Deanship of Graduate Studies

Al-Quds University

Measurement of Radioactivity in Some Liquid Foodstuffs Samples Collected from Palestinian Markets

Anwar Mohammad Ali Al-Jaradat

M.Sc. Thesis

Jerusalem/Palestine

1445/2023

Measurement of Radioactivity in Some Liquid Foodstuffs Samples Collected from Palestinian Markets

Prepared By:

Anwar Mohammad Ali Al-Jaradat

B.Sc.: Palestine Polytechnic University, Palestine

Supervisors:

Prof. Khalil M. Thabayneh Physics Department 'Hebron University'

Co-Supervisor : Dr. Husain Alsamamra 'Al-Quds University'

"A thesis Submitted to the Faculty of Science and Technology, Al-Quds University in Partial Fulfilment of the Requirements for the Degree of Master of Science in Physics"

Jerusalem/Palestine

1445/ 2023

Al Quds University

Deanship of Graduate Studies

Physics Department

Thesis Approval

Measurement of Radioactivity in Some Liquid Foodstuffs Samples Collected from Palestinian Markets

Prepared by: Anwar Mohammad Ali Al-Jaradat

Registration No.: 21811837

Supervisor: Prof. Khalil M. Thabayneh 'Hebron University'

Co-Supervisor: Dr. Husain Alsamamra

Master thesis submitted and accepted Date: 26/07/2023

The names and signatures of the examining committee are:

1. Head of Committee: Dr. Husain Alsamamra ……………… Signature
2. Supervisor: Prof. Khalil M. Thabayneh……………………Signature
3. Internal Examiner: Dr. Hazem Doufesh ………………. Signature
4. External Examiner: Dr. karam Awawdeh……………… Signature

Jerusalem / Palestine

1445/ 2023

Dedication

To Salma

Declaration

I certify that this thesis submitted for the degree of the master is the result of my research, except where otherwise acknowledged, and that this thesis, neither in whole nor in part, has been previously submitted for any degree to any other university or institution.

Signed: Anwar

Anwar Mohammad Ali Al-Jaradat

Date: 26 /07/ 2023

Acknowledgements

First I want to thank God for providing me to give me the ability to complete this task, I'd like to thank my supervisor, from Hebron university Prof. Khalil Thabayneh, for his help, to guide and support me from the beginning of the study idea through the completion of this task, I'd also to thank Dr. Husain Alsamamra For the help and support he gave me, I'd also like to thank Hebron University and laboratories.

Abstract

Radon has been identified as one of mankind's health dangers because long-term radon exposure raises the risk of getting lung cancer. The objectives of this thesis to measurement the concentration of radon and radium in 57 samples of liquid foodstuffs collected from different markets from West Bank and describes radioactivity as an alpha particle created by the decay of radium to radon, by using passive technique - Solid State Nuclear Detectors SSNTDs $(CR39)$ which were etched chemically after 90 days of exposure by using $6.25\,M$ of $NaOH$ at 70°, then optical microscope was used to calculate the average number of tracks per unit area then calculated the radon concentrations , the effective radium contents, the annual effective Dose for inhalation and ingestion of radon and effective dose equivalent.

This study showed the results of both the concentration of radon and radium, and it was as follows; The results of radon concentration levels in fruit juice samples are getting between 51.0 Bq/m^3 to 278.8 Bq/m^3 and the concentration of radium getting between 0.714 Bq/kg to 3.90 Bq/kg . The results of radon concentration levels in milk samples are getting between 61.2 Bq/m^3 to 258.4 Bq/m^3 , the concentration of radium getting between 0.85 Bq/kg to 3.61 Bq/kg with average 2.6 Bq/kg . The results of levels of radon concentration in soft drinks and other liquid foodstuffs samples are getting between 64.6 Bq/m^3 to 224.4 Bq/m^3 , and the concentration of radium getting between 0.90 Bq/kg to 3.14 Bq/kg .

The obtained values show that the levels of radon and radium concentration of all samples are less than the safe limits as recommended by ICRP, there is no health hazards related to radiation.

List of contents

List of Tables

List of Figures

Abbreviations

WHO	World Health Organization
EPA	Environmental Protection Agency
ICRP	International Commission on Radiological Protection
EU	Council of Europe Union
IAEA	International Atomic Agency
H_{inh}	annual effective dose of inhalation in liquid foodstuffs
H_{ing}	annual effective dose of ingestion in liquid foodstuffs
AED	Annual Effective Dose
$CR39$	Track detector (Plastic Nuclear)
SI	International System
SSNTDs	Solid-State Nuclear Track Detectors
Ci	Curie
Bq	Becquerel
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation

Chapter One

Introduction

1.1 Definition of Radiation

Radiation is the release or energy in form of waves or high speed particles (photons) over empty space or over some medium that form up the electromagnetic spectrum and are created by particle interactions with matter or by the radioactive disintegration of unstable atoms (radionuclides). The incoming particle and the material it strikes both determine the type of radiation emission. [1,2].

There are many kinds of radiation all around us, this contain some radiation consists of particles that have mass and energy , and may or not have an electric charge like alpha (α), beta (β), neutrons and protons particles , electromagnetic radiation consists of particle that have energy but does not have mass or charge as qualified by quantum theory is called, "photons" or "quantum", that contains a discrete quantity of electromagnetic energy which travels at the speed of light ($3 \times 10^8\, m/s$) like gamma radiation (γ) radio waves, x-rays , visible light , ultraviolet , and infrared ,microwaves. [3,4].

The word "radiation" originates from the phenomenon of traveling waves outwardlye in all directions (waves radiate) from a source [3]. The most popular unit of energy is the electronvolt (eV) which used to express radiation that used in nuclear and atomic physics, equal to the kinetic energy acquired by an free electron when the electron's electrical potential reises by one volt [5,6].

1.2 Types of Radiation

Radiation can be classified to two kinds ionizing or non-ionizing, depending on its energy (frequency of the radiation) and ability to penetration of matter [7].

1.2.1 Ionizing radiation

Ionizing radiation is kind of radiation that has enough energy to eject electron from the last orbit out of orbital (to break chemical bonds) leading to the formation of ions., to be a free electron not bounded to the nucleus. The atom then returns as an ion that is positively charged. [8].

- **Types of Ionizing Radiation**

Radioactive materials release three types of ionizing radiation: alpha (helium nuclei), beta (often electrons), and gamma rays.

Three different kinds of ionizing radiation are emitted from radioactive materials: alpha (helium nuclei); beta (usually electrons); and gamma rays.

Alpha particles are positively charge particles helium nuclei (two neutrons and two protons and charge positive 2), Alpha particles are ordinarily arise from the radioactive decay of the heavy radioactive elements like (polonium-210 , radium-226, and uranium-238) with a velocity of roughly 0.05 that of the speed of light and with energy ranging from $4\ to\ 9$ MeV to ionize matter when they deviate due to a nucleus' positive charge and drag its orbital electrons with them. [9].

To assess and contrast the ionizing powers of charged particles by useing the term specific ionization, is identified as number of pairs of ions per unit path length created by ionizing radiation.

$$Specific\ ionization\ =\ No\ of\ ion\ pairs\ formed\ /\ path\ length\ (cm)$$

And is affected by each of its energy (the mass and velocity of the charged particle), the particle's charge as well as the density of the absorbent material (the quantity of atoms available for ionization).

i. **Alpha particles** have little ability to penetrating things and can be stopped through the first layer of skin or a thin sheet of paper. Because their relatively have large size and electrical charged $+2$ is high and little velocity
nd alpha particle has very high specific ionization, alpha particles collide easily with material and lose their energy fast to produce ion pairs in a short path, and downs all of its energy in a very short distance [10].

ii. **Beta particles** consists of negative charged that can arise from the disintegration of any radioactive nuclei. And that are physically identical to electrons. So Beta particles have a negative charge are easily stopped by skin. Beta particles typically offer minimal risk to individuals unless they are swallowed or breathed.

As do alpha particles , Beta particles cause direct ionization of the matter it passes through, their biological effects are not as strong as those of alpha particles(but cause less harm over distances that are equal), because of their low ionization density . Penetrating power of beta particles is also weakly but more deeply than of alpha-particles, and external exposure to beta particles could influence the skin and under the skin tissue.

Compared to alpha particles, beta particles are significantly less heavy and charged. /And they have a longer range of penetration than alpha particles because they interact less intensely with the atoms in the materials they pass through..

The skin can be penetrated by beta particles, which can lead to radiation burns.

Similar to alpha emitters, beta emitters are most hazardous when breathed, consumed, or absorbed into the blood stream through wounds.

iii. **Gamma ray** is a packet of electromagnetic (or photon) radiation released from the nucleus pending radioactive decay and sometimes accompanied by emission of an alpha or beta particle., these rays have great penetrating power and can pass through the human body.

Gamma rays haven't a charge or mass and gamma radiation loses energy slowly, therefore interact with matter less intensely than ionizing particles.

Gamma rays have a long range of propagation. And depending on their starting energy, can propagate hundreds of feet. And in particular can present a risk from exposures outside to the body [7].

The following figure (1.1), shows the extent to which the three types of radiation to penetrate materials.

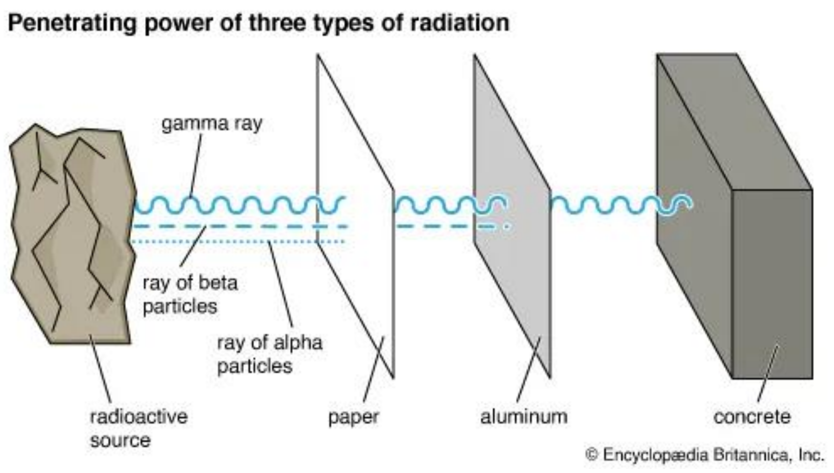


Figure (1.1) Power of Penetrating three types of radiation [12].

1.2.2 Non ionizing radiation

Is the second kind of radiation, it does not have sufficient energy to eject electrons from atom and produce ions , and that has a long wavelength. These are known as Extremely Low-frequency (ELF) waves, which have less energy than ionizing radiation and are not thought to be hazardous to human health.; Sunlight, infrared, radio waves, microwaves, and visible light are all examples of nonionizing radiation. [11, 12, 13].

1.3 The Effects of Ionizing Radiation

Regardless the radiation is come from nature or human-made, regardless it is a little dose of radiation or a big dose, there will be some effects exposure, dependant to the amount of dose, radiation kind, and the duration of radiation exposure. [12,13,16].

The transfer of energy to atoms and molecules within the cellular structure causes damage to live tissue.

Atoms are led by ionizing radiation to become excited or ionized. These ionizations and excitations can: output free radicals, shatter chemical ties, output new chemical bonds between macromolecules and Damage molecules that regulating vitality cell processes (e.g. proteins, RNA, DNA).

Radiation bring about ionizations of atom, which may influence molecules, organs, tissues, Cells, and the entire body [16].

Radiation could impact organism by destruction the cells that build the living organism. Radiation impacts on a cell are randomly. That is, the same cell could be exposed to the same sort and amount of radiation multiple times with varying results, including no results.

The chance of impacts increases whenever more radiation that shots a cells, then organism may be destruction or even die [17,18].

There are four possible impacts on the cell while a cell absorbs radiation:

1. The cell may sustain sufficient destruction to cause lose its ability to operate function, then the cell will perish.
2. The cell may lose its susceptibility to recreate itself.
3. The DNA damage could modify subsequent cell copies, which could lead to the evolution of cancer.

Rapidly dividing cells, such as those found in fatal tissues, are more susceptible to radiation than other cells, for this reason the foetus is sensitive to radiation [14].
Another example is a Cancerous tumours are eliminated through radiation therapy, and this results in radiation damage that is often repaired by the cells, but if the cell divides into two identical cells before it has time to repair the radiation damage, the new divided cells may differ from the original copy [18].

Radiation can have many different affects on the body, and these effects on health might take years to become apparent. These effects range from minor ones like skin reddening to grave ones like cancer and death. These effects depend on the type of radiation, the Dose (how much radiation was absorbed by the body) , whether the exposure was internal or external, and how long the person was exposed. Ionizing radiation has the potential to harm any living tissue within the human body. The body tries to reform the damage, but occasionally it can't because it's too severe or extensive. The body's natural healing procedure, which it uses to try to fix the radiation damage (mutations), has the potential to make errors as well. [12]

Exposure to very high dose of radiation can result radiation illness, with symptoms decrease of appetite, hair loss, purge or even death within a few months. This is called **Acute Radiation Syndrome**. Exposure to lower doses of radiation enhanced the chance of later-life cancer development or other harmful health effects. [5].

1.4 Radioactivity

Is a phenomena in which an unstable atomic nucleus (parent nuclide) breaks down (decays) spontaneously to produce atoms of a different element (daughter nuclide). without imposing any external condition, such as temperature, pressure, chemical treatment, etc. , This decay is accompanied loses energy by emitting ionizing particles and radiation that takes the form of high energy waves and invisible tiny particles such as (Thorium, Uranium and Potassium) are examples of spontaneously substances radioactive in nature.

Radioactive is stochastic process on the atomic level, making it impossible to forecast when an atom will decay. However, given a large number of similar atoms, the rate of decay is predictable. [19].

Since the formation of the earth. It had radioactive isotopes in it. All isotopes that have short half-lives they got decayed, and those isotopes with very long half-lives (at least 100 million years) stayed, consist of thorium and uranium and their decay products, such as radon.

1.4.1 What causes radioactivity?

In nature, atoms of different materials are stable and unstable (when it has too many neutrons compared to protons, or vice-versa or if the nucleus has excess internal energy), For an atom to become stable, the forces acting between particles that shaped the nucleus will make an attempt to become stable, by ejection of nucleons (combination of neutrons and protons) from nucleus or emission energy in different forms. the nucleus will radiate a negative beta particle when it has too many neutrons compared to protons , resulting in a change of a single neutron within a proton and the nucleus will radiate a positron (positive charge particles) when the number of protons is more than neutrons in the nucleus, turning a proton to the neutron. Also, excessive of the nucleus will lead to emitting an alpha particle by dismissing the alpha particles. Also, a large quantity of energy in the nucleus will releases a gamma ray, which rejects large energy without replacing any particle in the nucleus. This process will go on until the forces between the particles to get balanced [12,13].

1.4.2 The radioactive decay law

The law of radioactive decay is the fundamental principle governing radioactivity. A radioactive nuclide that decays spontaneously at a rate depending on the quantity of initial atoms N_0 present and as well as its decay constant $(\boldsymbol{\lambda})$, is given by:

$$N_t = N_0 \ e^{-\lambda t} \quad \ldots\ldots\ldots\ldots\ldots\ldots. \qquad (1.1)$$

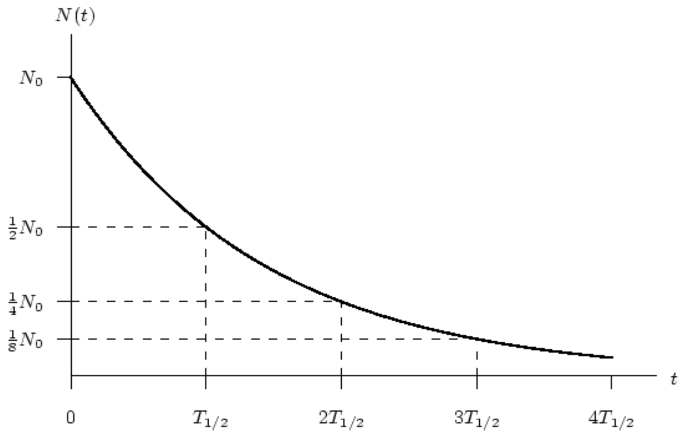


Figure (1.2): The exponential behaviour of a radioactive material's sample's number of nuclei N (t) vs time (t)[20].

1.4.3 The Activity

The $Activity\ A$ is represents as the number of decays of nuclei per unit of time (second) and it is measured in units Becquerel $(Bq) = [1/s]$. The old unit of activity, the curie, Ci ($1\ Ci\ =\ 3.7\ \times\ 10^{10}\ Bq$) [20].

$$A(t) = \frac{dN}{dt} = -\lambda N \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1.2)$$

1.4.4 Half –life and mean life time

Is the period time that take for a quantity to decreases to half of its initial value At the time $T1/2$ if we putting $N = 1/2\ N_0$ into the decay equation (1.1)

$$T_{1/2} = \frac{\ln 2}{\lambda} \qquad [\ln 2 = 0.693]$$

$$\lambda = \frac{0.693}{T_{1/2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1.3)$$

Mean life is the sum of the lifetime of all the atoms which then divided by the total number of atoms available, is given as:

$$\tau = 1/\lambda = T_{1/2}/ln\,2$$

1.4.5 Radioactive equilibrium

Each radionuclide in a decay chain reaches radioactive equilibrium when it decays at the same rate at which it is created, it is beneficial scientists to estimating the radiation exposure that will result current at different phases of the decay.

Each radionuclide in the decay chain reaches the radioactive equilibrium when its production and decay rates are equal. The condition in which the ratio between the activities of the subsequent members of the decay series remains constant is called equilibrium. [23].

The Equation that measures the parent nuclide's decay rate. (1.2) is,

$$\frac{dN_p}{dt} = -\lambda_p N_p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (1.4)$$

However, the daughter nuclide's net decay rate, which is also radioactive, is

$$\frac{dN_D}{dt} = \lambda_p N_p - \lambda_D N_D \ldots\ldots\ldots\ldots\ldots \ (1.5)$$

The daughter nuclide's rate of decay must be zero under equilibrium conditions, so equation (1.5) turn into

$$\lambda_p N_p = \lambda_D N_D \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (1.6)$$

Radiation equilibrium is of two types , the first type is called secular equilibrium , in this type the half-life of parent is too greater than half-life of daughter by a factor of 10^4, for example uranium-238 integration series

$$U^{238} \xrightarrow{\alpha} Th^{234} \xrightarrow{-\beta} \ldots\ldots\ldots\ldots\ldots\ldots$$

$4.5 \times 10^9 years$ 24.1Hours

In this case there is so much great differ between half-life of parent (in years) and half-life of parent (in days).

The second type of equilibrium is transient equilibrium, in this type the half-life of parent and daughter differ by small fraction, for example thorium234 integration series

$$Th^{234} \xrightarrow{-\beta} Pa^{234} \xrightarrow{-\beta} \ldots\ldots\ldots\ldots\ldots\ldots$$

24.1 d 1.18 min

In this case there is few differ between half-life of parent (in days) and half-life of parent (in minutes).

In a long decay chain, such as $U - 238$ series to a stable Pb atom, as long as the daughter atoms are not separated from the chain, radioactive equilibrium will finally be established, and a decay of a $U - 238$ will be followed by a decay of each member of the decay chain, as they all have a shorter half life than the $U - 238$ atom.

Some separation from the decay chain may happen when the decay product is a gas, such as Radon. Radon then becomes the parent of its decay chain to a Pb atom, if the Radon atom is emitted into the drag out or ground floor of a house, it may then enter and go down in a person’s lungs, and set up its radioactive equilibrium there. If enough Radon is in the lung, the daughter products will rest or stay in the lung. That is the danger of high Radon levels in a home's ground level [24].

1.5 Radioactive Decay of a Radionuclide

Combinations of nucleons (protons and neutrons) make up nuclei; some of these nucleons, known as nuclides, are highly stable while others are only unstable, so Thus, radioactive nuclide it may be have a high ratio of n/p however else ratio might be low, A radionuclide may it have an even number of neutrons and odd number of protons , or vice versa. Depending on the type of instability and the nature of the nuclide, various mechanisms of decay are possible.

Unstable nuclei can turn by released of particles (α decay and emission of neutrons and protons) or by released of electrons ($\beta-$) or positrons ($\beta+$), or emission of photons (γ −rays), this transformation results the conversion of mass into energy, and then the transition energy is the overall mass-energy transformation amount. [25].

Electron mass can also turn into vitality in a few decay types. The transition energy is the whole mass-energy transformation sum. The majority of this energy is transferred to discharged particles as active energy or transformed into photons, with only a little amount being changed as kinetic energy. [26].

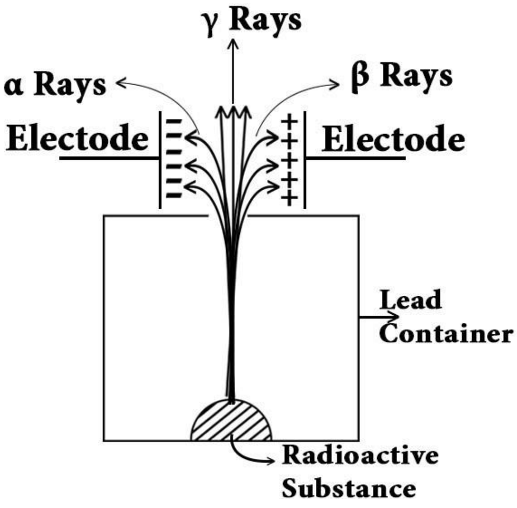


Figure 1.3: Separation of α, β and γ-rays in electric field [27].

The charge of each type is detected by placing them in electric field then passed through these fields. It was observed that the alpha particle deviated from straight line to the left (negative charge), also beta particle deviated from the straight line to the right (positive charge) and the γ-rays traverse through the field unaffected., This show that The $\alpha -$particles are positive charged particles, whereas the $\beta -$particles are negative and γ-rays have no charge.

1.5.1 Alpha Decay (*α*– Decay):

Alpha particles are positively charged and made up of two neutrons and two protons (helium nuclei), It has a weight of 4 atomic mass, this decay occur in the heaviest radioactive elements with $Z > 83.$, like uranium, radium and polonium[28].

The "mother" nucleus (M) is changed into a "daughter" nucleus (D) after alpha decay, having two fewer protons and neutrons than the mother nucleus.

A = atomic mass.

Z = atomic number.

Uranium-238 is the most common example of a nucleus that undergoes alpha decay [29].

$$^{238}_{92}U \longrightarrow \; ^{4}_{2}He + \; ^{234}_{90}Th$$

The daughter nucleus shifts two positions in the Periodic Table as a result of decays since it has two less protons and two fewer neutrons. [30].

Nearly all of the heavy elements with Z > 83 that emit alpha radiation naturally. For instance, when nuclei decay, the atomic number drops by two units and the mass number drops by four units.

$$Z^{A} \longrightarrow (Z-2)^{A-4} + {}^{4}_{2}He^{+2}$$

The Einstein formula for energy can be used to calculate the energy ΔE of alpha decay.

$$\Delta E = (m_1 - m_2 - m_\alpha)c^2 \; \ldots\ldots\ldots\ldots. (1.7)$$

where, correspondingly, $m_1, m_2 and\, m_\alpha$ are the nuclide masses of the mother and daughter nuclides and the alpha particle..

All nuclides with atomic masses more than 140 are unstable with regard to decay. Application of Eq. (1.7) reveals that the high binding energy of the four nucleons in the particle results from the relatively small binding energy of a particle in the nucleus. The nuclides with atomic masses more than 140 are unstable because decay cannot be observed because of the energy barrier that must be overcome by the particle because E is tiny [30].

Compared alpha radiation with other nuclear radiation, it has a higher mass and charge, which increases its ionization power but decreases its ability to penetrate materials. Alpha particles may only move a few centimetres in air. The starting energy of the particle affects the short distance of travel. As seen in figure 1.4 below, an 5.5 MeV alpha particle, such as the one released in the equation previously discussed, has a range of roughly 4 cm in air at standard pressure and temperature.

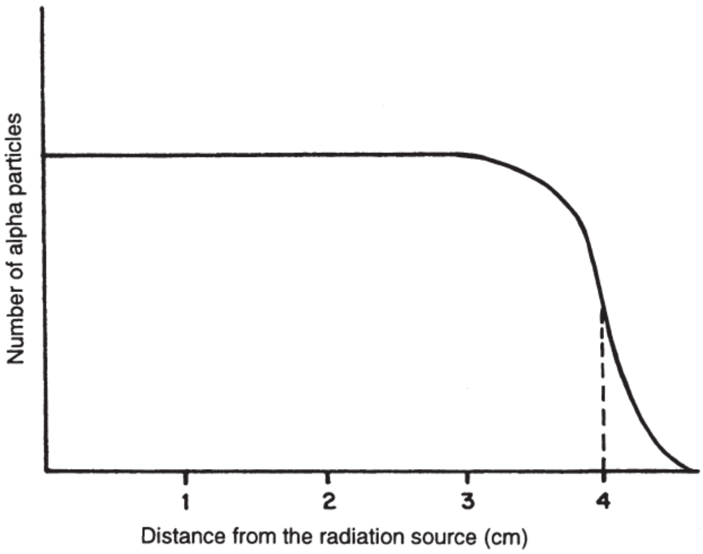


Figure (1.4): Range of 5.5 MeV α-particle in air [31]

1.5.2 Beta decay

A proton in a nucleus changes from a proton to a neutron (or vice-versa) in a radioactive process known as the **beta decay**. It occurs when a nucleus has either too few or too many neutrons for stability.

Common models of $\beta-$particles were found to curvature in an opposite direction, (as indicated in figure (1.3) separation of α,β and $\gamma-$rays in electric field), showing that $\beta-$radiation comprised of particles with a negative charge. These particles were observed to be scattered across the screen, indicating that they had velocities that reached as high as $0.99c$, which has longer ranges than alpha particles, and less ionizing properties than alpha particles. . The atomic number Z either increases by one or decreased by one as a result of the neutron converting into a proton or vice-versa. This process can be carried out in one of three ways [32].

The first way is called Negatron decay ($\beta-$ decay) A nucleus with neutrons to protons ratio N/Z greater the specified value from the stability curve (over great number of neutrons) can release one electron to change into a more stable nucleus.. This type of process is known as ***β− decay*** or **Negatron decay**, and the transformation can be symbolizes by

$$\boldsymbol{{}^{A}_{Z}X \longrightarrow {}_{Z-1}^{A}Y + e^{-} + \overline{v_e}} \quad \text{...........} (1.8)$$

$$n \rightarrow p + e^{-} + \overline{v}_e$$

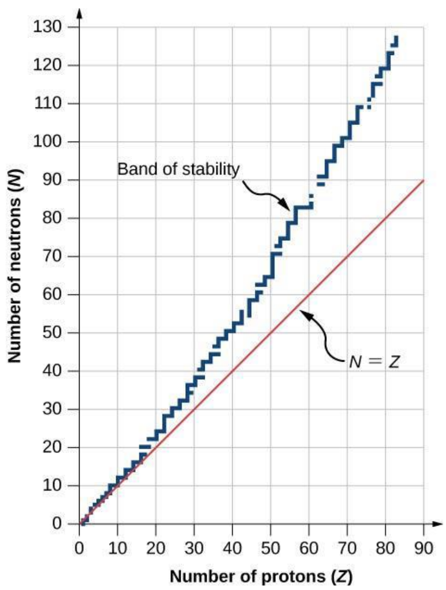


Figure 1.5 : stability curve [33].

Where ($\overline{v}_e$) is the anti Neutrino particle, (v_e) which has neither a mass nor an electrical charge, is a neutral particle.

The daughter nucleus's proton count rises by one unit as a result of the conservation of electric charge concept. The nucleon number, as indicated by equation (1.8), does not change. An example [33]:

$${}^{137}_{55}Cs \longrightarrow {}^{137}_{56}Ba + e^{-} + \overline{v}_e$$

The **second type** of beta decays is Positron decay ($\beta+$ decay), A nucleus with neutrons to protons ratio N/Z less than the specified value from the stability curve, these nucleus emits positively charged particle known as a positron is antiparticles of electrons, and another particle as a neutrino, and have properties similar to electrons but with a positive electric charge, which lowers the nuclear charge by one unit.

However, the nucleon number also doesn't change. This kind of process is known as "$\beta + - decay$" or "Positron decay", In this case, the transformation can be represented by

$$ {}_{Z}^{A}X \longrightarrow {}_{Z-1}^{A}Y + e^{+} + v_{e} \quad \text{....... (1.9)} $$

An example of this process is

$$ {}_{11}^{22}Na \longrightarrow {}_{10}^{22}Ne + e^{+} + v_{e} $$

The third type is the **electron captures** is process occurs a nuclear proton becomes a neutron and is concurrently converted when a proton-rich nuclide absorbs an inner atomic electron. This procedure, known as "electron capture," can be described as [32, 33]:

$$ p + e^{-} \longrightarrow n + v_{e} \quad \text{................ (1.10)} $$

$$ {}_{13}^{26}Al + e^{-} \longrightarrow {}_{12}^{26}Mg + v_{e} $$

1.5.3 Gamma Decay

Is the release of electromagnetic radiation of an extremely high frequency and energy, get rid of excess energy in order to stabilize the unstable nucleus, After an alpha or beta emission, most radionuclides leave the daughter nucleus in an excited state, When a nucleus is in an state of excitation, so it will transition to a lower energy (ground) state by release an electromagnetic radiation gamma ray until it reach to stable state in very short lifetimes (about $10 - 16\ sec$).

Gamma decay differ from alpha and beta decay, it does not include a change in the chemical isotope stay the same while the total energy (internal binding energy per nucleon) changes.

The formula that describing gamma decay can be written as

$$ {}_{Z}^{A}X^{*} \rightarrow {}_{Z}^{A}X + \gamma \quad \text{..................... (1.11)} $$

where $(*)$ pointing to an excited state. In most cases, the transition of the nucleus from an excited state with energy E_i to a less excited state with energy E_f is results in the energy of the photon released being E_{γ}:

$$ E_{\gamma} = E_i - E_f \quad \text{.................. (1.11)} $$

1.6 Decay Series

For heavy nuclei $Z > 81$ and substantial neutron excess that decay through a series of alpha and beta decays until it reaches a stabilization stage, it often happens that The daughter nuclei that have been created by radioactive decay once more to create other daughter nuclei, and so on, until ultimately a stable nucleus is left after numerous decay cycles. This process is called decay chain /series.

1.6.1 Decay Chain of Isotope Uranium-238

The Radium Series is the name given to the $U - 238$ chain. The elements in this series, which begins with the isotopes $U - 238$, are astatine, bismuth, lead, polonium, protactinium, radium, radon, thallium, and thorium [36,37,38].

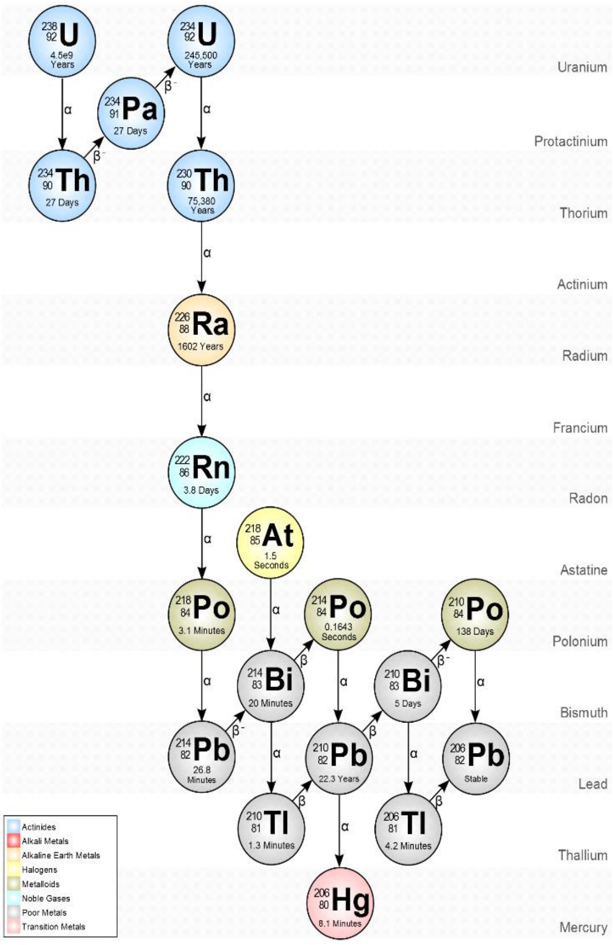


Figure (1.6): The Uranium-238 decay series[37].

1.7 Radiation Hazards

1.7.1 Types of Radiation Hazards

Radiation could kill or injury the tissues and cells. that's the result of interact of biological materials of ionizing radiation which causes interacts with intracellular molecules including DNA, the damage or harm depends on the intensity , radiation kind and total amount absorbed, depend specifically on how sensitive each organ and tissue.

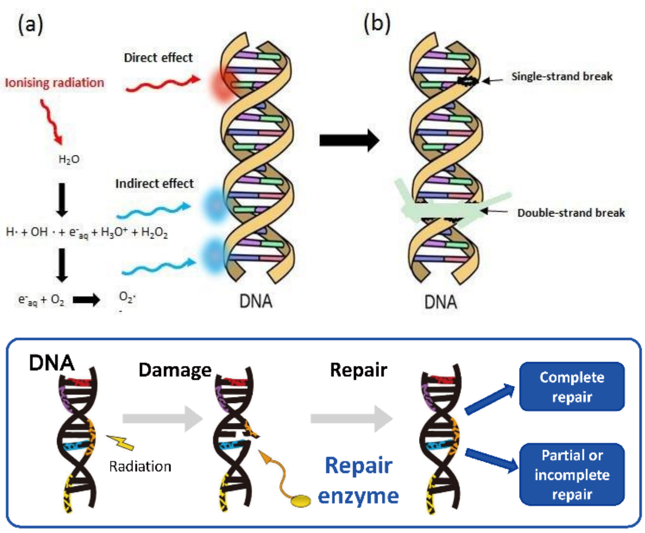
Impacts of radiation could be in form of two types in nature the first type is called deterministic, the second called stochastic as follows:

I. **Non-stochastic:** causes harm to populations of cells, has a threshold dose, and also increases in reaction intensity as dose is increased.

II. **Stochastic effects:** Genetic and malignant conditions for which the likelihood of an effect occurring without regard to its severity is regarded as a function of dose without a threshold [39, 40].

The dose rates radiation and dose levels linked with intake of pollution food are relatively low overall, and effects of radiation can happen just in severe cases.

Radiation damage can happen from direct interactions with DNA that changes its chemical structure, or it might result from interactions with cellular water that produce reactive oxygen species (ROS). Breaks DNA strands as well as other modifications to DNA or its bases are examples of damage. Most DNA rope breaks are effectively and accurately repaired, but in the case double strand breaks and some DNA base wounds may be left without do repaired or correctly repaired, causing mutations. Cell division and mutation later may begin the process that in the end result in cancer. The progeny may be affected if the altered cell is a reproductive cell [41, 42].



Source: Morgan, Annual Meeting of the National Committee on Radiation Protection and Measurements (NCRP) (44th, 2008)

Figure 1.7: radioactivity effects on DNA cells [42].

1.7.2 Radiation Dose Unit

Units of measurements are vary by ambient medium (water, air), below units are used to find the absorbed dose and also to explain the dose limits in the field of radiology, they are:

(i) Radioactivity

The radioactivity of a given amount of substance is the number of nuclear that decays that take place per unit of time, the standard international unit of Radioactivity used:
Becquerel (Bq) is the SI radioactivity.

$$1\,Bq\ =\ 1\,/\,s$$

Also, Radioactivity is measured in another unit called curies, is the original or old unit, and is the rate of disintegration in one gram of pure radium-226 per second. Where

(Bq) 1 $curie\ =\ 37\ billion\ Bq.$ One trillionth of a $curie\ =\ 0.037\ Bq,$ so

$1\ becqurel = 1\ raidioactive\ decay\ per\ second = 2.703 \times 10^{-11}$Curie.

(ii) Radiation energy

The unit electron volt (eV), is used to measure the energy of ionizing radiation where 1 eV is an incredibly little energy [43].
Another standard measurement of radiation energy is the "$Joule$" whereas

$$1\ eV = 1.602176634 \times 10^{-19}\ \text{Joule.}$$

1.7. 3 Absorbed dose (D)

Is a measure of the physical amount of energy that a substance has absorbed. Gray (Gy) is the SI unit for absorbed dosage. Where $1Gy = 1\ J\ kg^{-1} = 100\ rad$

$$D = \frac{\Delta E}{\Delta m} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 1.12$$

Where $\Delta m\,,\Delta E$ respectively is the mass of the material into which the energy is absorbed and the energy lost from the radiation beam.

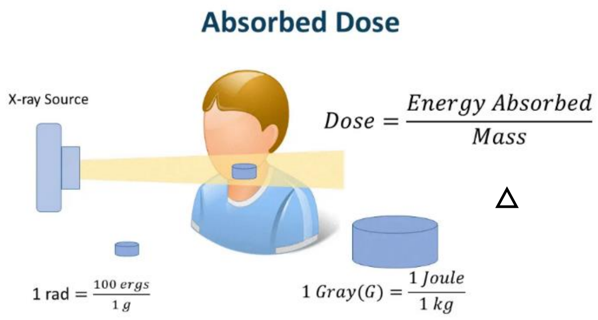


Figure (1.7): The concepts of absorbed dose[43].

1.7.4 Equivalent and Effective Dose of Radiation

The biological impacts of ionising radiation on quantity and quality of radiation, characteristics of tissue or organ. The unit Sievert is used to measure the biologically relevant dosage. The conversion of Gray into Sievert depends on the radiation type and organ. The terms used here are [42]:

(i) Dose equivalent (D_E):

The dose equivalent is the expression of the dose in terms of its biological impact. is determined by multiplying the radiation dosage absorbed by a $weighting\ factor\ Q$, where Q is Quality Factor of the relative biological effectiveness (RBE) of radiation[44].

$$DE = D\ x\ Q \ldots\ldots\ldots\ldots (1.13)$$

Table 1.1: Factors of Radiation

Type	relative biological effectiveness ($\boldsymbol{Q}$) (ICRP, 2007)
α-particles	20
Beta, X and γ rays	1
Electrons	1
protons	5
Thermal Neutrons	3
Slow neutrons and fast neutrons	5, 20

Weighting for ionizing radiation[42]

(ii) The effective dose (E)

The stochastic health risk to the entire body, which is the probability of cancer induction and genetic consequences, is represented by the tissue-weighted sum of the dosage equivalent in all tissues and organs of the human body.

$$E = \Sigma \; D_E \quad W_T \quad \text{.................}(1.14)$$

Table 1.2 Tissue Weighting Factors (WT) for some organs and tissues[42].

Tissue or Organ	Tissue Weighting Factor (W_T)
Gonads (testes or ovaries)	0.20
Colon	0.12
lung	0.12
Stomach	0.12
Breast	0.05
Liver	0.05
Skin	0.01
Bone surfaces	0.01

1.7.5 Exposure (X)

Concept of Exposure is the quantity most popular that used to determination the quantity of radiation delivered to a point (radiation concentration) when alpha, gamma ray photons or X-ray interact with air (ionization in air).

It is defined as the division of the total charge of the ions produced in air (dQ) by air of mass dm

$$X = \frac{dQ}{dm} \dots \dots \dots \dots \dots (1.15)$$

Roentgen (R) the traditional unit of exposure, identifies the quantity of energy absorbed by dry air. Named after the physicist Wilhelm Rontgen Nobel Prize in Physics, 1901), and the Sl unit of exposure is(C/kg).

$$1\ R\ =\ 2.58\ x\ 10^{-19}\ C/kg$$

1.7.6 Dose rate

Is the amount of radiation delivered or absorbed per unit time. It is mostly specified equivalent dose per time using the unit micro Gray per hour ($\mu Gy/h$).

Acute radiation is supplied over a short period of time (less than 24 hours) whereas chronic radiation is delivered over a longer length of time [48]. Figure below provides an illustration of the dose rate concept.

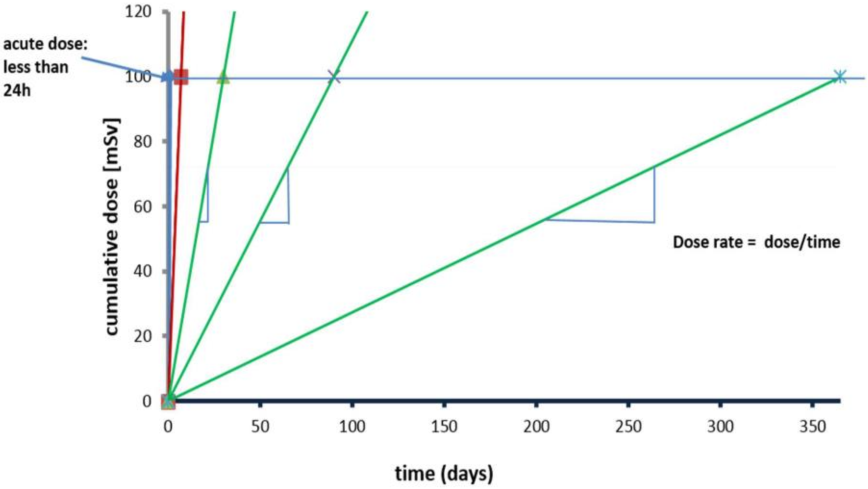


Figure (1.8): Acute dose (red line) or chronic dose (green lines) of the same cumulative dose of radiation. [49].

1.8 The Health Effects of Radiation

The energy from ionizing radiation is transmitted to the body of the organism and leads to the ionization of the atoms of the cells. Heavy charged and beta particles directly ionize the atoms of the cells when passing through them. The energy of gamma radiation or X-rays is transmitted to the electrons in the cell atoms and these electrons ionize, which leads to the formation of radioactive isotopes inside the body, and the radiation emitted by these isotopes leads to the ionization of the cells.

And whether the ionizing radiation comes from outside of body or results from contamination of the body from the inside with radioactive substances, this leads to the emergence of biological effects in the body that can appear later in the form of clinical symptoms.

Radiation interaction with a living cell When radiation falls on a living cell, some components of the cell, especially water molecules, are ionized, leading to chemical changes that lead to a alterations to the structure and function of the cell, and this takes place during several stages.

i. Physical stage

It takes place within a very short time, about 10 seconds from the moment the radiation enters the cell, and the radiation gives out energy that is passed to the water molecule and ionization occurs.

$$H_2O + Energy \longrightarrow H_2O^+ + e^-$$

ii. The physio - chemical stage

This stage takes place during a short time after the ionization occurs, and during this time the positive ions interact with the negative electrons that were formed as a result of ionization with other water molecules, resulting in these interactions with new compounds, such as the positive ion can decompose into a positive hydrogen ion and hydroxide as follows:

$$(H_2O)^+ \longrightarrow H^+ + OH$$

The electron can combine with a water molecule to form a negative water ion

$$H_2O + e^- \longrightarrow (H_2O)^-$$

Then this negative ion decomposes to form hydrogen and negative hydroxide ion

$$(H_2O)^- \longrightarrow (OH)^+ + H$$

The hydroxide can also combine with each other to form hydrogen peroxide

$$OH + OH \longrightarrow H_2O_2$$

iii. The chemical stage

Both hydrogen and hydroxide are characterized by their intense chemical activity. Hydrogen peroxide is also a strong oxidizing agent. When these compounds are in the cell, they interact with other organic compounds in the cell, such as chromosomes, leading to the breaking of their long chain structures.

iv. The biological stage

The time of this stage ranges from several minutes to several tens of years, and at this stage the effects of chemical changes that occurred in the cell begin to appear. Some of these effects are:

a. Death of a living cell
b. Preventing or delaying cell division or increasing the rate of growth and division
c. Permanent changes in the cell are transmitted genetically during cell division [50].

Chapter Two

Literature Review and Previous Studies

2.1 Some Radioactive Elements

2.1.1 Uranium

Uranium is a radioactive chemical a component of the actinide series in periodic table which was discovered and named in 1789, with atomic number 92 and an atomic weight of 238 g/mol, is a very high density, slightly paramagnetic, flexible, silver-white radioactive metal, is naturally radioactive, it decays too slowly (weakly radioactive) by releasing an alpha particle. The uranium is not very radioactive as evidenced by its low specific activity because the half-life of it is about 4.5 billion years, this the reason why uranium exist on the earth, exist in varied but negligible amounts in soils, water, air, plants, animals, and all people. Uranium is unique because its physical characteristics give it the potential to generate large amounts of energy [51, 52].

Natural uranium contains three primary radioactive isotopes with different numbers of neutrons, the first isotope Natural uranium, $U-238$, forms over 99% of the total mass or weight, the second isotope is $U-235$ with 0.72%, and a very small amount of $U-234$ is about 0.0054% and is produced by alpha disintegration of $U-238$, these isotopes have the same chemical characteristics, but they have different radiological properties, Earth's two most prevalent isotopes, $U-238$ and $U-235$, have been present since the planet's formation.. Uranium occurs in fertilizers and soils, so the element is present in food and human tissues [52, 53].

Uranium can be enter into the body by two ways, the first way by inhalation, the second way by eating food, drinking water, or respiration air, Absorption through the gastrointestinal tract from food or water is the main cause of internally deposited uranium in the general population, After ingestion, the majority of uranium emerges within a few days and does not enter the bloodstream. [52,54, 55].

2.1.2 Radon

Radon chemical radioactive noble gas, with atomic number 86 and atomic weight 222, is the product of decay series of uranium and radium as a transitional stage in the typical radioactive decays over thorium and uranium slowly decay into a variety of transient radioactive nuclides and lead, with half-life of only 3.82 days, this gas cannot be observed or seen or felt through the senses (taste, smell or sight) can only be detected using of special equipment and protocols because it is a radioactive noble gas that is colourless, invisible, odourless, and tasteless. Because is noble gas is not chemically reactive with most materials, so it will move freely as a gas throw the ground [56].

Radon's unique features as a radioactive gas, it use as a geophysical sensor for locating buried faults and structures geological, in exploring for uranium, and for forecasting earthquakes, and used as a tracer for studying of process of atmospheric transport. The radon has been various other applications in water research, meteorology and medicine [56. 57].

2.1.3 Radium

Radium is a radioactive element with atomic number 88, is was first discovered in 1898 by the chemists Marie curie and Pierre curie, is occur naturally in crusts of earth (soil and rocks) with little concentrations, and it is a silver-white heavy metal (when it is in pure form [58].

Radium exist in nature in different forms as isotopes 25 isotopes have been known, the two most common and abundant isotopes is the first $Ra-226$ is form as the product of decay in Ur−238 chains, the second isotope is $Ra-228$ is form as the product of $Th-232$ chains decay, the most radiotoxic radium isotopes are these two. [56, 59].

Radium exists widely in environment in generally with low concentrations in plants, animals, ground / surface water, soil, and rocks [58].

Radium was identifies as important pollutant in environment in 1950 [5], so is primary studied because its hazard of health human, this radioactive element can enter the body human by ingestion or by inhaled air the enter the bloodstream after several months after inhaled radium that remains in lung [56.58].

Radium has been used in radiography of metals in treating cancer, also the research and instrument calibration used it as neutron source with combined with other metals, in the past time radium was used in luminous of paints in watches and clock dials by mixed with fluorescent zinc sulphide and used for other instruments such as military, airplanes and compasses [56.58.60].

2.2 Characteristics of Radon

2.2.1 Physical and Chemical Properties of Radon

Radon ($Rn-222$) is chemical radioactive gas. It is created, then decomposes into the polonium isotope $Po-218$ via alpha decays, which further decays lead isotope, bismuth and polonium and at the end with a stable lead isotope $Pb-206$, Figure below shows radon decay chain and alpha decay properties of radon which short-lived decay products [61].

In chemical terms, radon is an inert noble gas having a very limited capacity to construct molecules in a lab setting. Radon is a colourless, tasteless, odourless gas that, when chilled below the freezing point, displays a brilliant phosphorescence that changes colour as the temperature drops, turning yellow at liquid air temperature and orange-red at that point. The concentration of radon is frequently larger than the concentration of 226 and some of it may diffuse into other media, such as the nearby water or air, under standard conditions has density of so the radon it the heaviest gas in nature [62, 64].

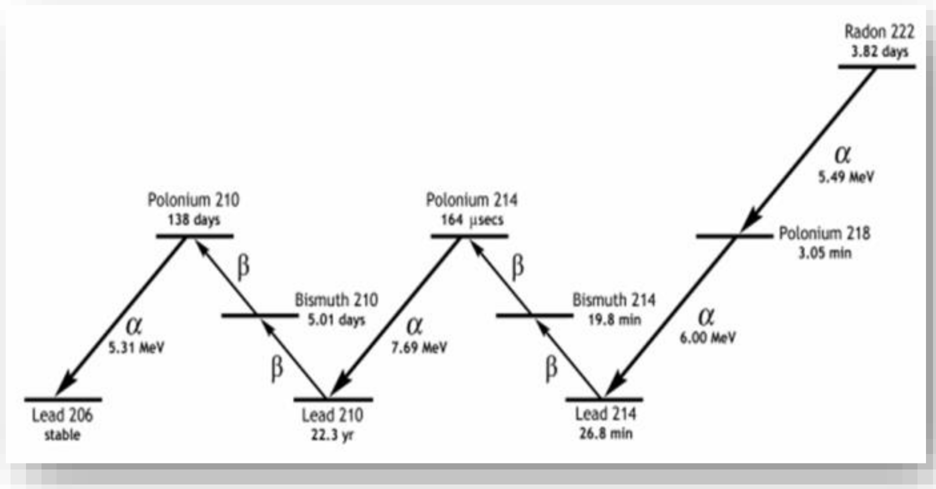


Figure (2.1): radon decay chain [63]

The electronic arrangement of the radon atom was a stable closed shell, which gives it the chemical characteristics of a noble gas element. Radon's spectrum resembles that of other closed-shell elements. Because of radon's highly limited chemical activity due to its electronic structure, certain interactions may be conceivable given that it has a comparatively low first-ionization potential of 10.7 eV. [65].

Table (2.1).Chemical and Physical Properties of $\boldsymbol{Rn-222}$ [69, 70, 71]

Property	**Radon**
Atomic number	86
Mass number	222
Group	Group 18 (noble gases)
Electronic shell	[Xe] $4f^{14}5d^{10}6s^2 6p^6$
Period	Period 6
Atomic mass	222 g/mol
Physical state	Gas at 0$^{\circ}C$ and 760 $mm\ Hg$
Density	9.73 $\times\ g.L^{-1}$ at 20$^{\circ}c$
Fusion Heat	3.247 kJ/mol
Heat of vaporization	18.10 kJ/mol

Molar heat capacity	$20.78\ J/(mol.k)$
Oxidation states	$0, +2, +6$
Natural occurrence	From decay
Crystal structure	face-cantered cubic FFC
Thermal conductivity	$3.61 \times 10^{-3}\ W/m.K$
color	Colorless
odor	odorless
Melting point	$-71^{\circ}C$
Boiling point	$-62^{\circ}C$
First ionizing energy	$1037\ kJ.mol^{-1}$

2.2.2 Radon Sources in Environment

2.2.2.1 Sources of radon in soil

indoor radon are found in high levels in everywhere, we know medically that radon can cause health risk such as lung cancer, radon comes from many sources around us such as water, soil and rocks, and the level of radon differ from place to another and because houses vary in their susceptibility to radon gas, so it's significant that all houses be measured for level of radon, in this section will talk about geological important information about radon gas such as how does it formed and the types of soil it come from and how radon moves through the land or water borne into houses to find out the source of radon in rocks and soil we have to start with the primary source (uranium), all kinds of rocks and soil contains little quantity of uranium, so a million pounds of rocks have $1-3$ pounds pf uranium, the soil forms from decomposed of rocks down mechanically and chemically at the earth crust, so the most soil contains small amount of uranium, the same amount of uranium in the rock which the soil was derived [72].

The soil coming from special types of rocks such as granites, metamorphic and sedimentary rocks, contain higher average level of uranium 80% of source of radon around us is coming from soil that derives from rock, the radon gas has mobility to fixed in the solid mater in rocks and soil much greater than other radioactive element because radon is in the form of gaseous state, so radon can easily to escaping form fractures and fissures of rocks between the pore spaces in the soil grains, If radon can travel a long way before decomposing, there is a greater chance that it will gather in high concentrations inside buildings. [63 , 73].

When the formed Radon atom enters deeply the pore space between the soil and the plantings, radon will not be released from the crops and remains present in the mineral components and becomes a part of its components. If water is present in the pores of the soil, the moving radon atom slows down very quickly to remain in the pores, the radon diffusion length in soil can vary from 1 cm in damp clay to 2 m in well-drained gravel soils, according to figure below :

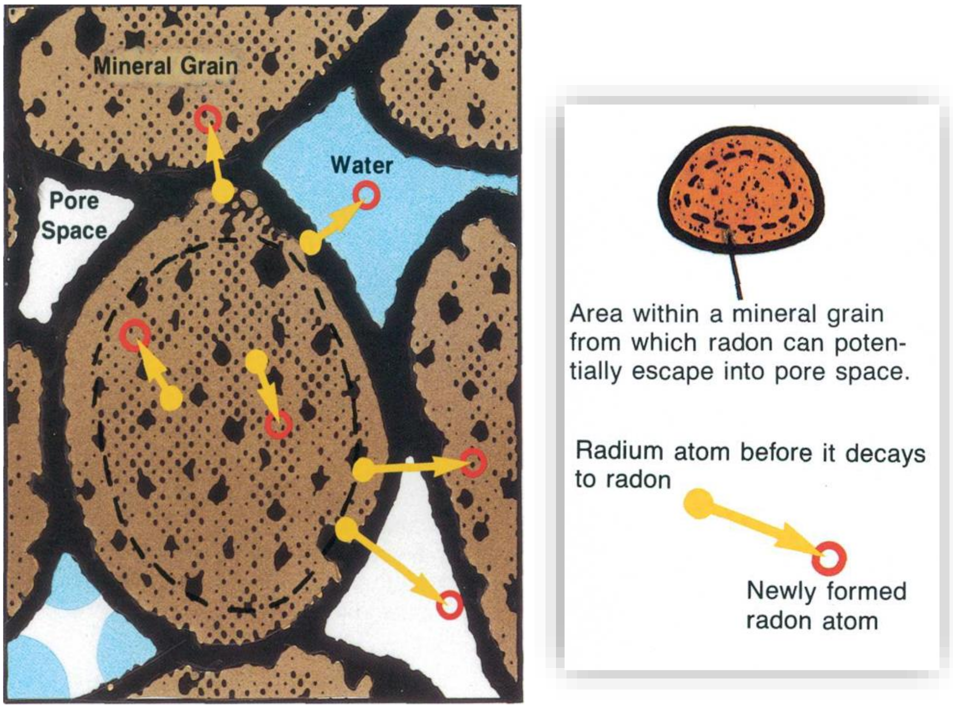


Figure (2.2) show the mechansim of entry of radon into the pores of the soil.

The speed and method movement of radon’s via soil is controlled by the amount of water located in the pores of the soil, the percentage of interconnectedness the porosity of the soil pores that determines the soil's permeability (ability to transmit air and water) as shown in figure below, where Radon moves more easily through permeable soils, such as rough sand and gravel, than clays.

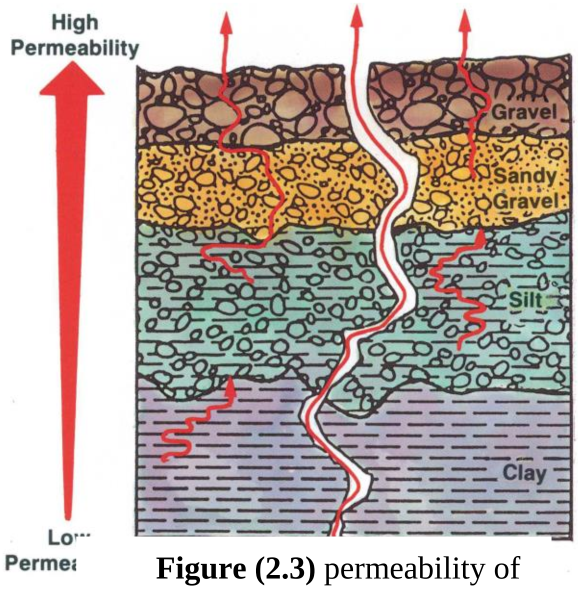


Figure (2.3) permeability of radon on soil

2.2.2.2 Sources of radon in Air

The main source of exposure to household air radon is from soil and rocks beneath that make up the foundation of the house, these rocks emitting radon that attached to dust which is penetrate the indoor, And through breathing, we are exposed to radon, which is released from construction [74].

Radon spread to the atmosphere by diffusion after it moves through the pores of the soil and broken rocks.

When the house or any building is built, Coarse gravel and rocks are placed in the base layer of the house, so radon moves from the surrounding soil to the basement, which consists of gravel, soil and rocks, from here radon is transmitted to the surrounding air, the basement or Cracks in the foundation in building may enable higher radon concentrations to enter the air around them. [75, 76].

2.2.2.3 Source of Radon in Water

Another source of radon in building is water systems supply that used in place, the water come from a lake, reservoirs or rivers contains very small amount of radon so is not concern because the radon run out into the air before it reaches building, so buildings that approves on surface water generally do not have a problematic or effect health with radon, In developed countries, water is treated by separating radon gas from water [76].

But in the other hand, in many countries rely mainly on groundwater and there have not systems to purify water from radon, can dissolve and accumulate in water from underground source which gives an opportunity for radon to move to our bodies by enter the air in our home when the water heated and agitated through used of it in washing dishes, showering and washing clothes all this with small amount of radon, but ground water is considered a dangerous source of radon when these water are areas that have high levels of uranium in the underlying rocks.

2.2.3.4 Sources of radon in Foodstuffs

Airborne Radon attached to dust particles which it rests onto the ground, or fall to the ground by rain washed, so soil and vegetation both might be contaminated, due to the decomposition of radon in the soil through rain or dust deposition, the deposited radon becomes strongly attached to the foliar of the plant, or the radon transferred throughout the plant by absorption of foliar for radon that carrier of radon.

In the long term, the radioactivity of radon can be transmitted to the herbage due to the absorption of radon in the soil by the roots, then the plant will take the trace element normally specially if it is necessary for the metabolic process of the plant and their radioactive isotopes, and the result contaminated soil may stick to the plant.
The concentration of radon varies from plant to another due to its different chemical composition, Vegetation, such as silage cattle or fresh food, transfers activity of radon to animals by eating, the radon concentration radioactivity depends on the area in which the animals are grazed, For example, dairy products such as powdered milk and whey contain certain concentrations of radon, as a result of the production of lactating animals that eat contaminated grass (radon for radioactive milk [78].

In general, the environmental cover complements each other. Contaminated soil will pollute plants, and this pollution is transmitted to both animals and humans through eating meat, plants and juices, the mechanisms by which radon enters the food chain showed in figure below.

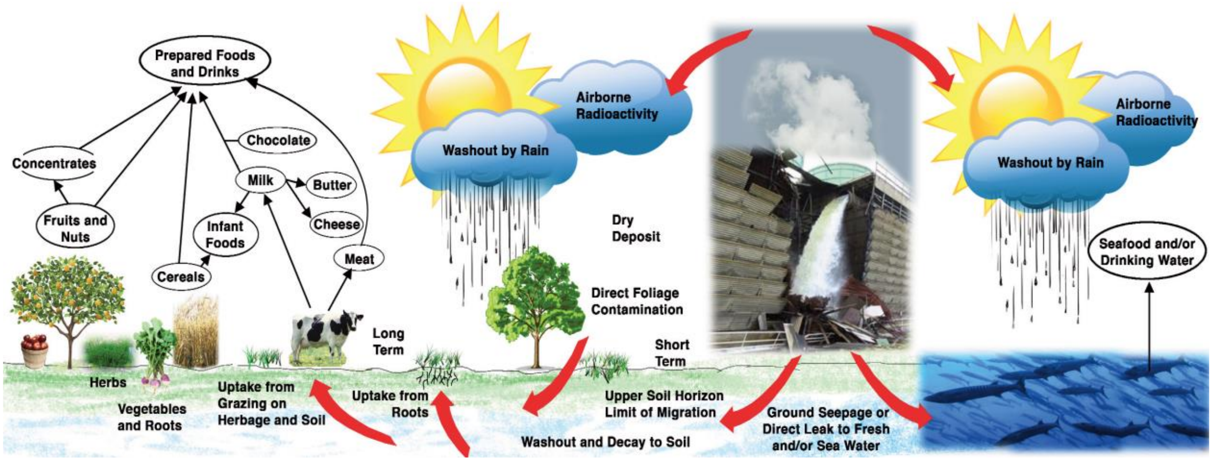


Figure (2.4) primary mechanisms by which radon enter the food chain

The food chain can pass radiation pollution that is present in the soil and water on to people and other animals. Humans can become contaminated with various radioactive isotopes $(Ra-226, Rn-222, U-238)$ when they consume plants, animal meat, or liquid foodstuffs. Plants have radioactive isotopes in them that came from the soil, where they were absorbed together with other natural materials [78].

2.2.3 Radon isotopes and daughters

There are 35 known non stable radon isotopes (all radioactive) with atomic mass numbers starting from $195\ to\ 229$, radon occurs as three naturally isotopes [80] :

I. $Radon - 222$: This is the isotope belongs to members of the $238U$ decay chains, is the longest-living radon isotope, with a half-life of (3.83) days, can only travel a certain amount in the atmosphere. It also emits alpha particles with an energy of (5.4 MeV).

II. $Thoron - 220$: knowing as thoron, is the isotope belongs to members of the $232Th$ decay series, has a half-life of $55.6\ second$, and it has concentration activity higher than$219Rn$, but lower relative to $222Rn$.

III. $Actinon - 219$: is formed during the decay of $Uranium - 235$, and it is also an alpha emitter, its short half-life ($3.98\ s$) and it has activity concentration much less relative to $222Rn$ in comparison to 222-Rn, its health effects are ignore.

Table (2.2) chemical symbols and half-lives of Radon isotopes [79]

Name of isotopes	**Chemical symbol**	**Series decay start with**	**Energy released**	**Half – life**
Radon	^{222}Rn	^{238}U	5.4 Mev	3.82 days
Thoron	^{220}Rn	^{232}Th	6.40 Mev	55.6 second
Actinon	^{219}Rn	^{235}U	6.94 Mev	3.95 $second$

2.3 Characteristics of Radium

2.3.1 Physical and Chemical Properties of Radium

Is an radioactive element with symbol Ra, with atomic number of 88, and atomic weight 226, is belongs to Group 2 and Period 7 of the periodic table of elements family alkaline earth metal atom in periodic table, it has 33 known isotopes, Under standard conditions is the heaviest known and only radioactive element member in alkaline earth metal, that is very reactive, family to state of oxidation, is simple ionic compounds because it has the inclination to form the colourless cation Ra^{+2} in high basic aqueous solution and does not form any complexes , when radium mixed with beryllium it emits alpha, beta, and gamma rays produces neutrons, its density is 5.5 g/cm^3, and is a brilliant white metal with a melting point of $700^{\circ}C$ and a boiling point of $1737^{\circ}C$, It exists in the solid state at room temperature, it speedily reacts with nitrogen when exposed to air quickly form a black coating of radium nitride, and it quickly turns into radium hydroxide when combined with water. it has portability to combine with non-metals including oxygen, fluorine, chlorine, and nitrogen, and can formation of hydrogen gas by reacts with acids, it is a good conductor.[81, 82, 83].

2.3.2 Radium sources in environments

Radium is present relatively at low levels, all humans has several level of exposure from it, but in some areas , levels of radium are present in the soil is higher, so the population in that area is exposed to higher levels of radium and the related gamma radiation from the outside, radium is permanently produces radon, which can spread into nearby neighbouring homes so it particularly hazardous, it also can also enter the environment by waste from mining at previous radium processing facilities, radium dial facilities, or radium dials, as well as from fuels like coal burning. by released radium in the air or from drinking water that comes from high in natural radium used sources, if humans work in a plant that processes ores or in a mine they may exposed to higher levels of radium, because production of oil and gas In some geologic formations can concentrate radium, often in pipe scale. Another source of radium in nature is from Phosphate rocks, it is more concentrated in phosphate mining areas, and Radium concentrations in food and air are very low. In water Radon is present basically in forms as divalent ion [81, 84, 85].

2.3.4 Radium Isotopes and Daughters

There is 33 known radioactive isotopes of radium, with mass numbers range from(206 - 230), the most four common isotopes of radon are found in nature are $Ra-223$ with half life 11.4 days and is member of the series of actinium with $U-238$ as parent nuclide, ($Ra-224$ with half life 3.7 days, $Ra-228$with half life 5.75 years) are both members of the series of thorium parented by $Th-232$ and the last isotope is $Ra-226$ belongs to the series of uranium headed with $U-238$ with half-life 1600 years [86, 87], The series of Radium it shown in below:

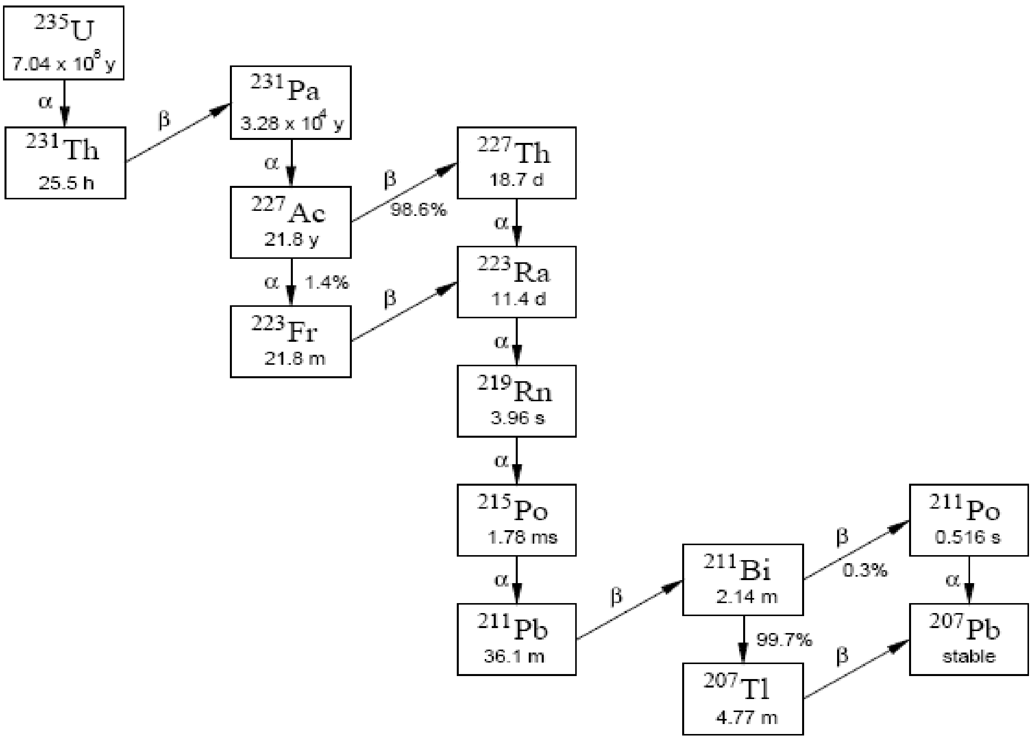


Figure (2.5) $Ra-223$ is a member of the $U-235$decay series [88]

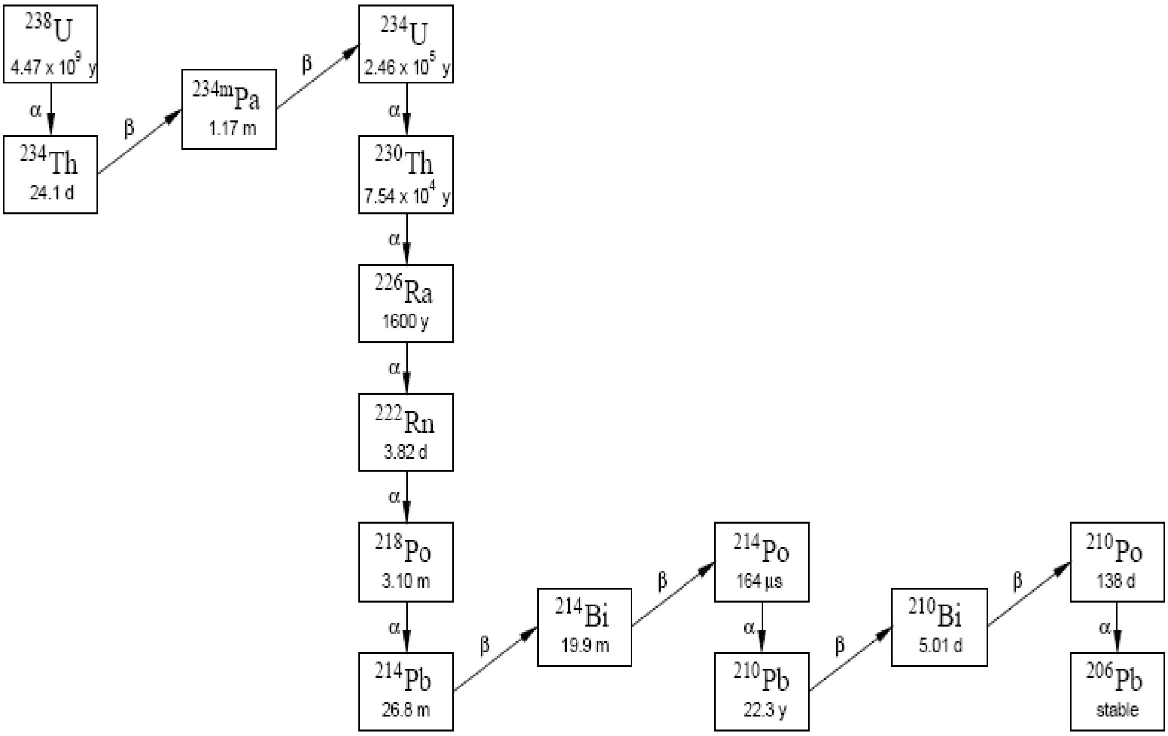


Figure (2.6): $Ra-226$ in the uranium ($U-238$) decay series [2].

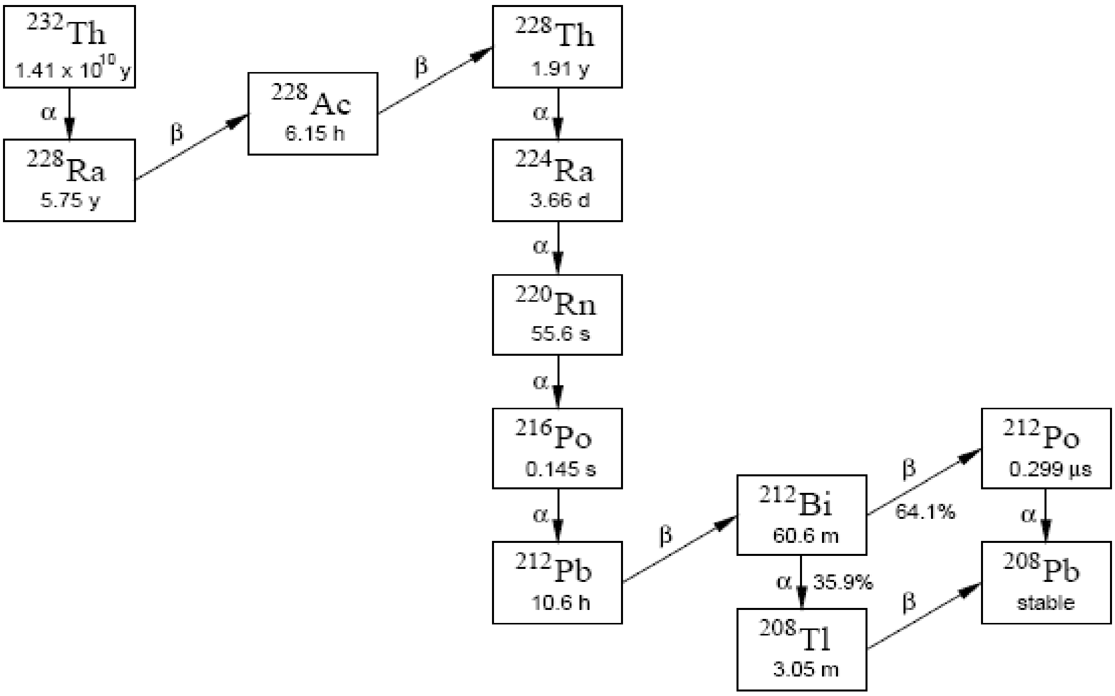


Figure (2.7): $Ra-228$ and $Ra-224$ in the ($Th-232$) decay series [2].

2.4 Methods to Reduce Radon and Radium Concentration in Food

Reducing levels concentration of radon and radium in sources of foods can be done by many techniques some methods remove radon from houses and others to reduce radon levels , includes suction of soil and sub membrane, fill the gaps of cracks and opening, pressurization of room, natural ventilation and heat recovery ventilation, some of the techniques used [89].

Soil suction: In this technique, radon or radium is withdrawn from the bottom the house and pulling it into the air above the house by suctioning the soil and getting rid of it through pipes. This method prevents the entry of radon or radium into the house

Sealing cracks and other openings: The air pressure in a basement is typically higher than that in the soil near the foundation because of the wind that blows over a house. Large amounts of soil gas may be sucked through gaps in the foundation as a result of this pressure difference. One of the most crucial ways to minimize radon and radium in the home is to fill or seal gaps or cracks. This increases the effectiveness of other radon reduction methods.

A heat recovery ventilator, or HRV In this technique, ventilation is used to reduce the levels of radon and radium in the house through the use of a ventilation device For heat recovery named air-to-air heat exchanger, There are natural methods for ventilation, such as opening windows and doors every 12 hours, and this method works to reduce radon and radium levels in the home by mixing the air coming from outside with the indoor air containing radon.

As for the levels of radon and radium in food in particular, it depends on several factors, including the type of soil in which the food is grown, where there are types of soils in which radioactive substances are present in a higher concentration than other soils, and on the fertilizers added to the soil and on the area in which they are planted, where there are areas of concentrations higher than other and the amount of water taken. One of the practices that reduce focus in food, such as not keeping food for long periods. Continuous ventilation of stored foods, eating fresh foods and avoiding canned foods, using a chemical to reduce radon and radium in food, such as Granular Activated Carbon (GAC) System, checking the proportion of radon and radium in food before packing, and developing electronic.

2.5 Health Effects of Radon and Radium

When air enters the body, it can be held for a long time in the lungs, skin, and stomach before entering the circulation and accumulating in fatty tissues. Radon and its progeny create their respective decay progeny during this period because to their short half-lives, and they are subsequently predominantly deposited in these organs. Some of the radon and progeny can provide significant doses to these organs prior to diffusion by depositing alpha decay energy [90, 91].

Bronchial epithelial tissue receives the largest alpha doses from breathed radon decay progeny, followed by the upper respiratory tract and skin, whereas other organs such as red bone marrow, liver, and kidney receive considerably low doses. Outside of the respiratory tract, radon and its decay products delivered the highest dose to the kidney. [92].

The stomach, on the other hand, receives the largest alpha radiation dosage from radon dissolved in drinking water, followed by the oesophagus and other digestive system organs. Because radon are tiny and selectively soluble in tissues with a greater fat content, fatty tissues in the yellow bone marrow and female breast may get comparatively large doses from radon and its offspring rather than other organs. Because of the low fat content of the foetus, the dose is considered to be equivalent to that of the maternal muscle and is approximately 34 orders of magnitude lower than the dose to the lung. Because alpha particles have a high LET, they can cause severe local ionization in irradiated tissues by depositing a considerable amount of energy and thereby causing damage to the targeted tissues. As a result, it is obvious that long-term exposure to radon can cause a variety of malignant or non-malignant health effects in various sections of the human body. It cause health effects largely by causing local damage as a result of alpha-particle contact with tissue atoms or molecules [93, 94].

The potential for health impacts is proportional to the radiation to which a person is exposed. In general, the larger your overall radium radiation exposure, the more probable we are to produce a detrimental health result. Long-term radiation exposure may increase the risk of certain cancers, such as lung and bone cancer.. Higher radium dosages have been linked to effects on the blood (anaemia), cataracts (eye growths), teeth (shattered teeth and cavities) and bones (reduced bone development. The majority are caused by gamma radiation, which can travel a considerable distance via the air. Being exposed to excessive levels of radium is hazardous [94].

2.6 Literature Review

Abdalsattar Kareem Hashim, et al. study, (2018), The concentration of alpha radiation activity was evaluated in 22 biscuit samples from an Iraqi market by using the alpha-sensitive $CR39$ plastic track detectors to measure radium activity and radon expiration rate. With a mean value of 58.9 Bq/Kg. the effective radium level is from 23.3 to 200.4 Bq/Kg. The mass unit's radon emission values between 0.172 to 1.515 $/Kg$, with a mean of 0.445 Bq/Kgh, while the surface unit's radon emission values from 3.988 to 34.3 Bq/m^3, with a mean of 10.081 BBq/m^3h. Furthermore, radon and radium activity rate had a direct link [95].

Ali Abid Abojassim. et al study., (2018), The radioactivity of $Rn-222, Ra-226\ and\ U-238$ in 22 samples of medical drugs (capsule) in Iraq were measured by using LR-115 detectors. Also, the average yearly of internal effective dose and risk of an excess cancer death per million persons due to ingestion of $Rn-222, Ra-226\ and\ U-238$ was rated. The results of study show that, radon concentrations from 0.51 Bq/m^3 to 60.16 Bq/m^3 with an average 16.78 Bq/m^3, radium concentrations from 1.69 $\mu Bq/kg$ to 795.51 $\mu Bq/kg$ with an average 145.95 $\mu Bq/kg$, whereas uranium concentrations from 0.02 $\mu Bq/kg$ to 8.91 with an average 1.64 $\mu Bq/kg$. The total average values of average yearly internal effective dose and risk of an excess cancer death per million person result of ingestion of $Rn-222, Ra-226\ and\ U-238$ were 145.95 nSv/y and 132.44 $/kg$. The results have shown all these data are within the allowed limits [97].

Al-Zahrani . et al. study ,(2012), The results of radioactivity analysis was done for each of $K-40\ ,Th-232\ and\ Ra-226$ in powdered children milk used in (Jeddah city). Saudi Arabia, The detected activity of $K-40$ was within the range with average activity of $234.18 \pm 1.9\ BqKg^{-1}$, while the average activities of $Ra-226$a, $Th-232$ were 0.46 $Bqkg^{-1}$, and 0.35 $Bqkg^{-1}$, respectively, although the activity of several samples were under the detection limit. The total average effective dose due to annual intake of $K-40\ ,Th-232\ and\ Ra-226$ from the ingestion of the powdered milk for children's were rated to be $410\ \mu Sv$ for infant $\leq 1 year$ and 157 μSv for children's (1-2 year) , which are lower than allowed value ($1mSv$) [98]

Islami et al. study ,(2013), In this study, the authors determined the concentrations of radioactivity $Ra-226. U-238, Th-232\ and\ K-40,$ in vegetables 10 plant samples were collected randomly from virus places of the study area south-eastern part of Bangladesh and detected the radiation risks to human from intake of these vegetables. The result showed that the average activity concentrations of $Ra-226. U-238, Th-232\ and\ K-40,$ in papaya samples were $80.95 \pm 13.61, 64.77 \pm 38.47, 83.53 \pm 20.50\ and\ 1691.45 \pm 244.98$ Bq/Kg respectively. The annual effective ingestion dose due to intake of papaya was 1.1 mSv/y. Which mean that the concentrations of radio-nuclides in the papaya samples was founded in study were higher than the world average values suggested by the UNSCEAR. The annual effective ingestion dose was found 3.8 times higher than total exposure per person resulting from the ingestion of terrestrial radioisotopes [98].

Asmaa Deiaa Nusseifl et al. study, (2020), The authors using a CR39 detector, determines the concentration of radon gas in four milk samples (Anchor, NIDO, MAHMOOD, and RAINBOW) gathered from Baghdad city's local markets. The results show that the greatest average value was found in the sample of RAINBOW milk (Oman), which was equal to 44.1 Bq/m^3, and the lowest average value was found in the sample of Anchor milk (New Zealand), which was equal to 24.7 Bq/m^3. Furthermore, the results show that the radon content in all of the tested samples was less than the required limit (ICRP). The effective annual dose values ranged from 0.779 to 1.389 mSv/y, with an average of 1.373 mSv/y, whereas the Annual Effective Dose (AED), surface exhalation rate, and effective 12 radon content for all samples were below the global standards, hence these types of milk can be regarded safe to use in terms of radon concentration [100].

Al-Sadil and Kadhim study (2019), they are studying radon concentrations in controlled airspace Ca and inside samples Cs, as well as conducting quantitative and qualitative estimates of some radionuclides, and then recognizing the proper limits knowingly allowed by typically using CR-39 detector in 30 different medicinal plants, Alpha particles recorded at the detector range between (18-54) $Tracks/cm^2$ and evaluated the concentration of radon in controlled airspace ranged between the lowest value (9.54) $Bq/m^3$and the highest value (9.54) Bq/m^3 [101].

Hayder Salah Naeem, et al. study, (2020), Researchers assessed the $Rn-222$ concentration in nineteen different types of plants taken from several marketplaces in Al-Samawah city, Al-Muthana province- Iraq, using a Continuous Radon Monitor (CRM model no.1029). The highest rates were recorded in Cinnamon (imported from India) was (21.5 Bq/m^3), while the lowest rates were in Nigella Sativa (imported from India as well) was (6.65 Bq/m^3). The measured rates above the established allowed levels (7 Bq/m^3) [102].

Hussein A. Hussein, et al. study, (2020), the authors using the Monitoring of radon (CRM-1029), measured the radon concentration in twenty types of benefits of grains food, which were collected from various markets in Samawah city in Iraq, the highest reading recorded in Chard (origin from Iraq) was (23.25 Bq/m^3), and the lowest recorded value were in Sesame (origin from Egypt) was (5.95 Bq/m3), the measured values were higher than known as acceptable levels were (7 Bq/m^3) [103].

Chapter Three

Experimental Methodology

3.1 Experimental Methodology

This study started in September of 2022, ended in May of 2023, and included the following main steps:

- Collection of Samples.
- Preparation of Samples.
- Preparation of dosimeters.
- Detectors collecting and chemical etching.
- Detectors scanning, counting tracks and calculation.

3.1.1 Types of liquid Foodstuffs Samples and Classifications

In this study, 57 various samples of liquid foodstuffs were collected from various markets in the west bank, classified in table below:

Table 3.1: liquid Foodstuffs samples collected for study aim

Number	Fruit juice	Milk + milk with fruit	Choco	Yogurt (Up Milk)	Soft Drinks	Other
1.	Juice Up	Candia milk with vitamins	Nadic Choco	Nadic strawberry	Pepsi	Crataegus Molasses
2.	Guava Nectar	Candia milk with fruit	Choco milk	Candia up	sprite	Grape Molasses
3.	Manga Nectar	Al-juneidi full fat	Aljuneidi Choco fresh	Chania up	Coca cola	Maize oil
4.	Red cherry	Al-juneidi free fat	Fresco Choco	Al jebrini up	XL	Sesame sauce
5.	Grapefruit	Alrabie banana milk		Fruit up	BLU	White vinegar
6.	Orange	Candia chocolate milk		Hi fresh up	Blueberry fanta	
7.	Lemon mint	Candia free lactose		Aljuneidi up	Grape fanta	
8.	Grape	Candia high pasteurized			Orange fanta	
9.	Kiwi, cactus	Almaraei strawberry milk			Bavaria Pomegranate	
10.	Pomegranate	Nadic chocolate milk			Bavaria Apple	
11.	Manga					
12.	Black tea					
13.	Cocktail					
14.	Grapefruit					
15.	Apple					
16.	orange					
17.	Lemon mint					

18.	Orange					
19.	Fruit Juice					
20.	Tamarindus indica					
21.	Black Grape					

3.2 Collection and Preparation of Samples

3.2.1 Samples Collection

Different samples of liquid foodstuffs collected randomly from different markets in west bank that we take it daily basis in our Kitchens, during the year2022, about $400\ millilitres$ were collected from each sample.

3.2.2 Samples Preparation

After collecting samples, the container is prepared to put the samples in it, then, it was placed in bottles plastic containers with a height of 12.5 cm and a diameter of 6 cm, Pre-calibrated for this size. Next, a CR39 detector was attached underneath the lid with a 1.5 cm distance of the container, between the liquid sample's surface and the CR-39 detectors, with the alpha-sensitive side facing down and a double-sided glue. Before the bottles were sealed, the name of the sample and the date it was packaged were written on it.

3.3Experimental Technique - Passive Techniques

The most popular technique radon measuring devices is *Passive Techniques* Passive methods, such as solid state nuclear track detectors (CR39), are preferable for observation radon exposure over time and for conducting extensive surveys at a reasonable cost. [105,106].

3.3.1 Solid State Nuclear Track Detectors (SSNTDs)

The CR39 is a clear and colourless plastic sheets with ($1cm\ x\ 1cm$) stable plastic sensitive to the tracks of alpha particles, is made by polymerization of the polyallyl diglycol carbonate $C_{12}H_{18}O_7$.

In this research we have used this type because it has many properties such as is accurate detector for radon measurements, low cost, cheap and is easily obtained, insensitive to moisture, temperature, light, moderate heating and beta and gamma radiation .

3.3.2 Preparation of Dosimeters

In this study was used the close vessel technique is plastic cylindrical Vessels or can as shown in figure (3.3) with height $12.5\ cm$ and diameter $6\ cm$ and contains CR39 nuclear nuclear track detector.

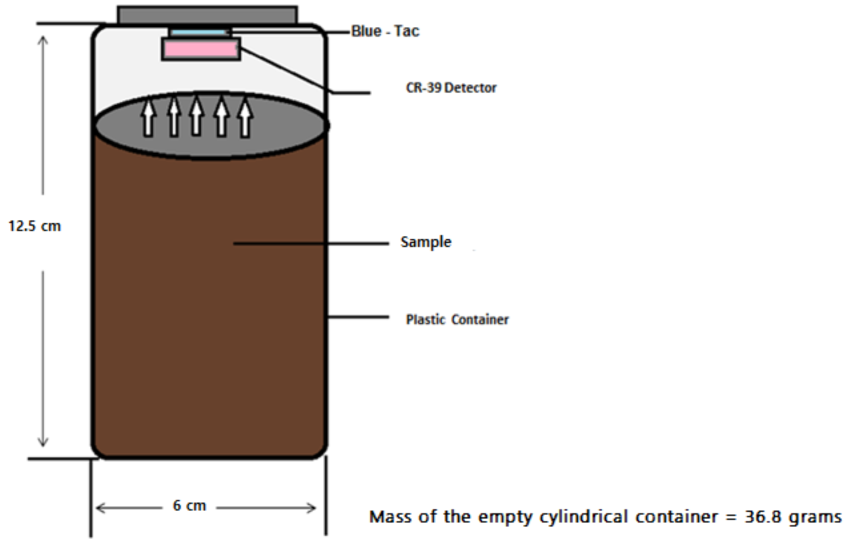


Figure 3.1: Schematic Diagram of the close vessel technique [107]

Cans were stored in the months from November 2022 through February 2023 for about 90 days.

3.3.3 Tracks Formation:

When alpha particles are formed in close proximity to the detecting material by radon or radon decay products, they can strike to create tiny areas of damage called alpha tracks. The shape and size of these tracks reveal information about the particles' mass, charge, energy, and direction of motion.

3.3.4 Collecting Detectors and Chemical Etching

The dosimeters were calibrated at Hebron University's Radiation. For 3 months, the detectors were exposed to liquid foodstuffs samples to collect $\alpha-$particle tracks at room temperature (almost 25 $°C$).

After 90 days, 57 detectors were removed from the dosimeters. The detectors were chemically etching in 6.25 M $NaOH$ at 70$°C$ for 4 hours , after four hours washed by distilled water using the setup shown in Figure (3.4) below, followed by drying to remove any remaining etchant from the detectors' surfaces[108].

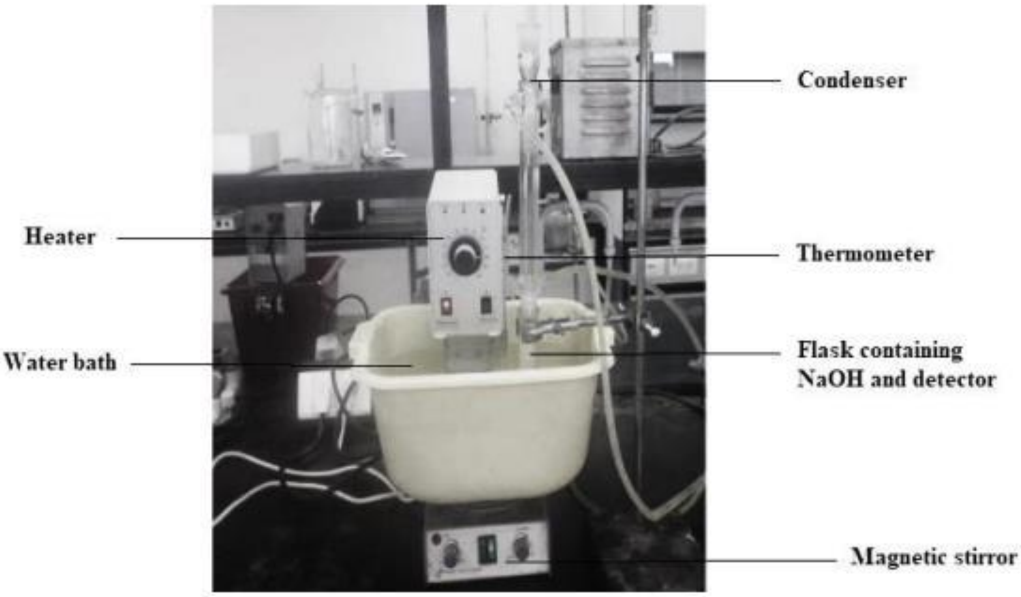


Figure 3.3: Etching process experimental set up

3.3.5 Detectors counting tracks

A digital optical microscope with 400 times the magnification was utilized to count the tracks per field of vision, by ten times moving the microscope stage from left to right to make sure no tracks are missed but counted twice.

Track densities are computed based on the number of tracks collected, and the liquid foodstuffs radon concentration is then determined.

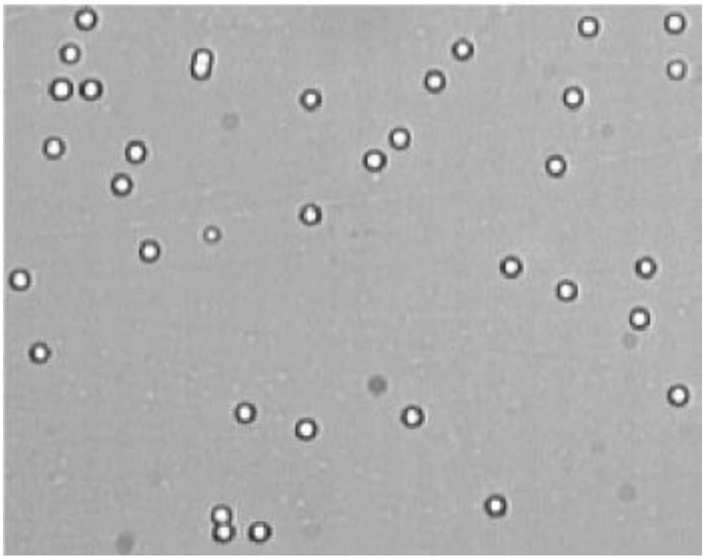


Figure (3.4): Tracks of alpha particles

3.4 Theoretical Calculations

3.4.1 The Activity Concentration of Radon

The formula of $Radon-222$ concentration of the liquid foodstuffs samples in unit (Bqm^{-3}) is [110]:

$$C_{Rn}(Bq/m^3) = \frac{c_0 t_0}{\rho_0}\left(\frac{\rho}{t}\right) = k\left(\frac{\rho}{t}\right) \ldots\ldots\ldots\ldots \quad [3.1]$$

Where C_{Rn} is the activity concentration of $Rn-222$ in a liquid foodstuffs sample, ρ_0 is $(number\ of\ tacks/cm^2)$ track density in detectors exposed to Ra^{226} , c_0 is the activity concentration of the ($Ra-226$) is equal $800\ Bqm^{-3}$, t_0 is the time of exposure to $Ra-226$, roughly 90 days , ρ is track density $(number\ of\ tacks/cm^2)$ and t exposure time (in days) of detectors. [109].

3.4.2 The Effective Radium Contents

The effective radium content Ra_{eff} in the unit (Bq/kg) of the liquid samples will be calculated from the formula:

$$Ra_{eff} = \frac{\rho VK}{M(T-\lambda^{-1}[1-e^{-\lambda T}])} \ldots\ldots\ldots \quad [3.2]$$

Where V is the air space volume in unit m^3, ρ is track density in unit $(Tracks/cm^2)$, M is the mass of the liquid sample in unit kg, k is the calibration factor in unit $(Bqm^{-3}).days/tracks/cm^2$, λ is decay radon constant is equal $(0.19\ days^{-1})$ and T is total exposure length (days).

The effective radium content $Raeff\ (Bq/L)$ has been calculated from the relation:

$$Ra_{eff} = \frac{C_{Rn}V}{V_W(T-\lambda^{-1}[1-e^{-\lambda T}])} \ldots\ldots\ldots \quad [3.3]$$

Where V is the cup effective volume in m^3 and V_W is the sample volume in (L)[110].

3.4.3 The Annual Effective Dose

The annual effective dose for inhalation and ingestion I will show it in next sections.

3.4.3.1 The Annual Affective Dose Due To the Inhalation of Radon

The following formula was used to determine the annual effective dosage of radon during inhalation (H_{inh}) due to the amount of radon present in liquid foods [111].

$$H_{inh}\ (nSv/yr) = C_{Rn} \times F \times R \times T \times 9nSv\ (Bqhm^{-3})^{-1} \ldots\ldots \quad [3.4]$$

where C_{Rn} is the average radon concentration indoor air in unit Bqm^{-3}, F is the factor equilibrium between indoor radon and its progeny is equal 0.4, R is the ratio air–water concentration is equal 10^{-4}, T is the time exposure to this concentration in

$hours$assumed to be $7000h/year$ and $9\,nSv\,(Bqhm^{-3})$ is the factor of dose conversion.

3.4.3.2 The Annual Effective Dose Due To The Ingestion of Radon

The annual effective dose due to the ingestion of radon from liquid foodstuffs samples(H_{ing}), was calculated from to the formula:

$$H_{ing}\,(mSv/yr) = C_{Rn} \times D_{ing} \times L \quad \text{[3.5]}$$

Where (H_{ing}) is the effective dose in unit $mSvy^{-1}$, C_{Rn} concentration of radon in liquid samples in unit $q\ell^{-1}$, D_{ing} is factor conversion equal to $1 \times 10^{-8} SvBq^{-1}$ for adult , $2 \times 10^{-8} SvBq^{-1}$ for child and $7 \times 10^{-8} SvBq^{-1}$ for infant , L is annual liquid consumption by an adult, child and infant in litters[89].

3.4.4 The annual exposure to potential alpha energy (effective dose equivalent)

The following relationship connects both of potential alpha energy E_p and average concentration radon C_{Rn} :

$$E_p = \frac{8760 \times n \times C_{Rn} \times F}{170 \times 3700}\,(WLM.\,y^{-1}) \quad \text{[3.6]}$$

Where n represent the fraction of time spent indoors, 8760 represent number of hours in years, 170 is the number of hours in working months and breathing in air and 3700 radon concentration [89].

Chapter Four

Results and Discussions

4.1 Introduction

This chapter will used as a document to provide and investigate the results of levels of radon concentration observed in Bq/m^3.

To calculate radon/radium concentration were used equation 3.1, 3.2 and to calculating the annual effective dose of liquid foodstuffs samples were used equation 3.2 which include fruit juice, in milk, milk with fruit and Yogurt (up milk) and soft drinks and others liquid foodstuffs samples.
The results are summarized in tables from 4.1 to 4.6 represented a radon concentration level arbitrage in liquid foodstuffs samples at the present work with those in west- bank. The correlation between radium/radon concentrations is depicted in figures 4.1 to 4.4 for fruit juice, in milk, milk with fruit and up milk and soft drinks and others liquid foodstuffs samples respectively.

4.2 Results of Measurements of $Rn - 222$ concentrations and $Ra - 226$ contents in liquid foodstuffs samples.

Tables 4.1 to 4.4 represent as the Rn-222 concentrations and radium content for all types of liquid foodstuffs samples, the values of C_{Rn} getting between 51.0 Bq/m^3 to 278.8 Bq/m^3 . Figure 4.1 shows that the C_{Rn} of fruit juice samples is the highest at orange 278.8 Bq/m^3, but the lowest value is Grapefruit 51.0 Bq/m^3, and the values of C_{Ra} are the highest in orange juice 3.90 Bq/kg, but the lowest value is grapefruit 0.714 Bq/kg.

Type	$C_{Rn}(Bq/m^3)$	$C_{Rn}(Bq/l)$	$C_{Ra}(Bq/kg)$	**Trade mark**
Juice Up	64.6	0.0646	0.90	Candia
Guava Nectar	71.4	0.07	0.99	Domty
Manga Nectar	251.6	0.25	3.52	Domty
Red cherry	176.8	0.17	2.47	Cappy
Grapefruit	51	0.05	0.71	Cappy
Orange	190.4	0.19	2.66	Cappy
Lemon mint	217.6	0.21	3.04	Cappy

Table 4.1: Results of $Rn - 222$ concentrations an $Ra - 226$ in Fruit juice Samples

Grape	142.8	0.14	1.99	Cappy
Kiwi, cactus	163.2	0.16	2.28	Cappy
Pomegranate	142.8	0.14	1.99	Cappy
Manga	129.2	0.12	1.80	Cappy
Black tea	210.8	0.21	2.95	Mathieu Teisseire
Cocktail	61.2	0.06	0.85	Al-juneidi
Grapefruit	207.4	0.20	2.90	Tabuzina
Apple	217.6	0.21	3.04	Tabuzina
orange	278.8	0.27	3.90	Tabuzina
Lemon mint	74.8	0.07	1.04	Tabuzina
Orange	132.6	0.13	1.85	Tabuzina
Fruit Juice	57.8	0.05	0.80	Domty
Tamarindus indica	81.6	0.08	1.14	Al-zahraa
Black Grape	268.6	0.26	3.76	Enjoy

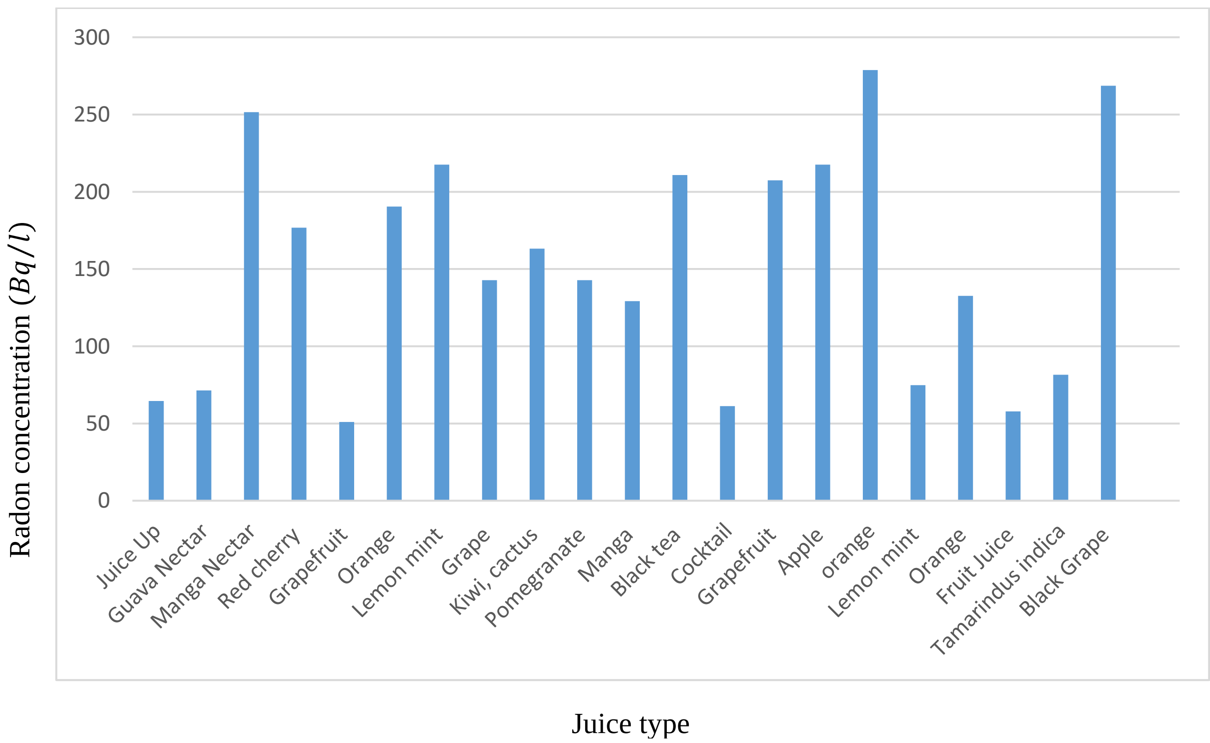


Figure 4.1: $Rn-222$ concentrations in juice samples

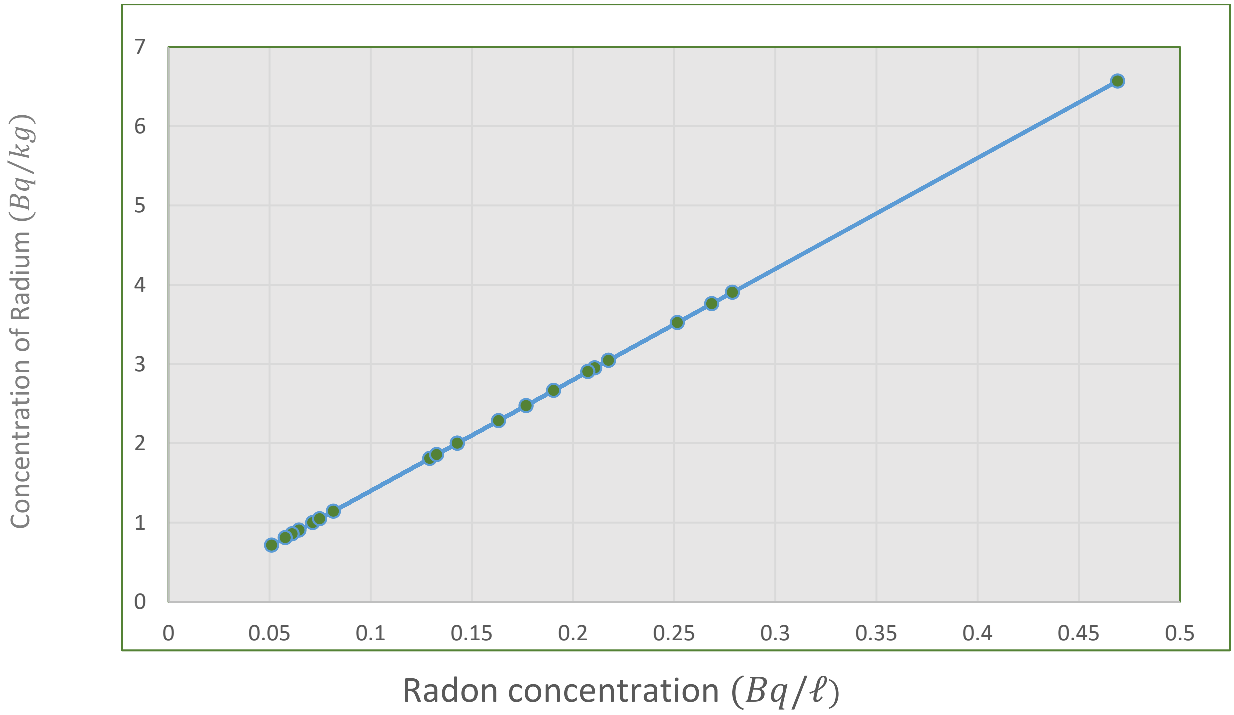


Figure 4.2: Correlation between $Rn-222$ concentration and $Ra-226$ content in juice samples

4.2.2 Results of $Rn-222$ concentrations and Radium contents in milk, milk with fruits and Yogurt (milk up) samples

The values of table 4.2 shows the radon concentrations in in milk, milk with fruit and yogurt (milk up) samples collected from different markets in west-bank, which the values of C_{Rn} of samples getting between 61.2 Bq/m^3 to 258.4 Bq/m^3. Figure 4.3 shows the highest radon concentrations for full fat milk with 258.4 Bq/m^3 and the lowest value for Choco milk with 61.2 Bq/m^3. the values of radium are the highest at concentrations for At full fat milk with 3.6176 (Bq/kg) and the lowest value for 0.8568 (Bq/kg).

Table 4.2: Results of $Rn-222$ concentrations and radium contents in Milk, milk with Fruit and Yogurt samples

Type	$C_{Rn}(Bq/m^3)$	$C_{Rn}(Bq/l)$	$C_{Ra}(Bq/kg)$	Trade mark
Milk with vitamins	176.8	0.17	2.47	Candia
Milk with fruit	156.4	0.15	2.18	Candia
Full fat milk	258.4	0.25	3.61	Al-juneidi
Free fat milk	146.2	0.14	2.04	Al-juneidi
Banana milk	78.2	0.07	1.09	Al-rabie
Chocolate milk	176.8	0.17	2.47	Candia
Free lactose milk	105.4	0.10	1.47	Candia

High pasteurized milk	91.8	0.09	1.28	Candia
Strawberry milk	125.8	0.12	1.76	Al-maraei
Chocolate milk	190.4	0.19	2.66	Al-jebrini
Choco milk	108.8	0.10	1.52	Al-juneidi
Choco milk	61.2	0.06	0.85	Fresca
Choco fresh	115.6	0.11	1.61	Sky candy
Choco milk	122.4	0.12	1.71	Candy
Strawberry milk	105.4	0.10	1.47	Al-maraei
Yogurt	149.6	0.14	2.09	Candia
Yogurt	112.2	0.11	1.57	Chanina
Yogurt	159.8	0.15	2.23	Al-jebrini
Fruit milk	180.2	0.18	2.52	Hi fresh
Fresh up	180.2	0.18	2.52	Candy
Yogurt	193.8	0.19	2.71	Al-juneidi

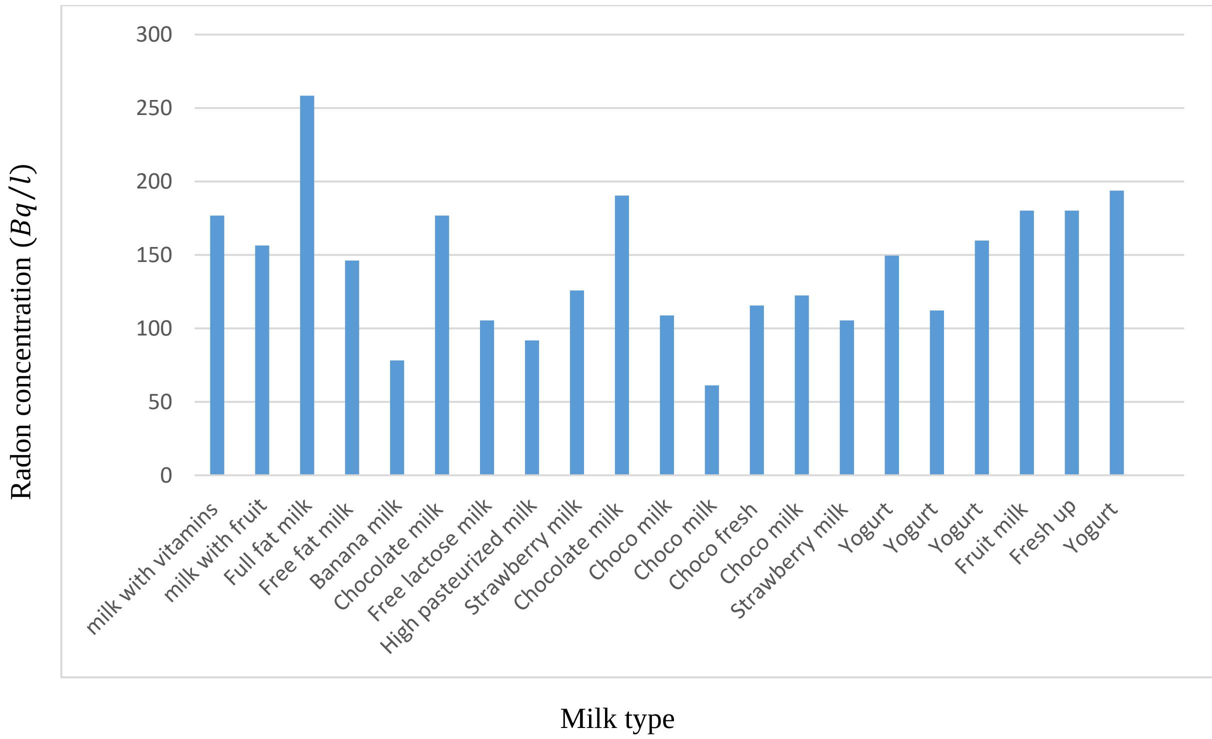


Figure4.3: $Rn - 222$ concentrations in Milk samples

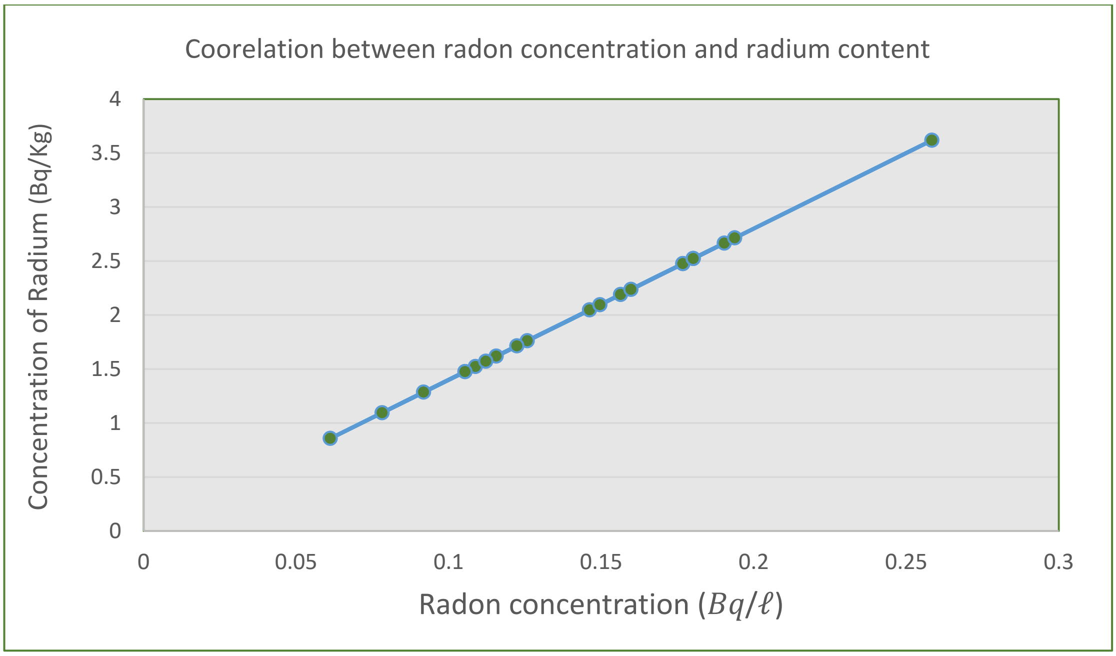


Figure 4.4: Correlation between $Rn-222$ concentration and $Ra-226$ content in Milk samples

4.2.3 Results of Rn-222 concentrations and radium contents in soft drinks and others liquid foodstuffs samples

The values of table 4.3 shows the radon/radium concentrations in soft drinks and others liquid foodstuffs samples collected from different markets in west bank-Palestine, which the values of radon concentration of samples getting between 64.6 Bq/m^3 to 224.4 Bq/m^3 with. Figure 4.4 shows the highest radon concentrations for orange and the lowest value for Bavaria Apple. The values of C_{Ra} are the highest at concentrations for orange with 4.2364 (Bq/kg) and the lowest value for 0.9044 (Bq/kg).

Table 4.3: Results of $Rn-222$ concentrations and radium contents in Soft Drinks and others liquid foodstuffs samples

Type	$C_{Rn}(Bq/m^3)$	$C_{Rn}(Bq/l)$	$C_{Ra}(Bq/kg)$	**Trade mark**
Pepsi	214.2	0.2142	2.9988	Pepsi
sprite	112.2	0.1122	1.5708	Coca-cola
Coca cola	180.2	0.1802	2.5228	Coca-cola
XL	180.2	0.1802	2.5228	Xl
BLU	200.6	0.2006	2.8084	BLU
Blueberry	166.6	0.1666	2.3324	Fanta
Grape	95.2	0.0952	1.3328	Fanta

Orange	224.4	0.2244	3.1416	Fanta
Pomegranate	187	0.187	2.618	Bavaria
Apple	64.6	0.0646	0.9044	Bavaria
Crataegus Molasses	71.4	0.0714	0.9996	Handmade
Grape Molasses	108.8	0.1088	1.5232	Handmade
Maize oil	91.8	0.0918	1.2852	Al-safi
Sesame sauce	207.4	0.2074	2.9036	Shawar
White vinegar	197.2	0.1972	2.7608	Al-tayebat

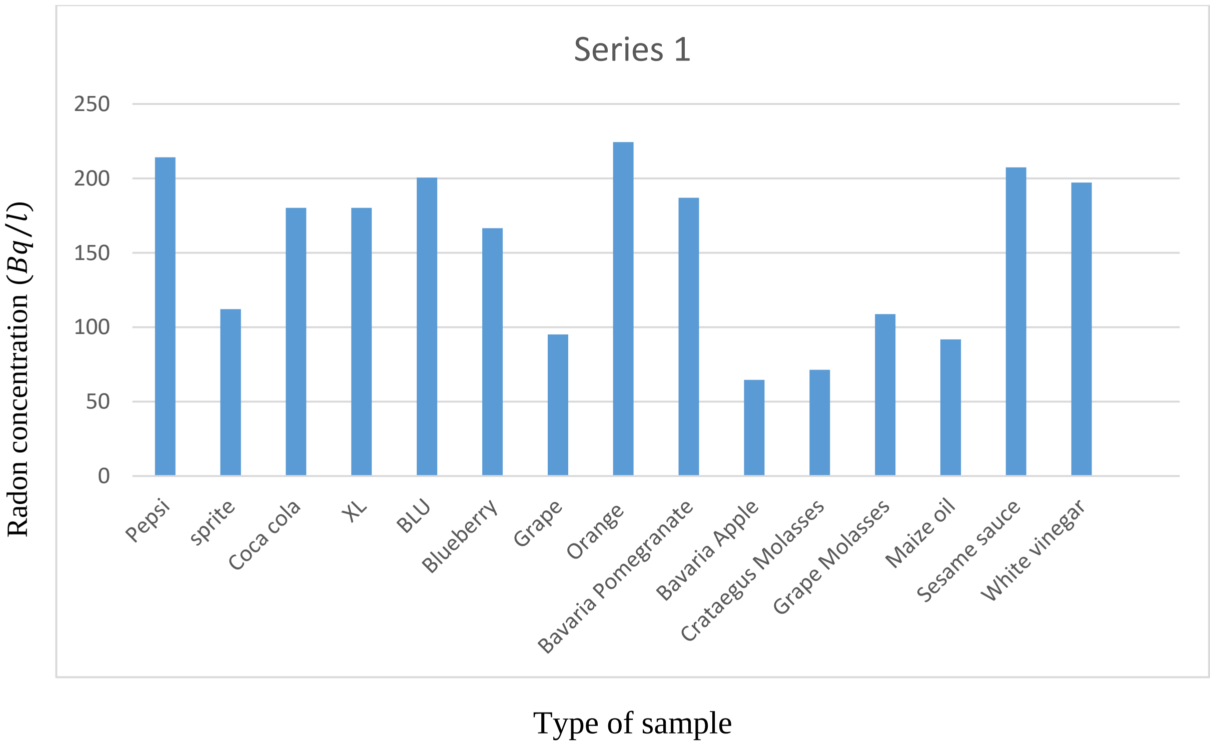


Figure 4.5: $Rn-222$ concentrations in Soft Drinks and others liquid foodstuffs samples

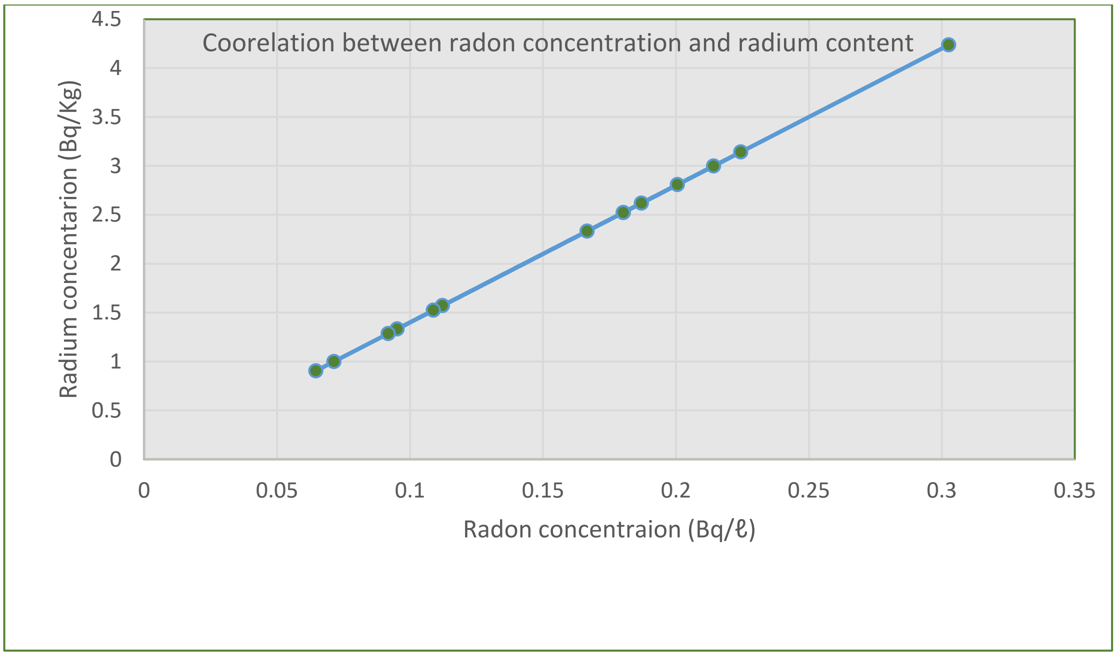


Figure 4.6: Correlation between $Rn-222$ concentration and $Ra-226$ content in Soft Drinks and others liquid foodstuffs samples

4.3. The annual effective doses for inhaled and ingested $Rn-222$ from liquid foodstuffs samples

Radon and its decay products enter the body mostly by inhalation by several ways among these ways is by liquid foodstuff.

The annual effective doses for inhalation and ingestion of radon from liquid foodstuffs is listed in Tables 4.4 to 4.6, for all types for adults, children, and infant were determined using UNSCEAR guidelines.

4.4 The annual exposure to potential alpha energy (effective dose equivalent)

Another aim of this study to find the (effective dose equivalent) from liquid foodstuffs samples that is listed in tables from 4.4 to 4.6 for liquid foodstuffs.

Table 4.4: Results of annual effective Dose and effective dose equivalent for Fruit juice samples

Type	Average of $H_{ing}(\mu Sv/yr)$			Average of $H_{inh}(\mu Sv/yr)$	E_p $(WLM.y^{-1})$
	Adult	**Child**	**Infant**		
Juice Up	0.64	1.29	4.52	0.16	0.30
Guava Nectar	0.71	1.42	4.99	0.17	0.33
Manga Nectar	2.51	5.03	17.61	0.63	1.18

Red cherry	1.76	3.53	12.37	0.44	0.83
Grapefruit	0.51	1.02	3.57	0.12	0.23
Orange	1.90	3.80	13.32	0.47	0.89
Lemon mint	2.17	4.35	15.23	0.54	1.02
Grape	1.42	2.85	9.99	0.35	0.67
Kiwi, cactus	1.63	3.26	11.42	0.41	0.76
Pomegranate	1.42	2.85	9.99	0.35	0.67
Manga	1.29	2.58	9.04	0.32	0.60
Black tea	2.10	4.21	14.75	0.53	0.99
Cocktail	0.61	1.22	4.28	0.15	0.28
Grapefruit	2.07	4.14	14.51	0.52	0.97
Apple	2.17	4.35	15.23	0.54	1.02
orange	2.78	5.57	19.51	0.70	1.31
Lemon mint	0.74	1.49	5.23	0.18	0.35
Orange	1.32	2.65	9.28	0.33	0.62
Fruit Juice	0.57	1.15	4.04	0.14	0.27
Tamarindus indica	0.81	1.63	5.71	0.20	0.38
Black Grape	2.68	5.37	18.80	0.67	1.26

Table 4.4 shows annual effective Dose ingestion H_{ing} and inhalation H_{inh} and effective dose equivalent for Fruit juice samples. The annual effective dose ingestion $Hing$ for adult getting between 0.51$\mu Sv/yr$) to 2.78 ($\mu Sv/yr$). And H_{ing}values for child getting between 1.02 ($\mu Sv/yr$) to 5.57 $\mu Sv/yr$). And H_{ing} values for infant getting between 3.57 ($\mu Sv/yr$) to 19.51 ($\mu Sv/yr$) .The annul effective dose inhalation H_{inh} getting between 0.12852($\mu Sv/yr$) to 0.70 ($\mu Sv/yr$). The effective dose equivalent E_p getting between 0.2397 ($WLM.y^{-1}$) to 1.31 ($WLM.y^{-1}$) .

Table 4.5: Results of annual effective Dose and effective dose equivalent for Milk, milk with fruit and Up Milk samples

Type	***Average of $H_{ing}(\mu Sv/yr)$***			***Average of $H_{inh}(\mu Sv/yr)$***	**E_p $(WLM.y^{-1})$**
	Adult	**Child**	**Infant**		
Milk with vitamins	1.76	3.53	12.37	0.44	0.83
Milk with fruit	1.56	3.12	10.94	0.39	0.73
Full fat milk	2.58	5.16	18.08	0.65	1.21
Free fat milk	1.46	2.92	10.23	0.36	0.68
Banana milk	0.72	1.56	5.47	0.19	0.36

Chocolate milk	1.76	3.53	12.37	0.44	0.83
Free lactose milk	1.05	2.10	7.37	0.26	0.49
High pasteurized milk	0.91	1.83	6.42	0.23	0.43
Strawberry milk	1.25	2.51	8.80	0.31	0.59
Chocolate milk	1.90	3.80	13.32	0.47	0.89
Choco milk	1.08	2.17	7.61	0.27	0.51
Choco milk	0.61	1.22	4.28	0.15	0.28
Choco fresh	1.15	2.31	8.09	0.29	0.54
Choco milk	1.22	2.44	8.56	0.30	0.57
Strawberry milk	1.05	2.10	7.37	0.26	0.49
Yogurt	1.49	2.99	10.47	0.37	0.70
Yogurt	1.12	2.24	7.85	0.28	0.52
Yogurt	1.59	3.19	11.18	0.40	0.75
Fruit milk	1.80	3.60	12.61	0.45	0.84
Fresh up	1.80	3.60	12.61	0.45	0.84
Yogurt	1.93	3.87	13.56	0.48	0.91

Table 4.5 shows annual effective Dose ingestion H_{ing} and inhalation H_{inh} and effective dose equivalent for Milk, milk with fruit and yogurt (Up Milk) samples. The annual effective dose ingestion $Hing$ for adult getting between 0.612 $\mu Sv/yr$) to 2.584 ($\mu Sv/yr$). And H_{ing}values for child getting between 1.224 ($\mu Sv/yr$) to 5.168 $\mu Sv/yr$). And H_{ing} values for infant getting between 4.284 ($\mu Sv/yr$) to 18.088 ($\mu Sv/yr$). The annul effective dose inhalation H_{inh} getting between 0.154224 ($\mu Sv/yr$) to 0.651168 ($\mu Sv/yr$). The effective dose equivalent E_p getting between 0.28764 ($WLM.y^{-1}$) to 1.21448 ($WLM.y^{-1}$).

Table 4.6: Results of annual effective Dose and effective dose equivalent for Soft Drinks and others liquid foodstuffs samples

Type	$\boldsymbol{Average\ of\ H_{ing}(\mu Sv/yr)}$			$\boldsymbol{Average\ of\ H_{inh}(\mu Sv/yr)}$	$\boldsymbol{E_p\ (WLM.y^{-1})}$
	Adult	**Child**	**Infant**		
Pepsi	2.14	4.28	14.99	0.53	1.00
sprite	1.12	2.24	7.85	0.28	0.52
Coca cola	1.80	3.60	12.61	0.45	0.84
XL	2.00	4.01	14.04	0.50	0.94
BLU	1.66	3.33	11.66	0.41	0.78
Blueberry	0.95	1.90	6.66	0.23	0.44

Grape	2.24	4.48	15.70	0.56	1.05
Orange	1.80	3.60	12.61	0.45	0.84
Bavaria Pomegranate	1.87	3.74	13.09	0.47	0.87
Bavaria Apple	0.64	1.29	4.52	0.16	0.30
Crataegus Molasses	0.71	1.42	4.99	0.17	0.33
Grape Molasses	1.08	2.17	7.61	0.27	0.51
Maize oil	0.91	1.83	6.42	0.23	0.43
Sesame sauce	2.07	4.14	14.51	0.52	0.97
White vinegar	1.97	3.94	13.80	0.49	0.92

Table 4.6 shows annual effective Dose ingestion H_{ing} and inhalation H_{inh} and effective dose equivalent for Soft Drinks and others liquid foodstuffs samples. The annual effective dose ingestion $Hing$ for adult getting between 0.646 $\mu Sv/yr)$ to 2.24 $(\mu Sv/yr)$. And H_{ing}values for child getting between 1.292 $(\mu Sv/yr)$ to 4.48 $\mu Sv/yr))$. And H_{ing} values for infant getting between 4.522 $(\mu Sv/yr)$ to 15.70 $(\mu Sv/yr)$. The annul effective dose inhalation H_{inh} getting between 0.16 $(\mu Sv/yr)$ to 0.56 $(\mu Sv/yr)$. The effective dose equivalent E_p getting between 0.30362 $(WLM.y^{-1})$ to 1.05 $(WLM.y^{-1})$.

4.5 Discussions

$Radium - 226$ is extensively distributed in the environment in varying concentrations in air, liquids, rocks, and sediments, is significant radiologically because it acts chemically like calcium and is deposited on bone surfaces and locations where minerals are metabolized. Radium uptake in plants is increased by raising the concentration of organic acids mostly citric acid, significant impact in $Ra - 226$ uptake by plants due to pH lowering and complex formation of organic acids with elements in the soil. Most of the components of radium are quickly eliminated after ingestion, but because of radium's chemical behaviour, which is similar to that of calcium, it is absorbed into the blood. Lungs or intestinal-Gastro and, like calcium, is deposited primarily in the bones [78, 104].

This chapter discusses the evaluation of radioactive isotopes. ($Rn - 222$, and $Ra - 226$) and showed the results of this study presented and discussed of different liquid foodstuffs samples, these samples have been analysed concentrations radon and radium by using the technique Nuclear Track Detectors (SSNTD) CR39.

Equations 3.1 through 3.6 , respectively, were used for calculating activity concentration of radon, effective radium contents, annual effective dose of radon and The annual exposure to potential alpha energy for samples that used in this study which include fruit juice, milk group and soft drink and other liquid samples, all the results of applied this equations are summarized in Tables 4.1 to 4.6 and The correlation between the radon concentration and effective radium content from liquid samples are represented in Figures 4.2 , 4.4 and 4.6.

The values of $Radon-222$ concentrations getting between 51 Bq/m^3 at Grapefruit cappy – 278.8 Bq/m^3 at orange tabuzina , According to the agency The International Commission on Radiological Protection ICRP in 2014, has defined limit values for radon concentration is 400 Bq/m^3 the $Radon-222$ Concentrations for all samples are below the acceptable ICRP value threshold.

All effective radium content levels for all liquid foodstuffs samples are not exceeds the ICRP recommended value. The average values of annual effective dose in mSv/y are within the recommended limit of ICRP values So at the end all types of liquid foodstuffs which are analysis are safe for using daily in our kitchens.

According to ICRP this organization has defined limit values for annual effective Dose which is 3.0 mSv/y to 10.0mSv/y. The results reveal that the overall annual effective dosage from all liquid foodstuffs samples was lower than the ICRP's recommended limits.

The values of annual exposure to effective dose equivalent getting between 0.23 $WLM.y^{-1}$ to 0.89 $WLM.y^{-1}$ According to ICRP this organization has defined limit values for annual exposure to potential alpha energy (effective dose equivalent) is 4 $WLM\ per\ year$, so these values are within the acceptable level [48].

Figures 2, 4 and 6 show the relation between radium concentrations with radon concentrations, a positive correlation has been observed between radium and radon with linear correlations coefficient equal to 0.99 .The results of study confirmed that there is a positive correlation between radium and radon, in addition to a relation between radium and radon is positive with a perfect linear correlation, this result leads us to the fact that radium is a perfect source of radon in all samples.

Chapter Five
Conclusions and Recommendations

Conclusions

- The passive technique containing SSNTDS type (CR39) was used in this study to assessment the radon concentration, annual effective dose, and radium concentration in 57 samples of liquid foodstuffs samples collected from different markets in west bank- Palestine, to assess the radiological hazards.

- The levels of radon concentration in fruit juice samples are given in table 4.1, the values was between 51.0 Bq/m^3 to 278.8 Bq/m^3. The results of radon concentration levels in milk samples are displayed in table 4.2, the values was between 61.2 Bq/m^3 to 258.4 Bq/m^3. The results of radon concentration levels in Soft Drinks and others liquid foodstuffs samples are given in table 4.3, the values was between 64.6 Bq/m^3 to 224.4 Bq/m^3 . The average radon concentration is found to be highest in fruit juice and lowest in milk samples, respectively.

- The annual effective Dose ingestion H_{ing} and inhalation H_{inh} and effective dose equivalent for Fruit juice samples reported in table 4.4, were yielded for adult getting between 0.51$\mu Sv/yr$) to 2.78 ($\mu Sv/yr$). And H_{ing}values for child getting between 1.02 ($\mu Sv/yr$) to 5.57 ($\mu Sv/yr$). And H_{ing} values for infant getting between 3.57 ($\mu Sv/yr$) to 19.51 ($\mu Sv/yr$). The annul effective dose inhalation H_{inh} getting between 0.12852($\mu Sv/yr$) to 0.70 ($\mu Sv/yr$).

- The annual effective Dose ingestion H_{ing} and inhalation H_{inh} and effective dose equivalent for Milk, milk with fruit and yogurt (Up Milk) samples reported in table 4.5 . The $Hing$ for adult getting between 0.612 $\mu Sv/yr$) to 2.584 ($\mu Sv/yr$). And H_{ing}values for child getting between 1.224 ($\mu Sv/yr$) to 5.168 $\mu Sv/yr$). And H_{ing} values for infant getting between 4.284 ($\mu Sv/yr$) to 18.088 ($\mu Sv/yr$). The annul effective dose inhalation H_{inh} getting between 0.154224 ($\mu Sv/yr$) to 0.651168 ($\mu Sv/yr$) .

- The annual effective Dose ingestion H_{ing} and inhalation H_{inh} and effective dose equivalent for Soft Drinks and others liquid foodstuffs samples displayed in table 4.6 . The $Hing$ for adult getting between 0.646 $\mu Sv/yr$) to 2.24 ($\mu Sv/yr$). And H_{ing}values for child getting between 1.292 ($\mu Sv/yr$) to 4.48 ($\mu Sv/yr$). And H_{ing} values for infant getting between 4.522 ($\mu Sv/yr$) to 15.70 ($\mu Sv/yr$). The annul effective dose inhalation H_{inh} getting between 0.16 ($\mu Sv/yr$) to 0.56 ($\mu Sv/yr$).

- In this study, the results demonstrate that the majority of the samples' radon concentration levels are within the ICRP-recommended acceptable limits.

- There is no health hazards related to radiation. This research is the first to be done in the field of liquid foodstuffs, and the results of measurements collected provide a baseline database of activity levels in this study that can serve as a benchmark for studies in the future to determine the effects of future occurrences. The survey region was chosen based on geological, topographical, and other preliminary research. This is because soil (clay and sand) is the essential source of Radon, and where we assume the presence of industrial nuclear waste buried under the soil.

Recommendations

- Implementation of a national radon elimination program aimed at reducing risks to both liquids with high radon concentrations.
- Avoid pasteurized liquids foodstuffs and replace them with fresh.
- Try to aerate liquids foodstuffs after buying or picking them up.
- Storing liquid foodstuffs for a short period and using a chemical to reduce radon from liquids foodstuffs, such as Granular Activated Carbon (GAC) System.
- Checking the percentage of radon concentration in liquid foodstuffs before packing.
- Create procedures and technological methods for storing liquids foodstuffs in a healthy, radon-free environment.
- The General Standard for Contaminants and Toxins in Liquid Foodstuffs should be used to establish radiological protection controls related to liquid foodstuffs and establishing food-related radiation protection systems based on the principle of risk analysis

References

1. Weisstein, Eric W. "Radiation". Eric Weisstein's World of Physics. Wolfram Research. Retrieved 11 January 2014.
2. Methqal D., Measurement of radon 222 in dwellings of old Nablus city, 2001.
3. Centers for Disease Control and Prevention the Electromagnetic Spectrum. 7 December 2015.
4. Minister of Public Works and Government Services Canada (PWGSC Introduction to Radiation ©) 2012 PWGSC catalogue number CC172-93/2012E-PDF ISBN 978-1-100-21572-3 Published by the Canadian Nuclear Safety Commission (CNSC).

5. Ms. Faten Ali Al_Agwar RSSC FUNDAMENTAL RADIATION CONCEPTS 072011.
6. Britannica, The Editors of Encyclopaedia. "Electron volt". Encyclopaedia Britannica, 5 May. 2014, https://www.britannica.com/science/electron-volt. Accessed 10 October 2022.

7. Cooper, N. G. Los Alamos Science Number 23 1995 Ionizing Radiation discover radioactivity.
8. JRIA, Japan Radioisotope Association Basic Knowledge of Radiation and

Radioisotopes (2019) (Scientific Basis, Safe Handling of Radioisotopes and Radiation Protection.
9. Supping P., Jincai Z., Engineering Geology for Underground Rocks, 2007,

10. Eric J Hall Radiation & Radioactivity, College of Physicians and Surgeons, Columbia University, New York. June 14, 2011.

11. CNSC Introduction to Radiation, Canadian Nuclear Safety Commission. http://nuclearsafety.gc.ca/eng/resources/radiation/introduction-to-radiation/nuclear-and-radiation-glossary.cfm.

12. WHO RADIOLOGICAL INF(department ,minerals and energy republic of south Africa) UNDERSTANDING RADIOACTIVITY & RADIATION IN EVERYDAY LIFE APRIL 2005.

13. Mai Yasser El-Shaer, MEDICAL EFFECTS OF RADIATION INTERACTIONS 2015 Islamic University of Gaza.
14. EPA, U.S. Environmental Protection Agency, 2011. "EPA Radiogenic Cancer Risk Models and Projections for the U.S. Population." EPA Report 402-R-11-001.

15. R. Macian, Biological Effects of Radiation, Reactors Concepts Manual,USNRC Technical Training Center.
16. BEIR V, National Research Council, Committee on the Biological Effects of Ionizing Radiation, Health Effects of Exposure to Low Levels of Ionizing Radiation, , National Academy Press, Washington, D.C.,1990

17. Fred A. Mettler, Jr., M.D. and Arthur C. Upton, M.D. Medical Effects of Ionizing Radiation, Grune & Stratton, Inc., Orlando, Florida, 1995.
18. Fathiya "Husam Shoqwara Measurement of Radon Exhalation from Building Materials Used in Nablus District, Palestine An-Najah National University 2012.
19. Diana Adlienė Kaunas BASIC RADIATION PHYSICS AND SOURCES OF RADIATION University of Technology, Physics Department, Student g. 50, LT-51368 Kaunas, Lithuania, 2017.
20. Mittal V.K., Verma R.C., Gupta S.C., "Introduction to Nuclear and Particle Physics", New Delhi, 76-141, 2009 .

21. Robert Miyaoka, Nuclear Medicine Basic Science Lectures Decay of Radioactivity, 2011.
22. Ehman W., Vance D. E. "Radiochemistry and nuclear methods of analysis", United Kingdom: John Wisely and sons, 51-203, 1993.

23. Bryant, P., A., Radiation physics and the structure of matter, 2019.
24. IAEA ASPECTS OF THE INTRODUCTION OF FOOD IRRADIATION IN DEVELOPING COUNTRIES, , 1973.
25. Adlienė D. Basic Radiation Physics and Sources of Radiation. Lithuania:Kaunas University of Technology, Physics Department, Studentų g, Kaunas; 2012.
26. J. Jeffrey Peirce, P. Aarne Vesilind Waste Radioactive, in Environmental Pollution and Control (Fourth Edition), 1998.

27. Dr. MAHMOOD RADHI AL-QURAYSHI, Dr. HAIDER QASIM AL-MOSAWI Radiation Physics and its applications in diagnostic radiological techniques.2017.
28. Prof. Dr MAHMOUD NAJIM .Types of Radioactivity: Alpha, Beta, and Gamma Decay ,2020.
29. Royal Society of Chemistry Radiochemistry Group, Alpha, Beta and Gamma Radioactivity No. 3 in a series of essays on radioactivity .
30. Annunziata M. F., “Radioactivity Introduction and History”, 1st edition: (10-132) USA, Elsevier, 2007.
31. A., Ferbel T., “Introduction to Nuclear and Particle Physics”, 2nd edition, London: World Scientific Pub. Co., 42-100, 2003.
32. Dr. Ali A. Ridha . Nuclear Physics; Ch.5 (Radioactivity).
33. Paola Cappellaro, Quantum Theory of Radiation Interactions, Massachusetts Institute of Technology via MIT OpenCourseWare, 2012.
34. CDC Center for Disease Control and Prevention, ATSDR, Case studies in environmental medicine radon toxicity, 2010
35. Walter Fendt , Radioactive Decay Series, July 20, 1998.
36. Ralph E. L., Howard L. Andrews, “Nuclear Radiation Physics”, 4th edition N.J., Englewood Cliffs, 120-280, 1972.
38 J. R. Lamarsh, Introduction to Nuclear Reactor Theory, 2nd ed., Addison-Wesley, Reading, MA (1983).
39 EPA , radon measurement in Schools,1993.
40 Sofiya Choudhary Deterministic and Stochastic Effects of Radiation * Radiotherapy Technologist, , India October 05, 2018.
41 ICRP. (2007) the 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37 (24-). The international commission on radiological protection, , Essen, Germany.
42 UNSCEAR. (2010b) Summary of low-dose radiation effects on health,, Report of the United Nations Scientific Committee on the Effects of Atomic Radiation 2010, Vienna.
43 Anno GH, Young RW, Bloom RM, and Mercier JR. Dose Response Relationships for Acute Ionizing – Radiation Lethality. Health Physics; 84: 565-575; 2003].
44 Hall, EJ and Giaccia, AJ. Radiobiology for the Radiologist, 7th edition. Lippincott Williams & Wilson, 2012.
45 Ourania Kosti, Rapporteur, Adopting the International System of Units for Radiation Measurements in the United States, 2017.
46 National Council on Radiation Protection and Measurements (NCRP), NCRP Report No. 160 Ionizing Radiation Exposure of the Population of the United States.2015.
47 C.H. CLEMENT, Compendium of Dose Coefficients based on ICRP Publication 60 , 2012.
48 J U Burnham (1992). "Radiation Protection, Chapter 4.
49 VKM Report 2017:25 Risk assessment of radioactivity in food Opinion of the Scientific Committee of the Norwegian Scientific Committee for Food Safety].
50 مباديء الاشعاعات المؤينة والوقاية منها اعداد 2007 /أ.د. محمد فاروق أحمد أ.د. أحمد بن محمد السريع

51 U.S. Department of Energy Office of Environmental Management Depleted Uranium Hexafluoride Management Program. Characteristics of Uranium and Its Compounds.2001

52 A. K. SARANGI URANIUM AND ITS MEASUREMENT IN ORE BY RADIOMETRIC METHOD) URANIUM CORPORATION; 2000.

53 Commissariat à l'Énergie Atomique et aux Energies Alternatives, CHAPTER 2, DEFINITION OF RADIOACTIVITY THE ORIGINS OF RADIOELEMENTS APPLICATIONS OF RADIOACTIVITY FROM RESEARCH TO INDUSTRY. 2005

54 Health Physics Society HPS Fact Sheet Adopted: Specialists in Radiation Safety Uranium1. December 2018

55 J. Garnier–Laplace, C. Colle and M. Morello radionuclide fact sheet Natural Uranium and the 14 May 2001.

56 Agency for Toxic Substances and Disease Registry, U.S .Toxicological profile for radon Archived 2016-04-15 at the Way back Machine, . Public Health Service, In collaboration with U.S. Environmental Protection Agency, December 1990.

57 R. William Field, Radon: An Overview of Health Effects Project: Health Care Providers - Radon Education , December 2011.

58 Internal Distribution, Human Health Fact Sheet ANL, the companion fact sheet on Radioactive Properties, October 2001.

59 IAEA, THE BEHAVIOUR OF RADIUM IN WATERWAYS AND AQUIFERS, 1980.

60 Eisenbud, Merril & Gesell, Thomas, Environmental Radioactivity, , Fact Sheet Division of Environmental Health Office of Radiation Protection, July 2002.

61 George AC. World history of radon research and measurement from the early 1900's to today. 2008.

62 J Ame Chem , Lawrence S. Chemical properties of radon. 1987.

63 Entesser Farhan Salman* , Amenah Kadhim Murad Radioactivity: Radon Gas, its Properties and the Risks of Increasing its Concentration, June 23, 2021

64 David R. Lide, CRC Handbook of Chemistry and Physics, October 2003

65 J.C. Bailor, H.J. Emeleus, R. Nyholm and A.F. Trotman Dickenson, Comprehensive Inorganic Chemistry, 1973,

66 L. Stein, Chemical properties of radon, in: P. Hopke (Ed.) Radon and Its Decay Products, American Chemical Society, Washington, DC, 1987.

67 Henry F. Lucas, Improved low-level alpha-scintillation counter for radon, Rev. Sci. Instrum., 28 (1957).

68 NCRP Report No. 97, Measurement of Radon and Radon Daughters in Air, National Council on Radiation Protection and Measurements, Bethesda, MD, 1988.

69 W. M. Haynes, ed., *CRC Handbook of Chemistry and Physics*, CRC. 2014.

70 John Emsley, *Nature's Building Blocks: An A-Z Guide to the Elements*, Oxford University Press, New York, 2nd Edition, 2011.

71 Khalil Thabayneh, Abdel S, A., and., Environmental Nuclear Studies of Natural and Manmade Radioactivity at Hebron Region in Palestine. Al-Quds Univ. J. for Research and Studies, 2008.
72 Ilic R, Durrani S.,., World Scientific Publishing, .Radon Measurements by Etch Track Detectors, Singapore, 2017.

73 Khalil Th., Jazzar M. M., Natural Radioactivity Levels and Estimation of Radiation Exposure in Environmental Soil Samples from Tulkarem Province, 2012.

74 D. Schwela, in Encyclopedia of Toxicology (Third Edition), 2014.
75 NabilM. A. Hamed Measurement of Radon Concentration in Soil at North Gaza, ,2005.

76 James K. Otton, Linda C.S. Gundersen, and R. Randall Schumann "Geology Of Radon, U.S. Department of Interior/U.S. Geology survey, 1995.
77 [European Atlas of Natural Radiation | Chapter 5 – Radon], 2018.
78 Tayseer I. Al-Naggar and Doaa H. Shabaan.Chapter Radon in Foods. July 8th, 2020.
79 Y. Ishimori, K. Lange, P. Martin, Y.S. Mayya, M. Phaneuf Measurement and Calculation of Radon Releases from NORM Residues © IAEA, 2013.
80 IAEA, Canadian Nuclear Safety Commission (2010). Radon in Canada's Uranium Industry. Retrieved September 30, 2010.

81 IAEA, The Environmental Behaviour of Radium Vol.1, INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1990.
82 D.W. Shoesmith Whiteshell ATOMIC ENERGY OF CANADA. LIMITED THE BEHAVIOUR OF RADIUM IN SOIL AND IN URANIUM MINE-TAILINGS , 1984.

83 Ajay Kumar, Arvind Kumar and Surinder Singh. Analysis of Radium and Radon in the Environmental Samples and some physico-chemical properties of drinking water samples belonging to some areas of Rajasthan and Delhi, India, 2012.
84 M.D. Siegel, C.R. Bryan, in Treatise on Geochemistry (Second Edition), 2014.
85 Cecilia Edsfeldt , THE RADIUM DISTRIBUTION IN SOME SWEDISH SOILS AND ITS EFFECT ON RADON EMANATION Stockholm 2001.
86 M.L. & Kirby, H.W. THE RADIOCHEMISTRY OF RADIUM, report, December 1, 1964.
87 IAEA 2010, Analytical Methodology for the Determination of Radium Isotopes in Environmental Samples INTERNATIONAL ATOMIC ENERGY AGENCY VIENNA, 2010.
88 MARTIN, P., HANCOCK, G.J., Routine analysis of naturally occurring radionuclides in environmental samples by alpha-particle spectrometry, (2004).
89 UNSCEAR (2000), the Effects of Atomic Radiation. Sources and effects of ionizing radiation, Report to the General Assembly, 1, New Yor, 2000..
90 World Health Organization (WHO), guidelines for indoor air quality: selected pollutants, 2010.
91 Bowie C, Bowie SHU. Radon and health. 1991.

92 Kendall GM, Smith TJ. Doses to organs and tissues from radon and its decay products. Journal of Radiological Protection. 2002.

93 NAS, National Academy of Sciences, Basic Principles of Radiation Biology. vol. 4, 1995.

94 Doug Brugge [1], Virginia Buchner. Radium in the environment: exposure pathways and health effects, 2012.

95 Najam, L., A., et al., Estimation of radon exhalation rate, radium activity and uranium concentration in biscuit samples in Iraq. 2019.

96 Federica Savino, Roberto Amato, Alfredo Irollo Radon Concentration and Risk Assessment in 27 Districts of a Public Healthcare Company in Naples, South Italy Filomena Loffredo, 24. Feb. 2021.

97 Ali Abid Abojassim* and Dhuha Jalil Lawi ALPHA PARTICLES EMISSIONS IN SOME SAMPLES OF MEDICAL DRUGS (CAPSULE) DERIVED FROM MEDICAL PLANTS IN IRAQ , 2018.

98 J. H. Al-Zahran, Natural Radioactivity and Heavy Metals in Milk Consumed in Saudi Arabia, 2012.

99 Nadir Hashim1, Catherine Nyambura ,Radon and Thoron; Radioactive Gases Lurking in Earthen Houses in Rural Kenya, 2019.

100 Nusseif, A., D., Mkhaiber, A., F., and Abdaljalil, R., O., Evaluating radon level in imported milk using CR-39 detector. Neuro Quantology.. 2020.

101 Al–Sadi, M., A., K., H., and Kadhim, I., H., Study of the radon concentrations in some medicinal herbs using CR-39 detector. Plant Archives. 2019.

102 Naeem, H., S., Algareb, R., S., and Hussein. H., A., Herbal plants show another evidence of radon contamination in Al-Muthanna Province. AIP Conference Proceedings. 2020.

103 Hussein, H., A., salah Naeem, H., and Algareb R., S., The estimation of radon gas measurement in grains in Samawah city markets using CRM-1029. Solid State Technology, 2020.

104 Binesh, A., et al., Determination of radon and radium in springs, wells, rivers and drinking water samples of Ramsar in Iran. International Journal of Science and Advanced Technology.2011.
105 Shawamreh, R., J., Measurement of Natural Radioactive Isotopes Concentration in Soil Samples in the Northern Part of West Bank-Palestine. Msc Degree. 2021.
106 Zaki, M., F., El-Shaer, Y., H., Particularization of alpha contamination using CR-39 track detectors. Springer. 69(4): 567-574. 2007.
107 Thabayneh, K., M., Measurement of Rn-222 concentration levels in drinking water and the associated health effects in the Southern part of West bank–Palestine. Elsevier. 103: 48-53. 2015.
108 Rasas, M., F., Measurement of Radon and Its Daughter's Concentrations in Indoor and Outdoor throughout Gaza Strip. Msc Degree .2003.
109 El-Ghossain, M.O., Abu Shammala, A.A., 2012. Radioactivity measurements in tap water in Gaza Strip(Al-Naser Area). J. Assoc. Arab Univ. Basic Appl. Sci. 11.
110 Abdalsattar Kareem Hashim, Laith Ahmed Najam., 2015. Radium and Uranium Concentrations Measurements in Vegetables Samples of Iraq. Detection, 3, 21-28.
111 Sujo, L.C., et al., 2004. Uranium-238 and thorium-232 series concentrations in soil, radon-222 indoor and drinking water concentrations and dose assessment in the city of Aldama, Chihuahua, Mexico. J. Environ. Radioact. 77, 05–219

ملخّص

" قياس النشاط الإشعاعي في بعض عينات المواد الغذائية السائلة تم جمعها من الأسواق الفلسطينية "

إعداد: أنوار محمد علي الجرادات

إشراف:

الاستاذ الدكتور خليل ذباينة

الدكتور حسين السمامره

تـم تحديـد الـرادون كواحـد مـن المخـاطر الصـحية للبشـرية لأن التعـرض طويـل المـدى للـرادون يزيـد مـن خطـر الإصـابة بسـرطان الرئـة. هـذا الغـاز المشـع يتصـاعد مـن الأرض ويختـرق المنـازل ويـدخل رئتـيهم مـن خـلال عمليـة

التنفس. تصف هذه الدراسة النشاط الإشعاعي على أنه جسيم ألفا ناتج عن اضمحلال الراديوم إلى الرادون. تهدف الدراسة إلى تقييم تركيز نشاط الرادون في 57 عينة من المواد الغذائية السائلة التي تم جمعها من أسواق مختلفة من الضفة الغربية - فلسطين ، باستخدام تقنية سلبية - كواشف الحالة الصلبة النووية (CR-39) SSNTDs , بعد 90 يومًا من التعرض تم تجميعها وتحميضها باستخدام 6.25 M من NaOH عند 70 درجة مئوية ، ثم تم استخدام المجهر الضوئي لحساب متوسط عدد المسارات لكل وحدة مساحة ثم حساب تركيزات الرادون ومحتوى الراديوم الفعال والجرعة الفعالة السنوية لاستنشاق الرادون وابتلاعه ومكافئ الجرعة الفعالة.

أظهرت هذه الدراسة نتائج كل من تركيز الرادون والراديوم وكانت كالتالي: تراوحت نتائج مستويات تركيز الرادون في عينات عصير الفاكهة بين $51.0\ Bq/m^3$ إلى $278.8\ Bq/m^3$ ، ويتراوح تركيز الراديوم بين 0.714 إلى $3.90\ Bq/kg$. كانت نتائج مستويات تركيز الرادون في عينات الحليب تتراوح بين 61.2 إلى $258.4\ Bq/m^3$ ويتراوح تركيز الراديوم بين 0.85 إلى $3.61\ Bq/kg$. نتائج مستويات تركيز الرادون في عينات المشروبات الغازية وغيرها من المواد الغذائية السائلة كانت تتراوح ما بين 64.6 إلى $224.4\ Bq/m^3$ ، وتركيز الراديوم بين $0.90\ Bq/kg$ إلى $3.14\ Bq/kg$.

أظهرت النتائج التي تم الحصول عليها أن مستويات تركيز غاز الرادون في جميع العينات أقل من الحدود الآمنة على النحو الموصى به من قبل ICRP ، ولا توجد مخاطر صحية متعلقة بالإشعاع.