of the Iraqi Ministry of Defense.

The GPS technology embedded in mobile phones allows for the determination of precise location coordinates using signals from satellites. By enabling the GPS feature on their mobile phones, the researchers or sampling team could collect accurate location data for each sampling site.

In the case of the artesian wells in Al-Zubair district as table (3-1), the GPS feature was used to determine the specific coordinates of each well. This information helps in mapping the distribution of the wells and understanding their spatial relationship within the district.

Table (3-1) Groundwater sampling sites in Al-Zubair District - Basra Governorate.

No.	Location	No.	Location	No.	Location	No.	Location
S1	N 30°20´47.2 E 47°42´49.2	S15	N 30°19´59.1 E 47°44´07.8	S29	N 30°06´16.7 E 47°52´21.5	S43	N 30°17´28.4 E 47°42´28.8
S2	N 30°20´45.5 E 47°43´19.0	S16	N 30°19´19.0 E 47°44´28.1	S30	N 30°07´21.8 E 47°51´17.8	S44	N 30°17´02.3 E 47°42´24.5
S3	N 30°22´04.4 E 47°42´27.2	S17	N 30°17´59.3 E 47°45´10.7	S31	N 30°18´46.9 E 47°43´08.2	S45	N 30°16´49.8 E 47°42´37.5
S4	N 30°23´53.6 E 47°39´43.0	S18	N 30°16´06.0 E 47°46´39.2	S32	N 30°18´33.4 E 47°43´17.0	S46	N 30°21´02.1 E 47°44´48.0
S5	N 30°23´39.0 E 47°38´04.3	S19	N 30°14´17.8 E 47°47´03.3	S33	N 30°18´47.5 E 47°43´38.3	S47	N 30°20´43.2 E 47°45´15.2
S6	N 30°20´47.2 E 30°20´47.2	S20	N 30°13´21.4 E 47°47´41.0	S34	N 30°18´15.3 E 47°43´02.1	S48	N 30°20´36.3 E 47°45´45.3
S7	N 30°25´30.8 E 47°36´37.5	S21	N 30°12´27.5 E 47°48´09.4	S35	N 30°18´11.0 E 47°43´25.3	S49	N 30°20´09.1 E 47°45´56.2
S8	N 30°24´24.6 E 47°33´32.7	S22	N 30°11´27.4 E 47°49´18.9	S36	N 30°17´47.9 E 47°42´43.0	S50	N 30°19´42.2 E 47°46´06.7
S9	N 30°24´14.7 E 47°33´04.6	S23	N 30°10´14.3 E 47°49´21.2	S37	N 30°17´32.0 E 47°42´35.5	S51	N 30°19´21.6 E 47°46´39.2
S10	N 30°24´28.5 E 47°32´15.3	S24	N 30°09´21.0 E 47°49´48.5	S38	N 30°17´41.4 E 47°42´04.2	S52	N 30°18´47.5 E 47°46´53.9

S11	N 30°22´43.0 E 47°34´52.2	S25	N 30°08´30.4 E 47°50´55.0	S39	N 30°17´32.0 E 47°41´39.1	S53	N 30°23´55.7 E 47°36´00.5
S12	N 30°21´27.9 E 47°34´18.1	S26	N 30°08´02.2 E 47°50´55.0	S40	N 30°17´11.0 E 47°40´55.6	S54	N 30°24´10.1 E 47°36´11.3
S13	N 30°20´29.1 E 47°35´03.9	S27	N 30°06´38.8 E 47°51´59.5	S41	N 30°16´16.0 E 47°40´06.4	S55	N 30°24´09.5 E 47°36´02.8
S14	N 30°22´04.7 E 47°34´28.3	S28	N 30°06´04.8 E 47°52´28.8	S42	N 30°17´30.7 E 47°42´02.6	S56	N 30°23´40.1 E 47°36´20.6

The surface water is collected from the Shatt al-Arab river, specifically from its first confluence in the Qurna district to its second confluence in the Hartha district, as the figure (3.1) including the Karmat Ali district. The Shatt al-Arab river holds great importance for various purposes, such as desalination of drinking water, irrigation of palm groves and agricultural crops, and local fishing . The areas surrounding the Shatt al-Arab river have significant populations that rely on its water resources.

The al-Sharsh area in the al-Qurna district has a population of approximately 120,000 people, the al-Deir district has a population of around 130,000 people, the Shatt al-Arab district has a population of approximately 250,000 people, and the al-Hartha district has a population of about 154,000 people, according to the 2014 census. These populations utilize the Shatt al-Arab water for various activities along its path and on both sides. The length of the Shatt al-Arab river path from the first confluence to the second confluence is approximately 65 km. Where surface water was examined, taken from the Shatt al-Arab waters from the first confluence in the Qurna district to the second confluence in the Hartha district, the Karma Ali area, which is Areas belonging to Basra Governorate, southern Iraq.

Similarly, for the Shatt Al-Arab water sampling sites as table (3-2), the GPS feature was used to track the locations from the starting point in Al-Qurna district to the endpoint in Al-Hartha district, specifically the Karmat Ali region.

The GPS coordinates provide valuable information about the sampling points along the route, helping in the identification and analysis of water quality variations across different locations.

Table (3-2) Surface water sampling sites in Shatt Al-Arab - Basra Governorate.

Sample No.	Location	Sample No.	Location
R1	N 30°34´51.7 E 47°45´56.3	**R11**	N 30°48´08.0 E 47°34´55.0
R2	N 30°35´09.4 E 47°46´10.6	**R12**	N 30°51´14.7 E 47°32´21.4
R3	N 30°35´55.2 E 47°45´53.5	**R13**	N 30°53´03.8 E 47°31´07.5
R4	N 30°36´21.2 E 47°45´28.1	**R14**	N 30°54´11.1 E 47°30´13.2
R5	N 30°38´43.8 E 47°45´32.4	**R15**	N 30°56´51.5 E 47°28´28.9
R6	N 30°41´06.7 E 47°45´20.2	**R16**	N 30°57´26.8 E 47°28´19.2
R7	N 30°43´30.0 E 47°44´40.0	**R17**	N 30°58´22.6 E 47°28´23.9
R8	N 30°44´51.0 E 47°41´59.6	**R18**	N 30°59´04.5 E 47°28´37.5
R9	N 30°45´15.3 E 47°39´50.6	**R19**	N 30°59´43.0 E 47°27´58.1
R10	N 30°45´30.5 E 47°39´12.2	**R20**	N 31°00´12.7 E 47°26´37.4

Because of the importance of water for humans and agriculture and studying it radiologically, because most areas of Basra Governorate were bombed in the recent wars that Iraq was exposed to, especially the Al-Zubair area, where military barracks were inhabited. It has also been observed recently that high rates of cancerous diseases are occurring in Basra Governorate in general and in Al-Zubair District in particular, in addition to the contribution of this study in assessing the suitability of water for various uses such as water desalination, domestic use, irrigation and fishing in terms of the presence of radioactive contamination. Whether or not the study results can provide guidance for water management practices, public health protection measures, and sustainable use of Shatt al-Arab water resources.

3.3 RAD7

RAD7 represents a semiconductor material (often silicon) which transforms alpha radiance to an electrical sign immediately. The interior sample cell of RAD7 points out to a (0.7 liters) hemisphere in a combination of an electrical conductor on the interior. The planar Silicon alpha detector, which is solid state and ion implanted, is at the center of the hemisphere, as illustrated in figure (3.5). It works on the basis of charged alpha emitters being electrostatically collected on the surface of a silicon solid-state detector and then detected via spectroscopic analysis [77]. A total of four five-minute counting cycles are executed by RAD7, bringing the total analysis duration to 30 minutes [78].

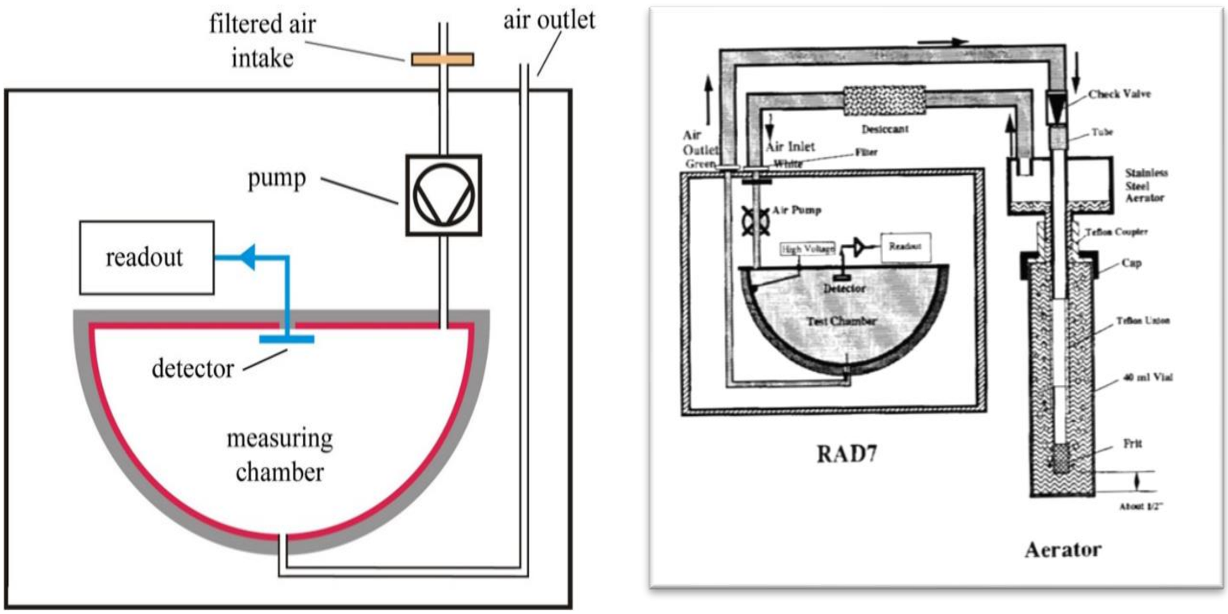


Figure 3.2: RAD7 measuring chamber [77].

RAD7 converts the radiation energy of the alpha particle resulting from the decomposition of ^{218}Po or ^{214}Po directly into an electrical signal, as RAD7 is able to determine the type of isotope by distinguishing the electronic energy associated with particles, and thus it is possible to know the radon isotopes ^{218}Po from knowing the alpha radiation with an energy of 6MeV or ^{214}Po with an energy of 7.97MeV [74].The polonium nucleus ^{218}Po has a relatively short half-life, and by its dissolution it will agree (50%) to enter the detector, which leads to the production of an electrical signal and alpha particle energies [10].

3.3.1 RAD7 Spectrum

RAD7 performs spectrum analysis of alpha radiation emitted by radon and thoron gases. It divides the energy spectrum into windows to analyze specific energy ranges associated with different isotopes. The readings from specific windows areusedto calculate the concentrations of radon and thoron gases, while the composite window represents system noise [77]. The information you provided describes the spectrum analysis process in the RAD7 device, which is used for detecting and measuring radon and thoron gas concentrations. [78].

1. Alpha radiation detection: The RAD7 device detects alpha radiation emitted by radon and thoron gases. When alpha particles pass through the detector, they generate an electrical signal.

2. Signal amplification: The electrical signal produced by the detector is amplified by the electronic circuits within the RAD7 device. This amplification process enhances the signal for further processing.

3. Conversion to digital format: The amplified signal is then converted into a digital format, which allows for easier analysis and manipulation of the data.

4. Energy range: The energy of the alpha particles detected by the RAD7 device ranges from 0 to 10 MeV. However, the concentration analysis focuses on the energy range from 6 to 9 MeV. This energy range corresponds to the dissolution of radon and thoron isotopes.

5. Spectrum division: The apparent spectrum is divided into 200 channels, each representing a specific energy level. These channels are further organized into 8 windows, labeled alphabetically from A to H.

6. Window arrangement: The windows A, B, C, and D represent specific energy ranges within the overall spectrum. Window A corresponds to the energy range from 5.40 to 6.40 MeV and specifically captures the energy of particles resulting from the dissolution of ^{218}Po isotope. Windows B, C, and D represent energy ranges associated with the dissolution of ^{216}Po, ^{214}Po, and ^{212}Po isotopes, respectively.

7. Concentration calculation: Windows A and C are used for extracting radon gas concentration, while windows B and D are used for calculating thoron gas concentration. The total readings within these windows provide information about the concentration levels of radon and thoron gases.

8. Composite window: The windows E, F, G, and H are combined into a composite window referred to as O. The readings within this composite window are primarily attributed to system noise rather than specific gas dissolutions.

9. Average age and memory storage: All the readings within the energy ranges of interest (e.g., windows A, B, C, and D) as figure (3.6) are divided by the average age, which represents the time it takes to collect the data. This division allows for calculating the average of the readings, which is then stored in the memory of the RAD7.

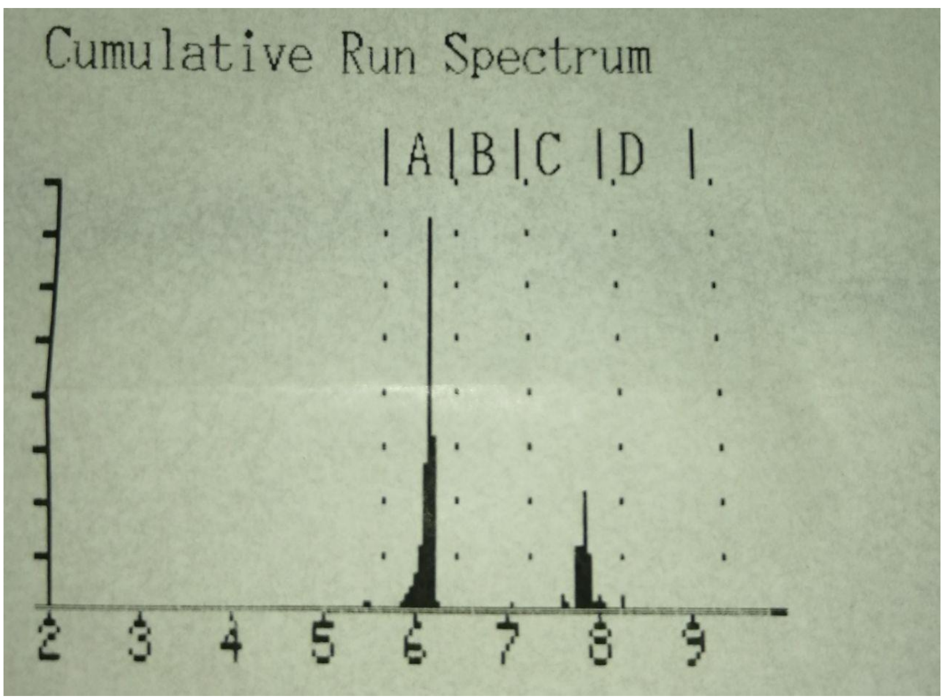


Figure 3.3: Alpha energy spectrum window.

3.3.2 Measurement

When the RAD7 detector is turned on, it prepares itself electronically for the stages of conducting the examination of the samples to be examined, and before starting the measurement, it must be noted that the memory of the device is not full by observing the sequence of the last cycle number so that it is less than 99 and the readings are transferred to the personal calculator before scanning the memory. Run the RADH$_2$O for new measurements At the beginning of the test, we dry (desiccant) the RAD7 from moisture by circulating the outside air into the device by operating the air pump of the detector for a period of 10 to 15 minutes, depending on the weather of the area in which the examination is conducted and the humidity in the air, and after completion drying period ,it's been noticed the humidity inside the device, which should be less than (6% to 9%), and then the 250 ml water test container is attached through the closed air cycle with the air pump, after which we press the start button, and the duration of the single sample test is 30 minutes, divided into five minutes for each stage, so that the first five minutes are for the air pump inside the water bottle, where air is pumped through the water, which leads to the creation of air bubbles inside the bottle that move the water molecules, which leads to the liberation of radon gas dissolved in water and the air returns to the device again, and this process continues during the first five minutes, after which the pump stops working to end its role in the examination process, and in the next five minutes the device stops in order to reach a state of balance and the remaining 20 minutes are allocated for four cycles of 5 minutes each At the end of each cycle, the device bell sounds, and the radon concentration reading appears. The readings are printed for each cycle, the average of the readings, the highest value and the lowest value of the radon concentration in the sample examined, as well as printing the spectrum of alpha particles released during the examination process. The percentage of radon gas removal from water in the closed air loop with the device is high in the water sample with a volume of 250 ml, which is 94% [77] as shown in figure (3.7) Schematic diagram of the work of the RADH_2O.

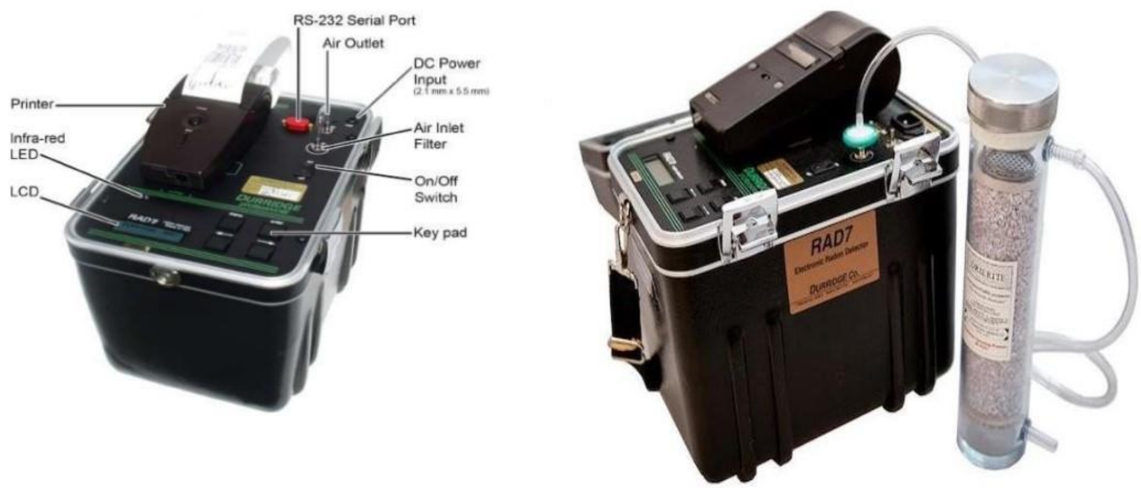


Figure 3.4: RAD -7 detector [77].

3.4 The Annual Effective Dose and Lifetime Cancer Risk

The annual effective dose (AED) at (μSv/y) is according with the ingestion of ^{222}Rn at the time of drinking water for adults was counted employing equation [79]:

$$AED\left(\frac{Sv}{y}\right) = C\left(\frac{Bq}{L}\right) x\ WC\ \left(\frac{L}{y}\right) x\ DCF\left(\frac{Sv}{Bq}\right) \quad (3.1)$$

Where:

C : represents the concentration activity ^{222}Rn.

W_C : is the annual water consumption of yearly water for a person (2 L/d) [79].

DCF : refers to the ingestion dose changed determinant for the identical radionuclide , which is equal for radon ingestion by people as 0.0035 μSv/Bq [79].

The lifetime cancer risk in accordance with ingestion of ^{222}Rn from samples was measured in water by equation [80]

$$Lifetime\ cancer\ risk = AED\ x\ DL\ x\ RF \tag{3.2}$$

Where:

AED : is the annual effective dose.

DL : is the period of life (70 year).

RF : is the risk factor (0.055 Sv^{-1}) suggested via the International Commission on Radiological Protection (ICRP) [80].

3.5 Atomic Absorption Spectrophotometer

The Atomic Absorption Spectrophotometer (AAS) is a technique for determining wide range of heavy metals in liquid samples. It can measure parts per billion of a gram and analyze and determine the concentrations of more than 62 different metals in various materials such as such as cadmium (Cd), lead (Pb) [35]. AAS technique is developed in the nineteenth century, its modern form was enormously enhanced during the 1950s by Alan Walsh and a team of Australian chemists [81]. AAS model used in the present study is (AA-7000 SHIMADZU, Japan) and it is shown in the figure (38).

Figure 3.5: Atomic Absorption Spectrophotometer

3.5.1 Principle of Operation

The operation mechanism of an atomic absorption spectrophotometer (AAS) is based on the principle of absorption spectroscope where AAS measures the concentration of an element in a liquid sample by analyzing the amount of radiation absorbed by that element. Each element has characteristic wavelengths of light that it absorbs, distinguishing it from other elements. and the AAS device is equipped with a detector capable of distinguishing between the wavelengths of light transmitted by the sample and the wavelengths that pass through the sample without being absorbed. This detection process allows for the analysis of the sample and determination of the element's concentration.

To analyze a specific element, AAS device uses a lamp containing that element to emit light. For example, when examining the concentration of lead, a lead lamp is used. The emitted light must excite the lead atoms in the sample, causing them to radiate at wavelengths that are absorbed by lead atoms [81].

3.5.2 Atomization of the Sample

Within the AAS device, the liquid sample is atomized, converting it into free atoms in an excited state. This atomization process is achieved by passing an electromagnetic radiation beam emitted from the excited lead atoms through the vaporized sample. The greater the number of lead atoms present in the vapor, the higher the absorption of the vapor [71].

The device consists of Radiation Source (Cathode Tube), the energy source by atomizer, monochromator and detector. The figure (3.9) shows the components of this technique.

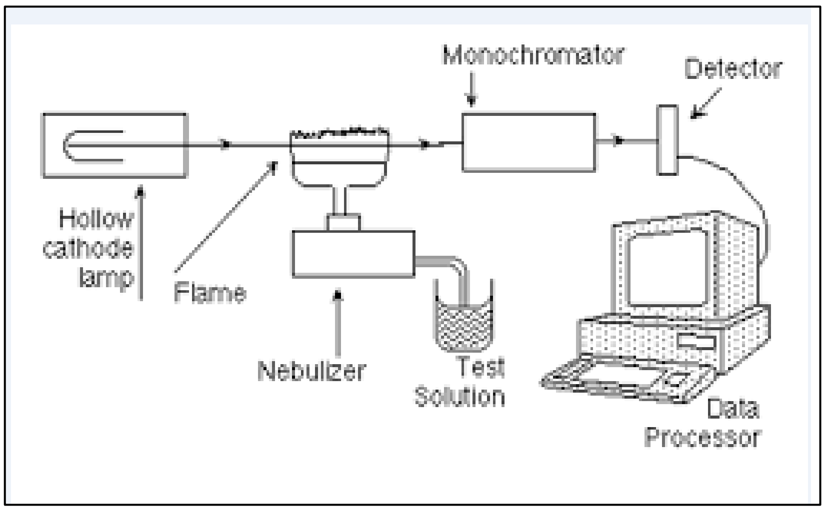
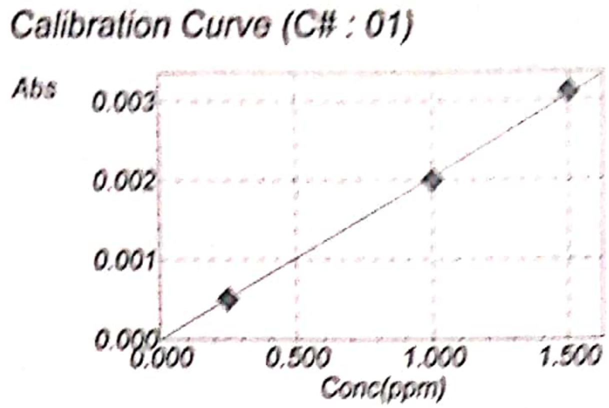


Figure 3.6: Atomic Absorption Meter Parts Diagram [35].

3.5.3 Calibration and Standards

AAS requires calibration using standard reference solutions with known concentrations of the target metals. These calibration curves help in quantifying the concentration of metals in the unknown samples by comparing their absorption values to the standard solutions. As figures (3.10) and (3.11) the concentrations of heavy elements are determined in the Uscience laboratory in Al-Diwaniyah governorate.

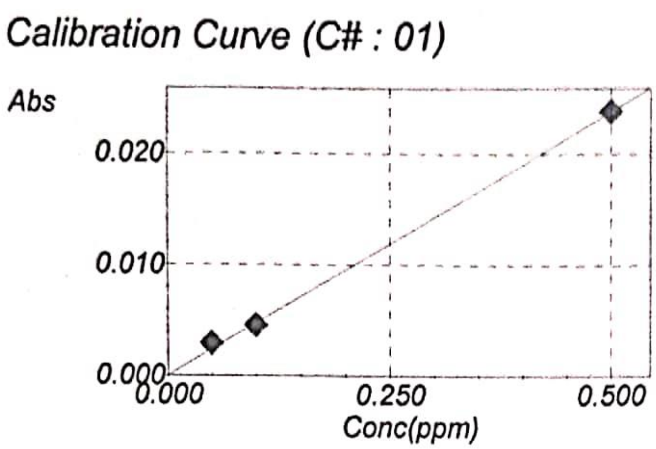


Conc (ppm)	Abs
0.2500	0.0005
1.0000	0.0020
1.5000	0.0031

Abs=0.0020453Conc+0.00000

r=0.9997

Figure 3.7: Calibration curve of element Pb.



Conc (ppm)	Abs
0.0500	0.0029
0.1000	0.0045
0.5000	0.0238

Abs=0.047600Conc+0.00000

r=0.9995

Figure 3.8: Calibration curve of element Cd.

In Figures 10:3, which represents the calibration curve for measuring the concentration of lead in groundwater samples, and 11:3, which represents the concentration of cadmium for the same samples, where standard solutions are prepared for each element using the 1000ppm balance solution using the equation C1B1=C2B2, and a series of dilutions is prepared from it, for example, preparing 1ppm, 2ppm, 3ppm, to draw the calibration curve on which the device is based in extracting concentrations, and after preparing the calibration curve when it It reads the models and converts the absorbance into concentration through the calibration curve, which is linear, according to the relationship between absorbance and concentration, as shown in the two figures above.

Chapter Four

Results and Discussion

4.1 Introduction

This chapter presents the results obtained from the current research, which discusses the concentration of radioactive ^{222}Rn in groundwater samples collected from artesian wells in the Zubair district. The concentration of heavy elements Pb and Cd in the same groundwater samples is also determined using the Atomic Absorption Spectrophotometer. Additionally, the concentration of radon gas in selected samples of surface water from the Shatt al-Arab River is measured, and the annual effective dose rate of radon and the lifetime cancer incidence factor are presented based on the samples collected in these areas. The chapter concludes with a summary of the findings and suggestions.

4.2 Measurement of Radon Concentration

RAD7 is used to measure the concentration of radon gas in groundwater and surface water samples. A total of 56 groundwater samples are collected from artesian wells in the center and periphery of the Zubair district. Additionally, 20 samples are collected from different locations along the Shatt al-Arab River, starting from the second meeting in the Al-Hartha district of the Karmat Ali district and moving towards the first meeting in the Qurna district. The sampling of surface water is done in an ascending manner due to the continuous flow of water towards the Arabian Gulf.

The results for the groundwater samples in the Zubair district are presented in Table (4-1), and the results for the Shatt al-Arab samples are presented in Table (4-2), where the equations (3-1) and (3-2) used to calculate annual effective dose and lifetime risk of cancer.

Table (4-1) presents the concentration of radioactive radon gas in groundwater samples collected in the Zubair district. The table includes information such as the sample number, mean concentration, highest concentration, lowest concentration, effective dose in µSv/y, lifetime cancer risk.

Table (4-1) The concentration of radioactive radon gas in groundwater samples

Sample No.	Mean (Bq/L)	High (Bq/L)	Low (Bq/L)	Effective dose µSv/y	Lifetime Cancer Risk $x10^{-3}$
S1	0.8±0.016	1.44	0.161	0.0056	0.0216
S2	1.32±0.02	1.92	0.48	0.0092	0.0356
S3	2.2±0.026	4.64	0.32	0.0154	0.0593
S4	1.4±0.021	2.02	0.959	0.0098	0.0378
S5	2.065±0.026	2.99	1.28	0.0145	0.0556
S6	6.31±0.045	7.19	5.09	0.0442	0.1701
S7	1.008±0.018	1.78	0.162	0.0071	0.0272
S8	1.32±0.02	1.91	0.639	0.0092	0.0356
S9	3.31±0.033	4.0	2.4	0.0232	0.0892
S10	1.175±0.019	1.91	0.16	0.0083	0.0317
S11	0.08±0.005	0.32	0	0.0006	0.0022
S12	1.91±0.05	3.02	1.28	0.0134	0.0515
S13	2.955±0.03	3.34	2.4	0.0207	0.0796

S14	1.8±0.02	3.2	1.12	0.0126	0.0485
S15	2.36±0.027	2.72	1.91	0.0165	0.0636
S16	4.52±0.038	5.92	3.68	0.0316	0.1218
S17	0.719±0.015	1.12	0.159	0.0051	0.0194
S18	3.875±0.035	5.12	3.02	0.0271	0.1044
S19	1.24±0.02	1.59	0.799	0.0087	0.0334
S20	0.918±0.017	0.959	0.795	0.0065	0.0247
S21	0.12±0.006	0.16	0	0.0008	0.0032
S22	1.48±0.022	1.91	1.12	0.0104	0.0398
S23	2.24±0.027	3.2	1.59	0.0157	0.0603
S24	4.39±0.038	4.88	3.82	0.0307	0.1183
S25	1.4±0.021	1.76	0.639	0.0098	0.03773
S26	0.2±0.008	0.32	0.159	0.0014	0.00539
S27	1.36±0.021	2.44	0.159	0.0095	0.0366
S28	2.16±0.026	3.36	1.28	0.0151	0.0582
S29	1.397±0.021	1.76	0.639	0.0098	0.0376
S30	1.56±0.022	1.76	1.28	0.0109	0.0421
S31	2.92±0.031	3.68	2.07	0.0204	0.0787
S32	3.475±0.033	5.280	2.4	0.0243	0.0936

S33	4.43±0.038	4.8	4.16	0.0311	0.1194
S34	3.155±0.032	4.32	2.56	0.0221	0.0851
S35	0.519±0.013	0.799	0.16	0.0036	0.0139
S36	3.712±0.035	4.45	3.2	0.0259	0.10003
S37	1.278±0.02	1.92	0.795	0.0089	0.0344
S38	4.04±0.036	5.28	3.36	0.0282	0.1088
S39	2.515±0.028	3.2	1.76	0.0176	0.0677
S40	3.63±0.034	4.16	3.18	0.0254	0.0978
S41	1.202±0.019	1.77	0.799	0.0084	0.0323
S42	1.44±0.021	1.92	0.639	0.0104	0.0388
S43	3.39±0.033	4.88	2.88	0.0237	0.0913
S44	1.36±0.021	1.6	1.12	0.0095	0.0367
S45	1.28±0.02	1.92	0.48	0.0089	0.0345
S46	5.392±0.042	7.190	4.00	0.0377	0.1454
S47	2.707±0.029	3.2	1.6	0.0189	0.0729
S48	1.555±0.022	1.91	1.27	0.0109	0.0419
S49	4.39±0.038	4.77	4.0	0.0307	0.1183
S50	3.155±0.032	4.0	1.92	0.0221	0.0851
S51	0.878±0.017	1.28	0.639	0.0062	0.0236

S52	3.08±0.031	3.84	1.91	0.0216	0.0831
S53	3.27±0.032	3.84	2.56	0.0229	0.0881
S54	6.90±0.047	7.88	5.6	0.0483	0.1859
S55	9.18±0.055	9.59	7.95	0.064٣	0.2474
S56	1.92±0.025	2.72	0.954	0.0134	0.0517
Minimum	**0.08**			**0.0006**	**0.0022**
Maximum	**9.18**			**0.0643**	**0.2474**
Mean	**2.47±0.02**			**0.0173± 0.001**	**0.0665 ±0.002**
UNSCEAR,2018)	**11.1B q/L**			**1mSv/y**	**0.2**

The results of the examination of groundwater samples appears in the above table that there is a difference in the results of the sampling of groundwater samples in different depths 8 to 14 m and this difference has led to a difference in the concentration of radon in groundwater As the lowest focus of radon gas in **S11** was the depth of the well from which it was taken 8 m, which is (0.08 Bq/L) in its located in the table and the highest concentration of radon gas was in **S55** and the depth of the well from which was taken 14 m was (9.18 Bq/L) at the site recorded in the table above, and there are samples where the radon concentration was clear, which is **S6**, which is (6.31 Bq\L), **S24** (4.39 Bq/L), **S33** (4.43 Bq/L) and **S38** (4.04 Bq/ L) The **S46** (5.392 Bq/L), the **S49** (4.39 Bq/L) and the **S54** (6.9 Bq/L) and these mentioned samples have been taken from the artesian wells whose depths range from 10 m to 14 m and this is a note that the more the well is deep the more the more the more. Radon's concentration was higher because it leaks from the rocks in the layers of the earth's crust from which the groundwater leaks.

The results of the examination are less than the limit recommended by the Environmental Protection Agency, which is (11.1Bq/L), and the annual effective dose is calculated for all samples, and it ranged from (0.0006 – 0.0643 μSv/y), and the results were less than the limit recommended by the Agency. Lifetime cancer risk, was the results appeared as Table (4-1)

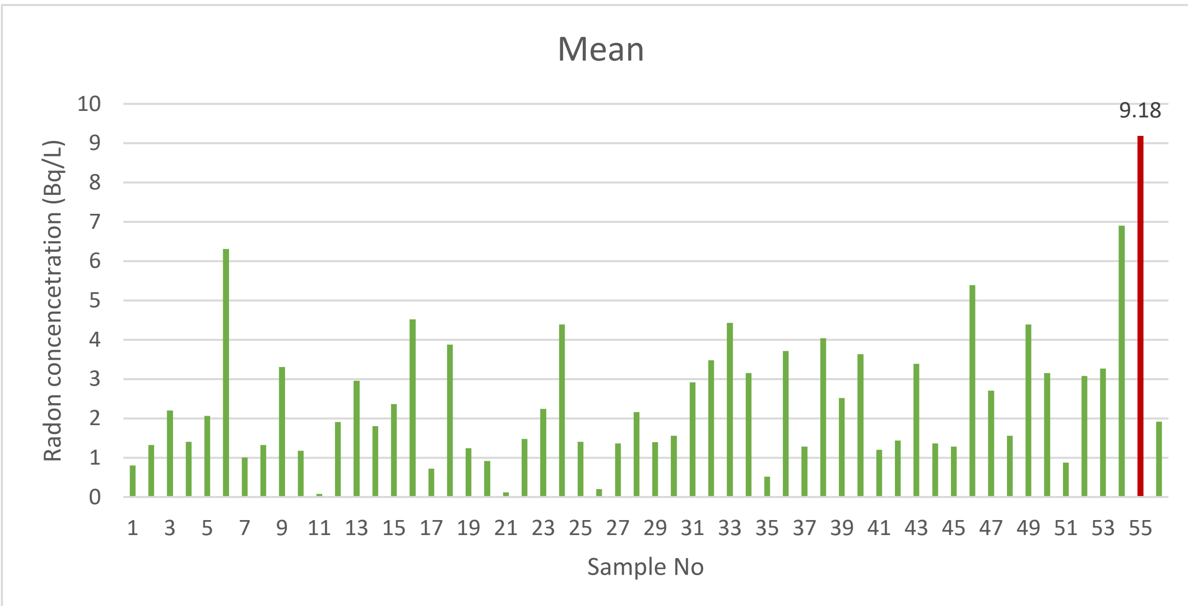


Figure 4.1: Variation in the concentration of radon gas in the groundwater of artesian wells in the vicinity of Al-Zubair district.

It is noted in Figure 4.1 above, which represents the radon concentration rate graph for 56 groundwater samples that were taken from artesian wells in the center and periphery of Al-Zubayr district, according to their locations shown in Table (3-1), that sample 55 has the highest value for the radon concentration rate, as it was taken from A well with a depth of 14 m, followed by samples 54 and 6, and the concentration decreases in samples 46 and 16, and samples 24 and 49, then samples 38 and 18 decreases in the rest of the samples, according to the nature of the soil and the depth of the well from which the sample was taken until it reached the lowest concentration in the samples 21 and 11, where the lowest concentration was recorded in sample 11. The depth of the well was 8 m, as the depth of the wells from which samples were taken ranged from 8 to 14 m, Accordingly, we find that the rate of radon concentration in the groundwater of the Zubair region was within the permissible range of 11.1 Bq/L according to EPA.

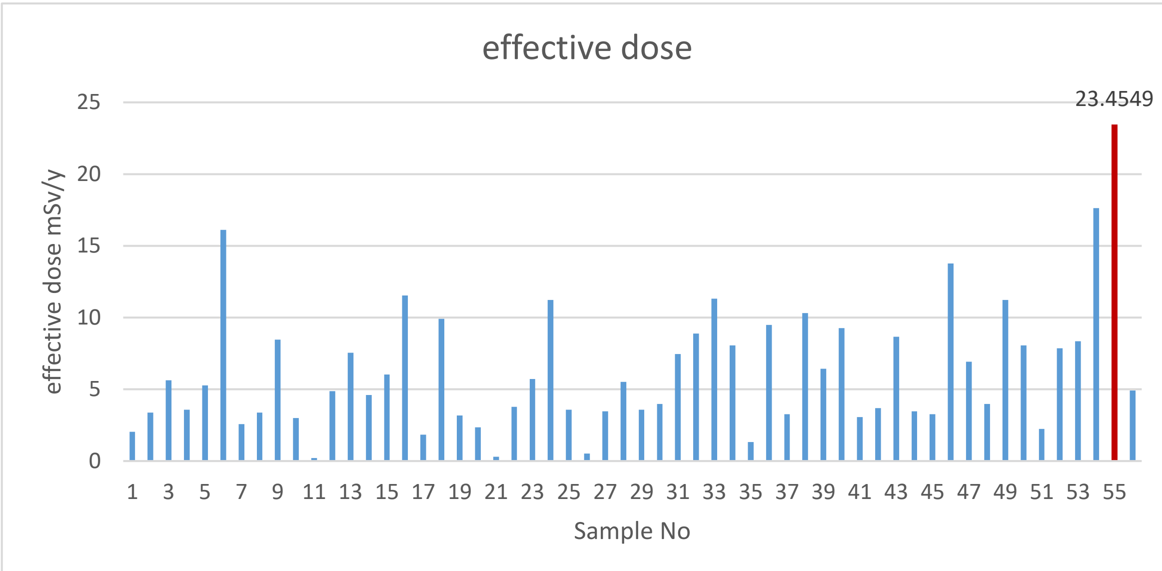


Figure 4.2: Scheme of the Annual effective dose of groundwater samples for the center and periphery of Al-Zubair district

It can be seen in Figure 2-4 above, which represents the pie chart for calculating the annual effective dose of 56 groundwater samples that were taken from artesian wells according to their locations shown in Table 3-1, that sample 55 has the highest reading of the effective dose for the same reasons I mentioned. For Figure 1-4 due to the difference in the depth of the well and the nature of the soil, Accordingly, we find that the annual effective dose rate in the groundwater of the Zubair region was within the permissible range of 1 mSv/y according to EPA.

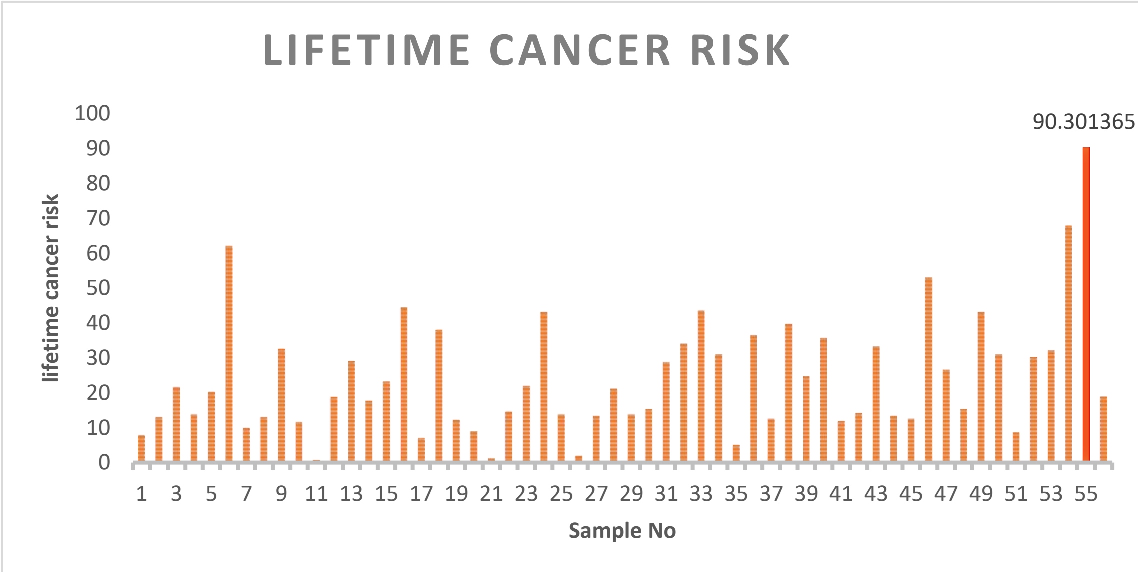


Figure 4.3: Results of Lifetime risk of cancer in groundwater samples in Zubair district

As can be seen in Figure 4.3 above, which represents the pie chart for calculating the incidence of cancer over the lifetime of 56 samples of groundwater taken from artesian wells according to their locations shown in Table 4-1, that sample 55 has the highest reading of cancer incidence for the same reasons. which I mentioned for Figure 4-1 due to the difference in the depth of the wells and the nature of the soil, Accordingly, we find that the factor of lifetime incidence of cancer in the groundwater of the Zubair region was within the permissible range of 0.2 according to the EPA.

The following are the radon concentration results that we obtained from the surface water examination of the Shatt al-Arab, as shown in Table (4-2). The average concentration was highest in samples 1, 13, 18 and 20, where it was (0.16 Bq/L), followed by sample 19 with a concentration rate of (0.159 Bq/L). Followed by sample 12 (0.12 Bq/L) and samples 2.6,9,16 less than it (0.08 Bq/L). The concentration decreases in samples 3, 4, 5, 11 and 17 by (0.04 Bq/L), and the value decreases to the lowest possible in the rest of the samples because the RAD7 device could not read it, as shown in the location of each sample in the table. The results of the rate of radon concentration in surface water were compared with the results of studies that preceded this study, the results of the examination of surface water samples taken from the Shatt al-Arab showed that there is a difference in the results of measuring the samples according to their different locations, the reason for the difference is the geological nature of the Earth.

Table (4-2) The concentration of radioactive radon gas in selected samples of Shatt al-Arab waters from the Qurna district to Karmat Ali

Sample No.	Mean (Bq/L)	High (Bq/L)	Effective dose μSv/y	Lifetime cancer risk x10^{-3}
R1	0.16±0.021	0.48	0.0011	0.0041
R2	0.08±0.014	0.16	0.0006	0.0021
R3	0.04±0.010	0.16	0.0003	0.0010
R4	0.04±0.010	0.16	0.0003	0.0010
R5	0.04±0.010	0.16	0.0003	0.0010
R6	0.08±0.014	0.16	0.0006	0.0022
R7	0	0	0	0
R8	0	0	0	0
R9	0.08±0.014	0.16	0.0006	0.0022
R10	0	0	0	0
R11	0.04±0.010	0.16	0.0003	0.0010
R12	0.12±0.018	0.32	0.0008	0.0033
R13	0.16±0.021	0.32	0.0011	0.0043
R14	0	0	0	0

R15	0	0	0	0
R16	0.08±0.014	0.318	0.0006	0.0022
R17	0.04±0.010	0.159	0.0003	0.0011
R18	0.16±0.021	0.318	0.00112	0.0044
R19	0.159±0.02	0.318	0.0011	0.0043
R20	0.16±0.021	0.48	0.0012	0.0043
Maximum	**0.16**		**0.0012**	**0.0043**
Mean	**0.072**		**0.0005**	**0.0019**
UNSCEAR,2018)	**11.1B q/L**		**1mSv/y**	**0.2**

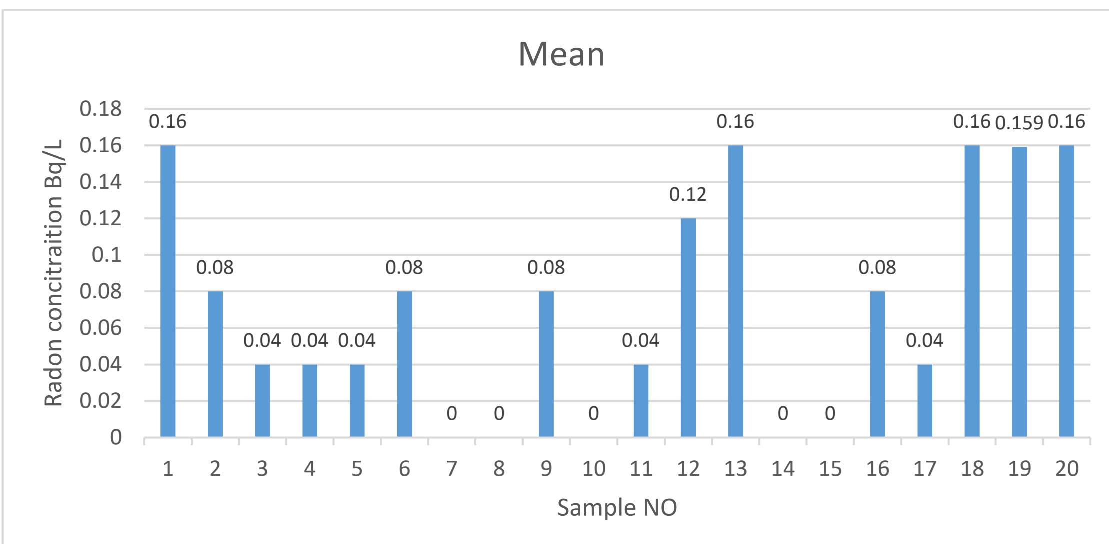


Figure (4.4): Compering ^{222}Rn concentrations in water samples with permissible value for water samples

It is noted in the above Figure 4.4, which represents the radon concentration rate diagram for 20 samples of the surface water of the Shatt al-Arab from the first meeting in the Qartah district to the second meeting in Karmat Ali in the Basra

Governorate, southern Iraq, as shown in the geographical location of the samples, as the highest concentration was in the samples 1, 13, 18 and 20, and very slightly less in sample 19, and it decreases in sample 12, then less than it in samples 2, 6, 9 , 16, and the decrease continues at the same level in samples 3, 4, 5, 11 and 17 until it reaches less in the samples. 7, 8, 10, 14 and 15 so that RAD7 cannot sense the concentration in these samples. This difference is attributed to the biological nature of the land and the location from which we took the samples, as the samples were taken from the cliff and from the middle of the river, and therefore the surface waters of the Shatt al-Arab do not pose any health risks because they are less than the levels mentioned by the competent authorities, which is 11.1Bq/L according to the EPA.

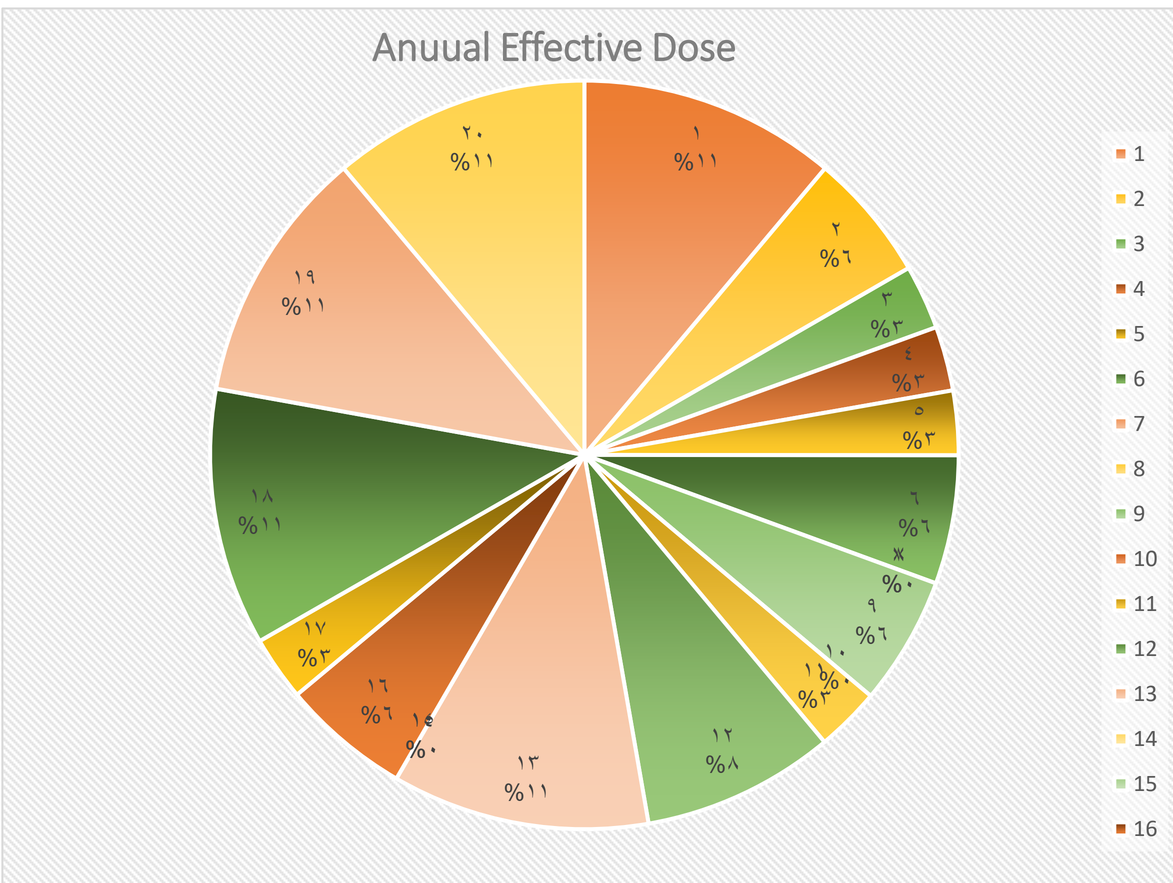


Figure (4.5): Percentage of AED in samples under study

It is noted in the above Figure 4.5, which represents the pie chart of the planar effective dose of 20 samples from the surface water of the Shatt al-Arab, as mentioned above, as shown in the geographical location of the samples. The highest value of the dose was in the above-mentioned samples in the same order, because the dose depends on the radon concentration, Thus, we find that the annual effective dose of Shatt al-Arab water was within the permissible range of 1mSv/y according to EPA.

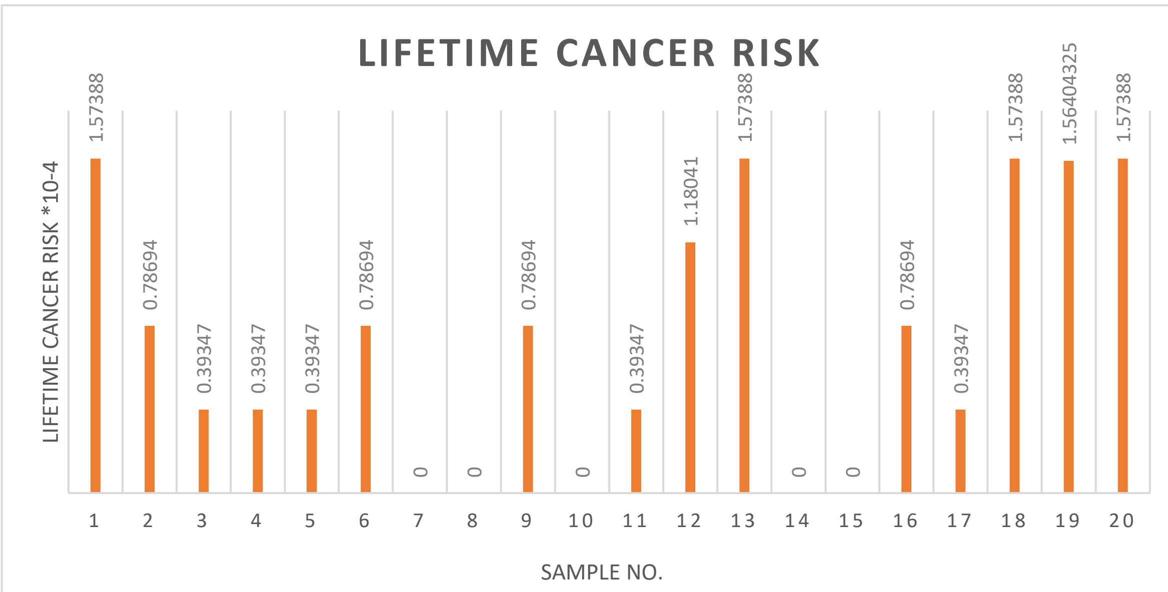


Figure (4-6): Results of lifetime cancer risk in samples under study.

It is noted in the above Figure 4-6, which represents the pie chart of the lifetime incidence factor of cancer for 20 samples from the surface waters of the Shatt al-Arab from the first to the second confluence, as indicated in the geographical location of the samples. The highest value of the incidence factor in the above-mentioned samples was in the same order of radon concentration and the effective dose because the incidence of the disease depends on the annual effective dose and the age of the person, Accordingly, we find that the lifetime factor of cancer in the waters of the Shatt al-Arab is within the permissible limit set by the competent authorities.

We compared the results of our current groundwater study with the results of other studies in Iraq as shown in Table (4-3).

Table (4-3) The average concentration of radon gas in the ground waters and surface waters in some areas of Iraq, compared with current study.

Regions of Iraq	Radon concentration Mean Bq/L	Reference
Karbala, Iraq	(4.152±2.20)	[16]
Iraqi Akashat	(0.035±0.0124)	[30]
Nineveh Iraq	(36.1±17.4)	[13]
Sulaymaniyah Iraq	(7.589±1.184)	[12]
Al -Haidariya Najaf Iraq	(0.276)	[32]
Dhi Qar Iraq	(0.40±0.205)	[27]
Hilla River	(0.115 ± 0.048)	[10]
Karbala	(2.508±0.09)	[17]
Basra River Karma	(0.312±0.196)	[23]
Al-Khora River, Basra	(16.217±0.097)	[23]
Najaf al-Haydariyya (surface water)	(0.182)	[32]
Najaf al-Haydariyya (drinking water)	(1.320)	[33]
Modern Anbar	(0.0310±0.0091)	[28]
current study { Zubair, Iraq	(9.18±0.08)	
current study { Basra Shatt al – Arab	(0.16±0.04)	

It is noted the discrepancy between the rates of concentration of radon gas in the groundwater between the Iraqi regions. Nineveh is the highest concentration of radon, being a rocky mountainous region, followed by the province of Basra and the Zubair region. In the current study, it is in the third rank in groundwater, followed by Karbala, then Sulaymaniyah, then Al-Haydaria, Al-Tajf, then Dhi Qar as is It is shown in Table 4-4. As for the surface water, the Basra Governorate in the Al-Khoura River records the highest concentration of radon, followed by Karbala, then Al-Haydaria, Al-Najaf in drinking water, then the Al-Karma River in Basra, then the Hilla River, then the Shatt Al-Arab water in the current study, and finally Al-Anbar. This discrepancy is due to the nature of the soil and rocks.

Table (4-4) Concentration of Pb and Cd in groundwater samples.

Samples No.	Pb concentration in groundwater mg/L	Cd concentration in groundwater mg/L
S1	0.4889±0.0013	0.0002±0.0001
S2	0.1467±0.0007	0.0252±0.0003
S3	0.2445±0.0009	0.0000
S4	0.1467±0.0007	0.0001±0.0001
S5	0.0978±0.0006	0.0008±0.0005
S6	0.1956±0.0008	0.0005±0.0003
S7	0.0000	0.0315±0.0003
S8	0.0000	0.0063±0.0001
S9	0.0000	0.0057±0.0001
S10	0.0978±0.0006	0.0210±0.0002
S11	0.0000	0.0004±0.0001

Contain Table (4-4)		
S12	0.3423±0.0011	0.0084±0.0001
S13	0.3423±0.0011	0.0008±0.0001
S14	0.1467±0.0007	0.0001±0.0001
S15	0.3423±0.0011	0.0000
S16	0.1467±0.0007	0.0042±0.0001
S17	0.0978±0.0006	0.0063±0.0001
S18	0.0489±0.0004	0.0008±0.0001
S19	0.0000	0.0294±0.0002
S20	0.0489±0.0004	0.0231±0.0001
S21	0.0000	0.0336±0.0001
S22	0.1956±0.008	0.0007±0.0001
S23	0.2934±0.001	0.0105±0.0001
S24	0.0978±0.0006	0.0005±0.0002
S25	0.0978±0.0006	0.0006±0.0001
S26	0.2445±0.0009	0.0189±0.0001
S27	0.5387±0.0001	0.0252±0.0001
S28	0.3423±0.0011	0.0008±0.0002

Contain Table (4-4)		
S29	0.0003±0.0011	0.0546±0.0002
S30	0.0978±0.0001	0.0147±0.0001
S31	0.0005±0.0006	0.0003±0.0001
S32	0.3423±0.0001	0.0546±0.0002
S33	0.3423±0.0011	0.0002±0.0001
S34	0.0010±0.0006	0.0002±0.0001
S35	0.0978±0.0006	0.0252±0.0001
S36	0.1467±	0.0004±
S37	0.5378±0.0002	0.0000
S38	0.4889±0.0003	0.0001±0.0001
S39	0.0001±0.0001	0.0003±0.0001
S40	0.3423±0.0011	0.0336±0.0003
S41	0.0015±0.0001	0.0336±0.0003
S42	0.0000	0.0001±0.0002
S43	0.0489±0.0004	0.0000
S44	0.0004±0.0001	0.0002±0.0001
S45	0.1467±0.0007	0.0045±0.0003

Contain Table (4-4)		
S46	0.0978±0.0006	0.0105±0.0002
S47	0.0978±0.0002	0.0441±0.0003
S48	0.0005±0.0001	0.0231±0.0004
S49	0.2934±0.0009	0.0273±0.0003
S50	0.2445±0.0007	0.0399±0.0005
S51	0.3423±0.0011	0.0001±0.0001
S52	0.2445±0.0009	0.0000
Mean	**0.015±0.008**	**0.166±0.002**
(IAEA,2018)	**10**	**0.06**

In this chapter, the heavy elements, lead and cadmium, were examined in 52 samples of groundwater from artesian wells in the center and periphery of the city of Zubair. High scores. In sample 27 and sample 37 (0.5378 mg/L), followed by the value (0.4889 mg/L) in samples 1 and 38, followed by (0.3423 mg/L) in samples 12, 13, 15, 28, 32 and 40, and the concentration gradually decreases in the remaining samples until it decreases to 0

As for the cadmium concentration, the highest concentration was (0.0546 mg/L) in samples 29 and 32, followed by (0.0441 mg/L) in sample 47, followed by (0.0399 mg/L) in sample 50, followed by (0.0336 mg/L) , in samples 21, 40 and 41the concentration gradually decreases in the rest of the samples until it reaches zero.

4.3 Conclusions

From the results obtained in the current study, the following can be concluded:

1- The average concentration of radon gas in groundwater is within the permissible levels according to the EPA, where the average radon concentration was 2.473 Bq/L.

2- The presence of a high concentration of radon gas in the surface waters of the Shatt al-Arab is low compared to the groundwater, where the average concentration of radon gas was 0.073, which is much less than the permissible value according to the EPA.

3- The average of effective dose for all samples is within the permissible range according to the UNSCEAR.

4- The average for the lifetime cancer risk for most of the samples are within the range allowed by the UNSCEAR.

5- The study showed that there is no radioactive contamination in the study area in most of the sites from which samples were taken with heavy elements (cadmium, lead).

6- The validity of water for irrigation and daily use because most of the sites do not exceed the permitted environmental standards despite the contribution of untreated sewage water in addition to the civil waste from residential neighborhoods on both sides of the river as well as the impact of agricultural drainage water.

7- Overall, based on the results obtained in this research, the concentrations of radon gas and toxic heavy elements in groundwater and surface waters in Al-Zubair district and the Shatt Al-Arab are within acceptable limits according to the

Environmental Protection Agency. This suggests that the water sources in the area are relatively safe for various uses, including irrigation, washing, showering, and drinking after appropriate treatment and desalination in remote areas. However, continued monitoring and regular testing of water quality are important to ensure the ongoing safety of these water sources and to detect any changes or potential risks in the future.

4.4 Future Work

1- Studying radon and thoron gas concentrations in soil and air in the same study area using RAD 7.

2- Generalizing the current study at the governorate level and making a map of radon gas concentrations in Basra Governorate as a prelude to making a map in the governorates of Iraq as a whole, similar to the rest of the world.

3- Use other techniques to study the same study area and compare the results.

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الخلاصة

تضمنت هذه الدراسة جزأين، الأول كان قياس تركيز غاز الرادون في عينات المياه الجوفية في منطقة الزبير بـ ٥٦ عينة، وأيضا قياس غاز الرادون في مياه شط العرب بـ ٢٠ عينة من نقطة تكوينه الأولى. من التقاء نهري دجلة والفرات في قضاء القرنة إلى التكوين الثاني، حيث يصب نهر الفرات مرة أخرى في شط العرب في كرمة علي بمحافظة البصرة، باستخدام كاشف الحالة الصلبة الإلكتروني RAD7.

أظهرت النتائج أن تركيز غاز الرادون في عينات المياه الجوفية تراوح من ٠,٠٨ إلى ٩,١٨ بيكريل/لتر بمتوسط ٢,٤٧١ بيكريل/لتر، وأن الجرعة الفعالة السنوية لتعرض الإنسان تراوحت من ٠,٠٠٠٦ إلى ٠,٠٦٤٣ ميكروسيفرت/ سنة بمتوسط ٠,٠١٧٣ ميكروسيفرت / سنة. تراوحت معدلات الإصابة بالسرطان مدى الحياة من ٠,٠٠٢٢ إلى ٠,٢٤٧٤ بمتوسط ٠,٠٦٦٥.

وفي المياه السطحية لشط العرب، بلغ معدل غاز الرادون في الماء ٠,٠٧٢ بيكريل/لتر، ومتوسط الجرعة الفعالة السنوية ٠,٠٠٠٥ ميكروسيفرت/ سنة، في حين بلغ متوسط خطر الإصابة بالسرطان مدى الحياة ٠,٠٠١٩. لذا فقد تبين أن تركيز غاز الرادون في عينات المياه الجوفية والسطحية يقع ضمن الحدود الطبيعية التي حددتها المنظمات المتخصصة. الحد الأقصى المسموح به لتركيز الرادون في الماء هو ١١,١ بيكريل/لتر، والحد الأقصى للجرعة الفعالة السنوية هو ١ ملي سيفرت/سنة، وفقًا لما حددته وكالة حماية البيئة.

أما الجزء الثاني من هذه الدراسة فقد تضمن تحديد العناصر الثقيلة في ٥٢ عينة من المياه الجوفية من العينات المدروسة لكل من الرصاص والكادميوم باستخدام جهاز الامتصاص الذري AAS، وأظهرت النتائج أن نسبة الرصاص تراوحت من (٠,٠ إلى ٠,٥٣٧) عند المتوسط الحسابي. ٠,١٦٦ ملغم/لتر كما تراوح تركيز الكادميوم من (٠,٠ إلى ٠,٠٥٤) عند الوسط الحسابي ٠,٠١٥ ملغم/لتر. أشارت النتائج إلى أن مستويات تراكيز الرصاص والكادميوم المذاب في مصادر المياه التي تم فحصها تقع ضمن الحدود الطبيعية المحددة من قبل المنظمات المتخصصة، ولا تشكل أي مخاطر صحية كبيرة.

جمهورية العراق
وزارة التعليم العــالي والبحث العلـمي
جامــعة بابـــل
كليـــة التربية للعلوم الصرفة
قســـم الفيزيـــاء

دراسة تراكيز غاز الرادون والمعادن الثقيلة في نماذج مختارة من المياه في الزبير، البصرة / العراق

رسالة مقدمة

إلى مجلس كلية التربية للعلوم الصرفة في جامعة بابل

وهي جزء من متطلبات نيل درجة الماجستير

في التربية /الفيزياء

من قبل

محمد ضرب شعبان كزار

بكالوريوس فيزياء / جامعة البصرة **1994** م

بأشراف

أ. م. د. أنعام هاني كاظم

أ. م. د. فاطمة محمد حسين

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