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Measurement of Radon and Its Daughter's Concentrations In Indoor and Outdoor throughout Gaza Strip

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﴿ يرفع الله الذين آمنوا منكم والذين آوتوا العلم درجات والله بما تعملون خبير﴾

سورة المجادلة أية (١١).

DEDICATION

TO

MY PARENTS

MY FAMILY

MY FRIENDS

ACKNOWLEDGEMENT

It gives me pleasure to express my thanks to all those who have assisted me in the preparation of this study. My sincere gratitude goes to my supervisors, Prof. M. M. Shabat and Associate Prof. S. S. Yassin, for useful discussions, kind help and guidance throughout this work.

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ABSTRACT

Solid-state nuclear track detectors CR-39 were used to measure Radon and its daughter's concentrations throughout Gaza Strip. The distribution of the detectors was based on the geographical location of the houses. Our survey included, Nuseirat camp (N), Bureij camp (B), Maghazi camp (M), Deiralbalah camp (D), Abraj An- Nuseirat (A), and Zahra City (Z). The detectors (500) were left in the houses for about four months during the period from August to December of 2001. After collection, the detectors were chemically etched using a 20% solution of KOH at temperature 70^0C for a period of 5 hours. At the end of the etching, detectors were washed thorough with distilled water and then left to dry. Tracks on 9 distinct regions (amplified of unit area of $1cm^2$) on each detector, were visually counted using an optical microscope with power of (40×10), that were observed. The average number of tracks/cm^2 was determined Radon and its daughter's concentrations over the six locations in the middle region of Gaza Strip were varied between 13.36 to 83.82 Bq/m^3 and had a maximum value of 97.06 Bq/m^3. The average Radon and its daughter's concentrations was 37.83 Bq/m^3 with average standard deviation of 11.23. Average Radon concentrations for each site were determined as follows: Nuseirat camp 37.46 Bq/m^3, Bureij camp 44.95 Bq/m^3, Maghazi camp 38.04 Bq/m^3, Deiralbalah camp 44.51 Bq/m^3, Abraj An-Nuseirat 28.79 Bq/m^3, and Zahra City 17.54 Bq/m^3.

ملخص

قياس تركيز غاز الرادون ومشتقاته داخل وخارج منازل قطاع غزة

لقد تم في هذه الأطروحة قياس تركيز غاز الرادون-222 ومشتقاته في الهواء داخل وخارج منازل قطاع غزة، باستخدام كاشف الحالة الصلبة (مجراع الرادون السلبي) للمسارات النووية والمعروف تجارياً باسم CR-39. حيث تم توزيع 500 مجراعاً حسب الموقع الجغرافي للمنطقة الوسطي وهي: النصيرات، البريج، المغازي، دير البلح، أبراج النصيرات والزهرة.

وبعد مرور أربعة شهور جمعت المجراعات وعولجت كيميائيا باستخدام محلول هيدروكسيد البوتاسيوم (KOH) المخفف بالماء المقطر بتركيز 20% وعند درجة حرارة 70^0 ولمدة 5 ساعات، ثم عدت المسارات المتولدة في الكواشف والموجودة في وحدة المساحة ($1cm^2$) بعد استخدام مجهر ضوئي قوته (40×10) عبر9 مناطق واضحة على الكاشف.

وقد وجد أ ن تركيز الرادون في أماكن الدراسة يتراوح بين $13.36\ Bq/m^3$و $83.82\ Bq/m^3$، وأن القيمة العظمى لتركيز الرادون هي$97.06\ Bq/m^3$. وتبين أن القيمة المتوسطة لتركيز الرادون ومشتقاته في المنطقة الوسطى تساوي $37.83\ Bq/m^3$، مع متوسط الانحراف المعياري الذي يساوي 11.23.

ووجد أن تركيز الرادون ومشتقاته في كل موقع كالتالي: النصيرات $37.46\ Bq/m^3$، البريج $44.95\ Bq/m^3$، المغازي $38.04\ Bq/m^3$، دير البلح $44.51\ Bq/m^3$، أبراج النصيرات $28.79\ Bq/m^3$ والزهرة $17.54\ Bq/m^3$.

CHAPTER (1)

RADON

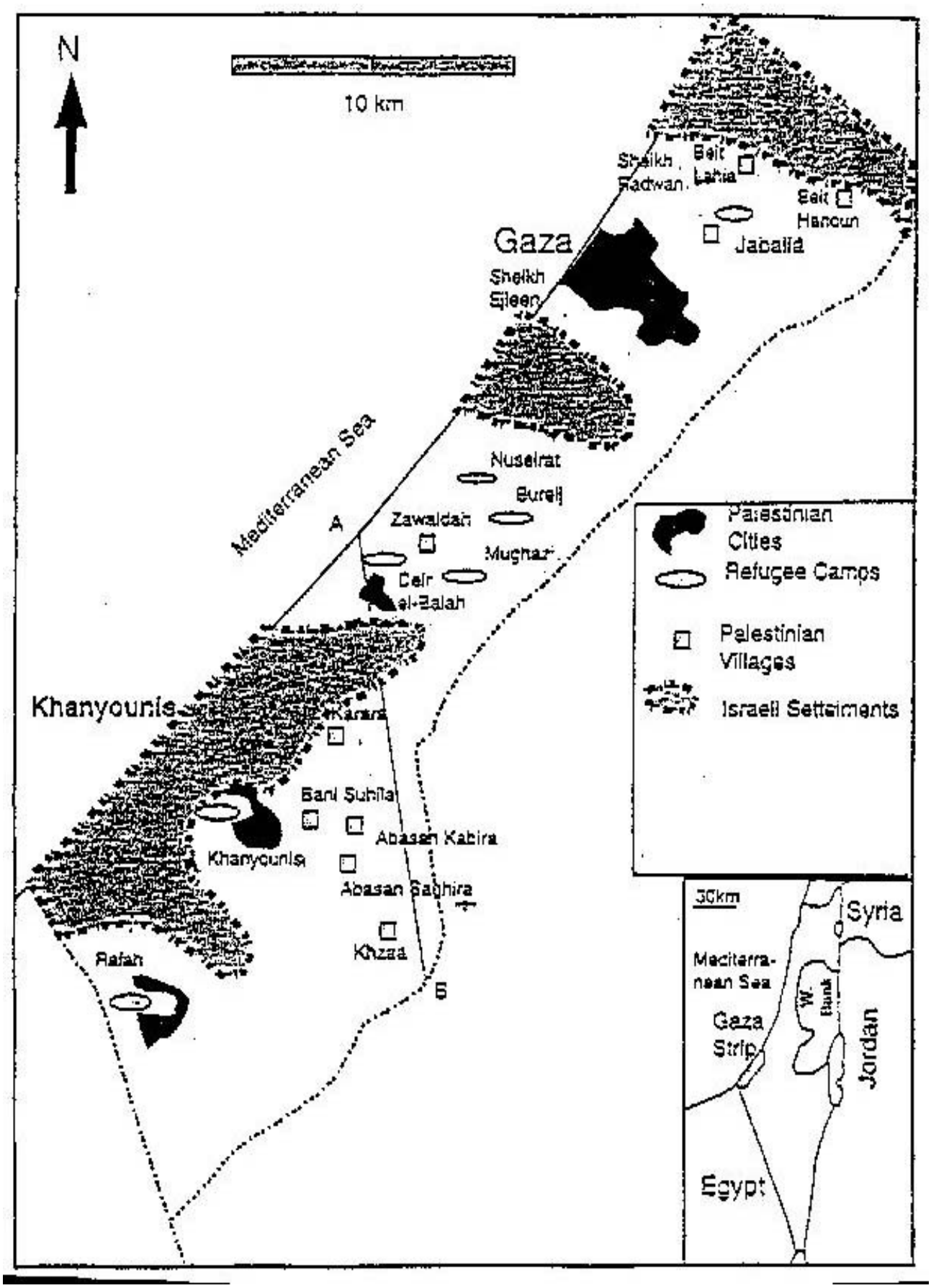
IN

ENVIRONMENT

1.1- Background

Gaza Strip is a narrow piece of land lying on the coast of the Mediterranean Sea at roughly 31^0 N latitude and 34^0 E longitude, about 32 km north of the Egyptian border. The coast has sand dunes of about 20 to 40 m in height above sea level. Gaza Strip is very crowded place with area, 360 km^2 as shown in the Map. It's whether is mild in winters dry and warm to hot in summers. The population size is estimated at 1,196,591 which is about 36.3% of the total population in Palestine in 2001; the population is mainly distributed in the cities, small villages, and eight refugee's camps that contain two thirds of the population [1]. Several environmental problems currently affect the Gaza Strip. These problems have not received serious investigation. Exposure to radioactive materials may be represent one of these environmental problems. The possibility of cancer induction due to indoor Radon has been attracting increasing attention in the scientific community during the past decade. It is now widely recognized that indoor Radon is one of the largest sources of exposure of ionizing radiation in the environment. Sand dunes along the coast of the Gaza Strip may well contain elevated concentrations of some of the radioactive minerals, like uranium and thorium, which are derived from the granite sources rocks present in the area. These sands and other surface materials may contain some radioactive substances, which produce elevated levels of Radon progeny. The main interest of the present work is to investigate this effect of radiation and how to measure its concentrations.

Radiation is energy traveling through space in enclosed of speed of light and electromagnetic waves. We encounter electromagnetic waves every day. These waves consist of visible light, radio and television waves, ultra violet, and microwaves with a spectrum of energies. These examples of electromagnetic waves do not cause ionizations (non-ionization) of atoms because they do not carry enough energy to separate molecules or remove electrons from atom.



Map of the Gaza Strip showing the location of the main cities, towns, refugee camps and Israeli settlements

Ionization energy is radiation with enough energy so that during an interaction with an atom, it can remove tightly bound electrons from their orbits, causing the atom to become charged or ionized. Examples of such ionization energy are gamma rays and neutrons [2]. The ionizing radiation is model carcinogen for risk assessment, few data are available on risk associated with low dose exposure, the effects of different types of radiation, in particular, the risks associated with the prolonged exposure of concern for the general population [3]. Radiation would be natural such as particles produced from radioactive materials, or artificial such as x-ray and applications of nuclear technology.

Figure (1.1) shows that the average effective radiation dose from Radon is estimated to be greater than the dose from medical treatments including x-rays, and very much greater than the dose from artificial activities including nuclear power, as an indication of the possible health impact [4].

Table (1.1) indicates that Radon and its daughters contribute the maximum percentage of annual effective dose equivalent. These numbers are average and were obtained by estimating the total dose for the U.S, and dividing by the number of people in the U.S. [4].

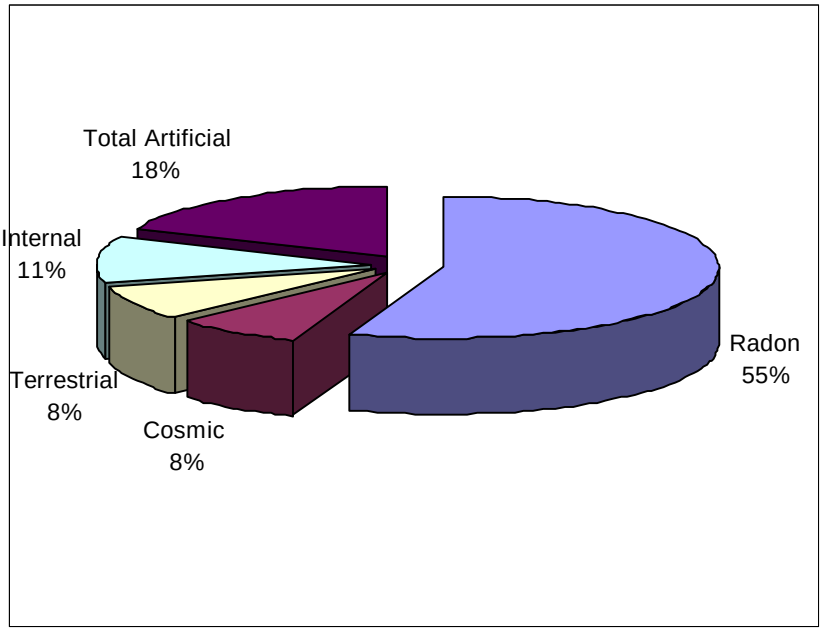


Figure (1.1) annual effective dose equivalent.

Source	Dose (mrem/yr)	Percent of total
Natural		
Radon	200	55%
Cosmic	27	8%
Terrestrial	28	8%
Internal	39	11%
Total natural	294	82%
Artificial		
Medical x-ray	39	11%
Nuclear medicine	14	4%
Consumer products	10	3%
Other		
Occupational	0.9	< 0.3
Nuclear fuel cycle	< 1	< 0.03
Fallout	< 1	< 0.03
Miscellaneous	<1	<0.03
Total artificial	66	18%
The total	360	100%

Table (1.1) annual effective dose equivalent.

The common types of radiation and its decay

There are three types of radiation: α, β, and γ decays. Unstable nucleons emit α or β decays to become more stable, γ decay is emitted when nucleons move from excited state to ground state without changing the nuclear species.

1) Alpha particles: consist of helium nuclei (He) which themselves consist of two protons and two neutrons. An alpha particle has a mass of 4 atomic mass unit (u) and carries two units of positive charge. It therefore have little penetrating power and can be stopped by the first layer of skin or a sheet of paper. However, if they are taken into the body, for example by breathing or

swallowing, alpha particles can affect the body's cells. The particles give up their energy over a relatively short distance inside the body. Alpha particles can cause more biological damage than other radiation. Uranium-238 (U), radium-226 (Ra) and Radon-222 (Rn) are typical alpha-particle emitters' [5].

a **Decay**: a nucleus emits an α particle (helium). The decay process is:

$$ {}^{A}_{Z}X_{N} \rightarrow {}^{A-4}_{Z-2}X'_{N-2} + {}^{4}_{2}He_{2} \qquad (1.1) $$

where X and X/ are the initial and final nuclei, A is the total mass number, N is the number of neutrons and Z is the number of protons in nucleus. An example of this process:

$$ {}^{226}_{88}Ra_{138} \rightarrow {}^{222}_{86}Rn_{136} + {}^{4}_{2}He_{2} \qquad (1.2) $$

in which the half-life time is ($t_{1/2}$ =1600 years)and the α particle appears with a kinetic energy of about 4.8 MeV[6].

2) Beta particles: consist of high-speed electrons of negative charge, which originate in the nucleus. Another type of beta particle consists of particles of the same mass as the electron but having positive charge, such as positron. Beta particles are emitted from the nuclei of both light and heavy radioactive atoms, they can be stopped by a sheet of aluminum, few millimeters thick. For example, both tritium (hydrogen-3) and lead-214 emit beta particles [5].

b **Decay**: here the nucleus can correct a proton or a neutron excess by directly converting a proton into a neutron or a neutron into a proton. These processes can occur in three possible ways:

$$ n \rightarrow p + e^{-} \qquad b^{-}decay \qquad (1.3) $$

$$ p \rightarrow n + e^{+} \qquad b^{+}decay \qquad (1.4) $$

$$ p + e^{-} \rightarrow n \qquad electron\ \ capture \qquad (1.5) $$

Some representations of β-decay processes are:

$$ {}^{131}_{53}I_{78} \xrightarrow[b^{-}]{} {}^{131}_{54}Xe_{77} \qquad t_{1/2} = 8.8 days \quad (1.6) $$

$$ {}^{25}_{13}Al_{12} \xrightarrow[b^{+}]{} {}^{25}_{12}Mg_{13} \qquad t_{1/2} = 7.2 \sec \quad (1.7) $$

$$ {}^{54}_{25}Mn_{29} \xrightarrow[e]{} {}^{54}_{24}Cr_{30} \qquad t_{1/2} = 312 days \quad (1.8) $$

In these processes, Z and N, each changes by one unit, but the total mass number A (Z+N) remains constant [6].

3) Gamma rays and x-rays: belongs to a class known as electromagnetic radiation. This type of radiation consists of quanta or packets of energy transmitted in the form of a wave motion. Gamma rays have great penetrating power and can pass through the human body. Typical radioisotopes that emit gamma rays beta particle emission are cesium-137 and iodine-131 [5].

g **Decay**: radioactive γ emission is similar to the emission of atomic radiation such as optical or x-ray transitions. An excited state decays to a lower excited state or possibly the ground state by emission of a photon of γ radiation of energy equal to the difference in energy between the nuclear states. γ emission is observed in all nuclei that have excited bound states (A > 5), and usually follows α and β decays since those decays lead to excited states in the daughter nucleus [6].

Equation of decay law:

The rate at which a particular radioactive material disintegrates is a constant independent of all physical and chemical conditions. Given a large number of atoms N of any radioactive element at time (t) then,

$$N=N_o \exp(-\lambda t) \qquad (1.9)$$

Where λ is a constant for the particular radioactive element called the disintegration constant or decay constant, and N_o to be the number of atoms present at t=0. The half-life time ($t_{1/2}$) gives the time necessary for half of the nuclei to decay. Putting $N=N_o/2$ in equation (1.9) gives

$$t_{1/2} = \mathrm{Ln}(2) / \lambda = 0.693/ \lambda \qquad (1.10)$$

It can be seen that at end of a time interval equal to $2t_{1/2}$ one quarter of the original material will still be in existence [7].

Radioactive series:

Practically all of the naturally radioactive elements lie in the range of atomic numbers from Z=81 to Z=92. These elements have been grouped into three

series, the uranium-radium series, the thorium series and the actinium series. The uranium series starts with uranium (A=238, Z=92) and goes through a series of transformations which involve the emission of α and β particles and ends with stable lead (^{206}Pb). The thorium series starts with thorium (A=232, Z=90), goes through a series of transformations in many respects similar to uranium series and end with lead (^{208}Pb). The actinium series was at one time believed to be an independent series, but its origin has been traced to an isotope of uranium, known as actino-uranium (^{235}U). This is the famous isotope of uranium of mass number 235, the end of this series is lead (^{207}Pb). For the current study, the most significant is ^{238}U-one, since ^{222}Rn is part of it. Figure (1.2) and figure (1.3) show the ^{238}U and ^{232}Th decay series respectively [8].

Radon: is a radioactive gas, first discovered in the early 1900s. During the early studies of radioactive elements at the turn of the century, it was found that "emanations," themselves radioactive were associated with many of newly identified radioactive elements. The gas associated with uranium and radium was called Radon. Subsequently, in precise usage, the term Radon has come to designate the symbol (Rn), the atomic number (86), atomic weight of (222) and the most abundant of the 18 radioactive isotopes of the element Radon. Chemically, Radon is a noble gas. As such, it is similar, for example, to helium and neon. Like any other noble gas, Radon is colorless and odorless. If it is in the air, it is inhaled along with all other gases. It is also exhaled promptly, and when dealing with Radon alone there would be little reason for concern. The Radon hazards do not come primarily from Radon itself, but rather from radioactive products formed in the decay of Radon. These products called the "Radon daughters," that also radioactive and attach themselves to whatever they contact. The main heath problems stem from inhaling of Radon daughters, or dust particles carrying Radon daughters, and subsequently lodging of the Radon daughters in the lung [9]. One other hand, Radon is used to initiate and influence chemical reactions [10].

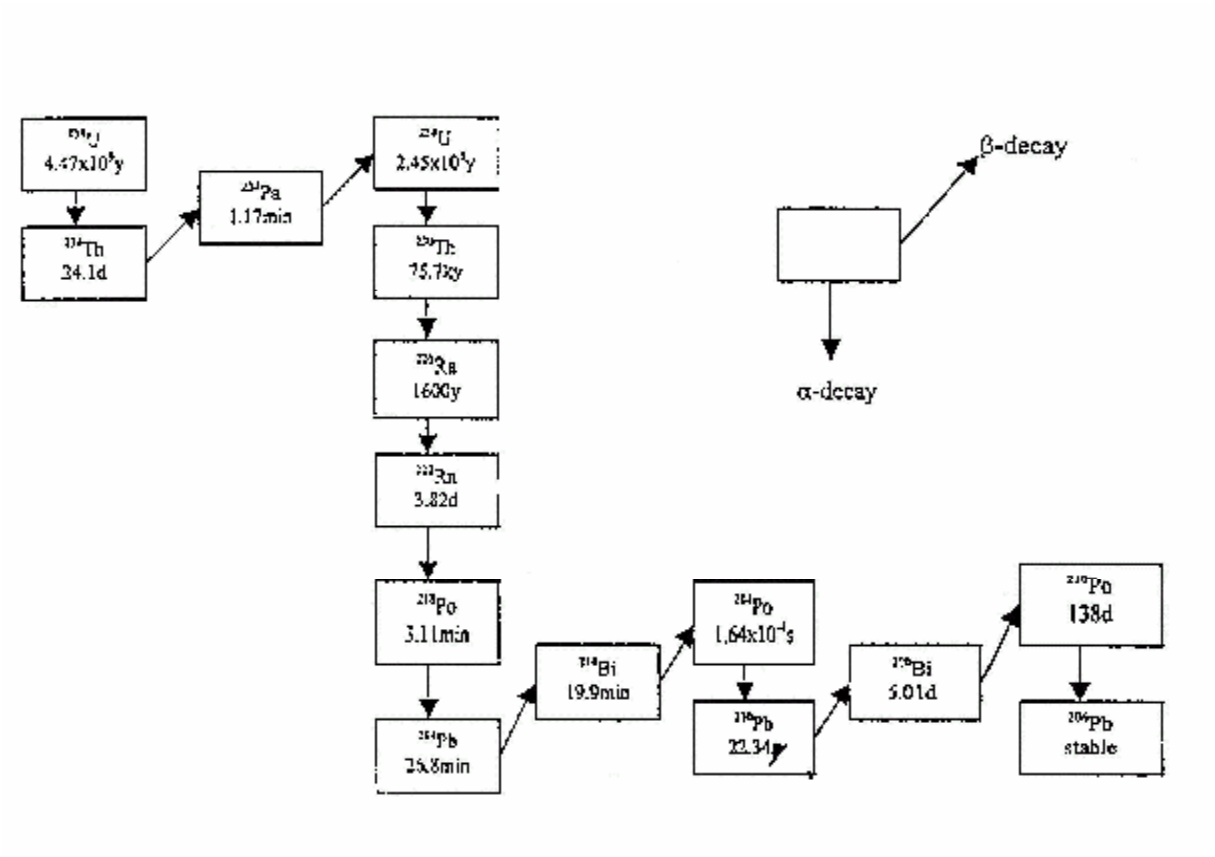


Figure (1.2) the decay series of ^{238}U

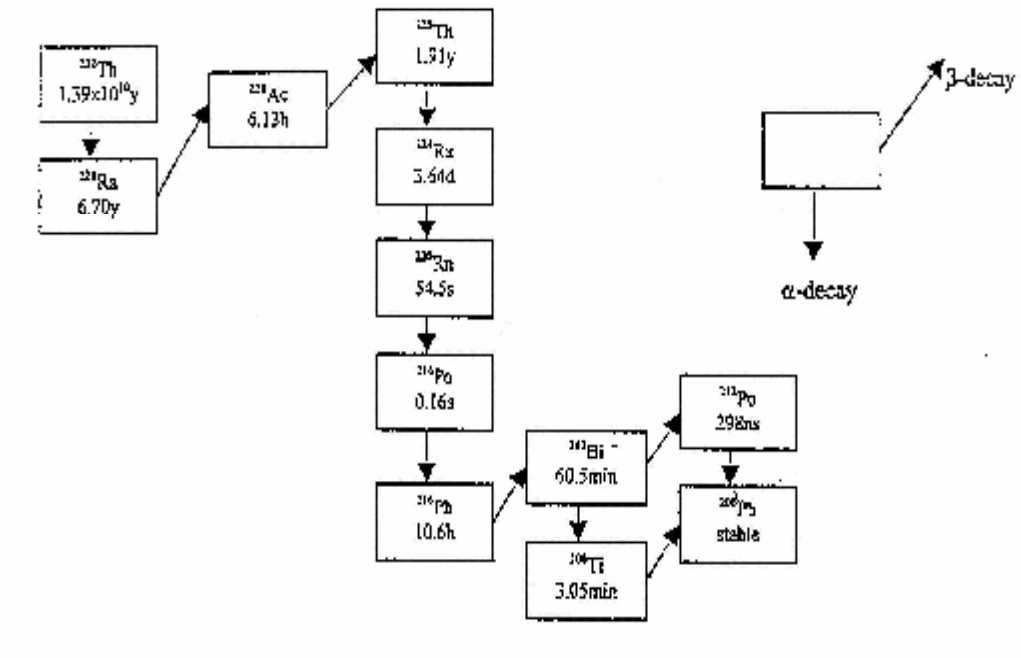


Figure (1.3) the decay series of ^{232}Th

1.2 - Characteristics of Radon and its decay products

Radon is naturally occurring radioactive gas that is mono-atomic. It is chemically inert and the heaviest of six noble gases constituting group-8 of the periodic table of elements. Unlike other gases in this group, it has no stable form, instead, all of its isotopes are radioactive. There are three naturally occurring isotopes of radon each associated with a different radioactive decay series. Radon-222 ($t_{1/2}$ = 3.82 days) is part of ^{238}U-(uranium) series. This nuclide is the most important one of the **three** isotopes of radon because of its concentration in indoor air and due to the health effects associated with the exposure to its progeny. Radon-220 ($t_{1/2}$ = 56 sec.) called a part of thorium (^{232}Th) series, also known as thoron in non-porous material is comparable to the activity of Radon-222, the much shorter half-life time of thoron causes its concentration in air to be relatively low and therefore usually of second interest. The third isotopes is Radon-219 ($t_{1/2}$ = 3.92 sec.) called actinon in reference to its presence in actinium (^{235}U) decay chain. This nuclide does not contribute to the low natural abundance of (^{235}U) and the very short half-life time of ^{219}Rn. For these reasons, only the measurement methodology for Radon-222 will be discussed below. Once Radon is formed in radium-bearing material, some of it leaves the grains to the pore space. This fraction is relatively free to move between the pores and its transport is possible. Radon can therefore reach the air or water to which humans have access, provided that transport is sufficiently rapid to be completed before the Radon decays. The half-life time of Radon is (3.82 days) and long enough that much of the Radon formed either in building materials or in the ground soil within approximately one-meter under the building reach the indoor environment. An important characteristic of Radon is that decays to radionuclides, which are chemically active. The progeny of Radon are solid elements although Radon is a gas. The decay products of Radon are radioactive isotopes of polonium, bismuth, lead and thallium. They can be divided into **two groups** according to the half-life time. The **short**-lived Radon daughters ^{218}Po (3.11 minute), ^{214}Pb

(26.8 minute), ^{214}Bi (19.9 minute) and ^{214}Po (164 μsec) with half-life time below 30 minutes and **long-**lived Radon decay products ^{210}Pb (22.34 years), ^{210}Bi (5.01 days) and ^{210}Po (138.4 days), appendix (A). As mentioned in the previous section the true cause for lung cancer is not the Radon but the inhalation of its short lived daughter's [11].

1.3 - Behavior of decay products

An important property of Radon progeny is their chemical activity. The decay products can attach to aerosol particles, indoor walls, furniture and the human lung if Radon is inhaled. After the decay of Radon, the daughters can deposit on surfaces before or after attachment to the particles. The health significance of the decay products is greatly influenced by their half-life decay modes and their behavior after decay. The α decay of ^{218}Po and ^{214}Po imparts the radiation dose of greatest significance. The overall concentration of decay products is represented by the potential alpha energy concentration (PAEC). It depends on the concentrations of the first three decay products (^{218}Po, ^{214}Pb and ^{214}Bi) and on the amount of polonium α energy that obtained. The behavior of Radon daughters is of high interest among scientists not only to satisfy a relationship between indoor Radon concentrations and decay product concentrations but also to provide a view of decay products exposures. This indicates the utility of control measures aimed at modifying concentrations of the decay product [11].

In indoor environment, the Radon concentration is reduced by ventilation rate whiles the progeny concentration reduced by the processes of removal. Also the behavior of the decay products is affected by their chemical activity, they attach to particles and deposit to surfaces. The chemical activity of Radon's decay products affects their concentration and their chemical and physical form in air, and hence affects the resulting dose to lung. Atmospheres with low α particle concentrations and hence high proportion of unattached decay products tend to have higher rates of decay product deposition into wall. This effect can be attained by the use of particle cleaning devices, which also

remove the decay products directly [11]. The concentration of Radon in the air is measured in units of picocuries per liter (pCi/l) or (Bq/m^3), with ($1pCi/l=37Bq/m^3$). One Bq corresponds to one disintegration per second. The concentration of Radon daughters is measured in units of working level (WL). One WL corresponds to 101.3 pCi/l of Radon equilibrium with its short-lived daughter in a typical indoor environment [9].

1.4- Ranges of alpha particles

For understanding the physical behavior of Radon and its decay products, it is helpful to know the penetrating power of α particles that are emitted in decay. Table (1.2) lists ranges in air and water of α particles emitted by ^{220}Rn and ^{222}Rn and their prompt alpha-active daughters. Alpha-decay energies are also given. Ranges in typical plastics are similar to those in water. For example, for the range of the 5.49 MeV ^{222}Rn α particle approximate values are 39 μm in water, 32 μm in polyethylene terephthalate (of density $1.2g/cm^3$), 31μm in polyethylene, 37μm in Lexan polycarbonate, but 23μm in soda lime glass (density ≈ $2.5g/cm^3$) [8].

Nuclide	α Energy (MeV)	α Range (μm in water)	α Range (μm in air)
^{222}Rn	5.49	39	4.08
^{218}Po	6.00	44	4.67
^{214}Po	7.69	66	6.91
^{220}Rn	6.29	48	5.01
^{216}Po	6.78	41	5.67
^{212}Po(64%)	8.78	83	8.53
^{212}Bi(36%)	6.05	45	4.73

Table (1.2) a **particle energy and ranges**

1.5- Sources of Radon :

For indoor Radon, the principal sources are soil, building material and water supplies. The outdoor Radon concentration is usually low and less than average indoor levels; it may therefore be neglected as a contributor to Radon exposure, which are of radiological health significance. In most countries the source of indoor Radon is in the soil or rock underneath to the house.

1.5.1) Soil as a Radon source

The major source of Radon in the atmosphere at least 80% is from emanations from soil that derived from rocks. These rocks contain some uranium, where the decay of ^{238}U through ^{226}Ra gives Radon. Certain types of rock, including granites, dark shales, light-colored volcanic rocks, sedimentary rocks containing phosphate and metamorphic rocks derived from these rocks, have higher average uranium contents. Radon gas from the soil can enter a home or building through floors, hollow-block walls, cracks in the foundation floor and walls, and openings around floor drains, pipes, and sump pumps [12].

1.5.2) Building material as a Radon source

Building materials that made from stone, sand, and or byproducts may contain uranium and radium and generate Radon. Many of these materials such as brick, wallboard or concrete are sufficient porous to allow Radon to escape into the air. Table (1.3) indicates the typical concentration of ^{226}Ra in various building materials.

Material	Concentration of ^{226}Ra (pCi/gm)
Wood	0.03
Concrete	0.43-1.65
Brick	1.1-2.6
Tile	2.1
Nature gypsum	0.11-0.27
Insulating material (glass wool)	0.35-1.1

Table (1.3) typical radium concentration in some building materials.

The Radon is more concentrated in the lower levels of the home (that is basement, ground floors and the first floors) [12].

1.5.3) Water supplies as a Radon source

In addition to soil and building material, water supply can be a route of entry of Radon that exist in the ground water, and also if the home water supply is derived directly from deep wells. Differences in water use patterns, ventilation and airflow can cause significant temporal variations in indoor Radon levels. Water in rivers and reservoirs usually contains very little Radon because it escapes readily into the air. The small water supply systems are often closed systems with short water transit times that do not allow Radon to be completely removed or decayed. Radon then escapes from the water into the indoor environment as people use the water for showers and washing [12].

The concentration of uranium and radium in seawater is much less than in the soils and rocks. Due to this low concentration and to the high solubility of Radon in water, little Radon is released from ocean surface waters into the atmosphere. Table (1.4) indicates the sources of the global atmospheric Radon. Thus, virtually the entire contribution to the Radon in the atmosphere comes from soil and ground water [9].

Source	Input to atmosphere (MCi/yr)
Emanation from soil	2000
Ground water	500
Emanation from oceans	30
Phosphate residues	3
Uranium mill tailings	2
Coal residues	0.02
Nature gas	0.01
Coal combustion	0.001

Table (1.4) sources of global atmospheric Radon

1.6- Mechanisms of Radon entry into buildings :

Radon is a gas; it has much greater mobility than uranium and radium, which are fixed in the solid matter in rocks and soils. Radon can easily leave the rocks and soils by escaping into fractures and opening in rocks and into pore spaces between grains of soil. Radon moving through soil pore spaces and rock fractures near the surface of the earth usually escapes into the atmosphere. Where a house is present, however, soil air often flows toward its foundation for **three** reasons, the presence of openings in the house's foundation, differences in air pressure between the soil and house, and an increase in permeability around the basement [13].

1.7- Objectives

Scientific researchers have debated the effects of ionizing ray on human health for many years. People have awareness of the risk from nuclear power station and effects of artificial source of radiation. However, they have shown little concern about continuous exposure to natural source of radiation. It is well known that Radon and its short-lived products in air, can cause lung cancer, and thus become a public health concern. Research studies conduced in others countries show that about 5% of all cases of lung cancer may be caused by Radon exposure [12]. Therefore, the purpose of this study is to measure the Radon and its daughter's concentrations throughout Gaza strip. Since Radon and its progeny are believed to be responsible for many diseases and environmental problem abroad, environment Protection Agency (EPA) recommends that action be taken to reduce Radon levels if the annual average is 4pCi/l (148Bq/m^3) or higher [12].

1.8- Scope of work

This research program aims to study a preliminary survey of natural radioactive materials in the middle region of Gaza Strip. This study will enable us to identify the environmental problem concerning radiation hazards.

A passive diffusion Radon dosimeters containing CR-39 solid-state nuclear track detector will be used in this survey. These dosimeters were distributed in

the houses that selected in the middle region of Gaza, (Nsuirat camp (N), Buraij camp (B), Maghazi camp (M), Deiralbalah camp (D), Abrag Al-Nsuirat (A), and Zahra City (Z)). This distribution of the detectors is based on the geographical location, climatological condition, and the nature of the soil and the type of the houses, see appendix (B). The detectors are left about four months, and then collected for chemical etching developments. The average number of alpha particles tracks are obtained and concentration of Radon is determined. Such a study will provide us with a basic data that useful for any future study.

The plan of this thesis is as follows :

The chapter one gives background about radiation types and characteristics of Radon and its decay products, as well as the geography of Gaza Strip. Chapter two includes the health and risk effects of Radon in additional to the factors affecting Radon concentrations and factors affecting risk estimates. In chapter three, the experimental techniques that used for measurements of the Radon concentrations are described. In chapter four, presents the general results obtained for different parameters. Finally, in chapter five the most significant conclusions and recommendations. Glossary, appendices and references are also included at the end of this thesis.

CHAPTER (2)

HEALTH AND RISK EFFECT OF RADON

2.1-Health effect of Radon

As discussed in the previous chapter, Radon gas decays into solid materials called Radon progeny, which are the source of the health risks of Radon. They initially have a positive electric charge resulting from the decay process. Due to their very small size and their charge, the progeny tend to adhere to anything that they contact: dust, particles, walls, furniture, etc. when they are inhaled, they adhere to the lungs [14]. During the radioactive decay, particles and/or electromagnetic radiation are released. Two of Radon progeny (^{218}Po and ^{214}Po) release α particles. Polonium atoms adhering inside the lungs will emit α particles to the surrounding lung tissue. If these particles were to hit the external skin, they would be stopped without damage by the dead outer layers of skin. But lung tissue has no such dead layer and therefore more sensitive. Long term projection of lung tissue by α can increase the risk of lung cancer. This increased risk of lung cancer due to progeny deposited in the lungs is the reason for the current concern about Radon [15]. The rate of lung cancer induction depends upon the kind, number, and location of the radioactive atoms deposited in the lung. These in turn depend upon many factors; including the Radon concentration in the air, the ratio of the concentration of the daughters to that Radon itself, the extent to which the daughters are attached to dust particles and sizes of the dust particles, the breathing rate, and the rate of deposition of the daughter atoms in various parts of the lung [9].

In Gaza Strip, recent report of cancer registry unit shows that, the total reported diagnosed cases through the years 1995-2001 were 2,404 {1,264 male, 1,140 female} cancer cases, number of these (314, 13.1%) bronchus and lung cancer [1].

The connection between Radon and lung cancer in miners has raised concern that Radon in homes might be causing lung cancer in the general population, although Radon in most homes are much lower than in mines. In converting Radon risks from mines to homes, the committee on Biological Effects on Ionizing Radiation (BEIR) was found most mines received Radon exposure

that, on the average, many times larger than those people in most homes; people in a few homes actually receive Radon exposures similar to those of some mines. It was necessary for the committee to estimate the risks posed by exposures to Radon in homes on the basis of observed lung cancer deaths caused by higher exposures in mines. The committee agreed with several earlier groups of experts that the risk of developing lung cancer increases linearly as the exposure increases [16].

Many scientists examined the applicability of data collected from the mines to indoor environment. This requires consideration of a number of factors, including the difference in population between the two locations. Population is much extended and broader in the indoor environment than in mines. In addition, the mines under consideration were in a high level of physical activity during exposure. Finally, the mine atmosphere contains a mixture of materials and substances that differs from ordinary environment. Scientists who examined these effects reached the conclusion that the result derived from the mines can be applied relatively to indoor environment [8].

2.2- Factors affecting indoor Radon concentrations :

Radon inside a house can be produced from several and different sources and the significance of every source changes from one place to another depending on the concentration of uranium, radium and Radon in that source. The ground under the house and building material generally contain uranium and radium. Radon released from these constituents is often the major source of Radon inside the house. The differences found in Radon concentrations among different houses stem more from differences in the rates of Radon entry than from differences in ventilation patterns.

The Radon concentrations in a given house depend upon several factors:

2.2.1) Nature of the soil and rock

-The radium content of the soil and rock under the building.

Some of the houses with the highest Radon levels found to be built over a certain type of rock that is well known to have a high content of radium. Radon concentrations are strongly with construction type with structure made of wood usually exhibiting lower values than these derived from geologic materials as shown in table (1.3) in previous chapter [8].

-The permeability of the surrounding soil.

A soil with high permeability will permit Radon to move more quickly through the pores to the surface and hence inside the house. A sandy soil is a good permeable where a clay soil is not [11].

-The nature and extent of the openings between the house and soil.

This with the previous two factors, determine the Radon entry rate. In general a house with a basement provides the greatest amount of house, soil contact and hence the greatest opportunity for Radon entry. A house with a crawl space generally provides the least contact between the building and the soil [11].

2.2.2) The chemical and physical transformations and processes of removal

Radon is chemically inert, but it is radioactive so it decays into another element called Radon progeny, which is chemically active. The chemical reaction of a pollutant reduces its concentration. Man can affect the concentration by reducing or preventing the elevated Radon levels inside the houses by removing the Radon source (contaminated materials), preventing Radon entry through ventilation and treating the openings, removing Radon from the house after entry through ventilation and air cleaning [8].

2.2.3) High level of the house

Radon concentration varies with height above the ground ranging from a maximum at the soil air interface to an immeasurably low value in the

stratosphere, variation are quite strong in the first few meters above ground. So the basement (lower part of a house) has higher Radon levels than the upper part of a house. Radon concentration varies from one building to the other within the same location. It is also different from one floor to the other within the same building [17].

2.2.4) Ventilation rate

As Radon is a gas, the ventilation in the houses is an important factor affecting the Radon concentration. In houses with self-ventilation, weather conditions outside mean that the ventilation rate indoors is changeable. Ventilation rates depend on wind velocity outside, the air exchange rate and Radon level inside. Decreased ventilation rates are important causes of the high indoor Radon concentrations. It is discovered that several classes of pollution could occur indoors at higher levels. This is owing to the pressure of gas stoves in the houses, therefore with increasing the ventilation rate is there deceasing in the indoor Radon concentration. Among the different rooms in a house the cellar normally has the lowest air exchange rate and it also closest to the ground. The ground is the most powerful Radon source [8]. So Radon concentration at bedrooms is higher than the living rooms and corridors [17].

The ventilation rate has **three** components. Infiltration refers to the uncontrolled leakage of air into the building through cracks and holes in the building shell. Natural ventilation is the flow of air into the building through open doors and windows. Mechanical ventilation is provision or removal of air by means of blowers or fans [11]. Almost all homes have some Radon; the levels can vary dramatically even between similar homes located next to each other. There are many factors; it is very difficult to predict the Radon level in a home. The only way to determine whether your home has Radon levels is to test for it.

2.2.5) Seasonal variation

The Radon concentration varies with time during the day, again the afternoon values are lower than the morning values [18]. This variation depends on how

people behave in houses; whether the doors and windows are open or kept closed; whether the kitchen fan is running and so on. There is also a seasonal variation of Radon levels. In summer, where the temperature is high or higher than winter, also the humidity changes from season to anther [11]. In Germany, shows the variation Radon concentration during one year, there is a clear rise of the Radon level in winter and decrease in spring down to the minimum level occurs in summer [8]. Also obtained data from 6 cities in Japan, show that the Radon concentration was minimum in summer and maximum in winter [18]. In general in the temperate climates the Radon concentration in a house during the winter is higher by a factor of about 1.5 to 2 than that during the summer with upstairs levels being less than downstairs [19]. The main reason for this difference is the difference on ventilation rate during the year. The seasonal variation of the indoor Radon levels depends on several parameters: type of house, Radon source and living habits of the inhabitants' [8].

- It is also evident that each house has its own specific "**life**" of Radon. Therefore it is not possible to generalize and say that is enough to measure the Radon level in one house and believe that the neighboring houses have the same Radon level.

2.3- Factors affecting risk estimates

There are however, several uncertainties associated with the estimation of risk from indoor Radon exposures. These include: gender and age at exposure, joint effect of Radon and smoking on lung cancer risks, and the exposure rates of Radon.

2.3.1) Gender and age at exposure

The probability of Radon-induced lung cancer is higher among males than females, reflecting the difference in baseline rates. The basis for this approach was the idea that different in baseline lung cancer rates between sexes could be explained by differences in smoking habits. The international commission on radiological protection (ICRP), 1993, on the other hand, decided to use the

same absolute risk coefficient for males and females, based largely on results for smoking and radiation exposure in the Japanese people. However, ICRP, recognized that risk factor for females may be an over estimate [8]. In Gaza Strip: in period 1995 to 2001, 314 patients died from bronchus and lung cancer: 245 men and 69 women [1].

Radiation risk to embryos is higher than to children, which in turn is higher than to adults. Their rapidly dividing cells and higher breathing rates may cause this increased sensitivity of children to radiation-induced cancers. It is compounded by their heavier exposure to Radon by spending more time inside the house and/or in the basement. Recent research in Europe confirms that Radon is much more harmful to children than the adults. Lung cancer incidence as a result of Radon exposure is estimated to be about ten times higher for people exposed at the age of about 15 than at about 50 [20]. However, the national council on radiation protection (NCRP), 1984, assumed that no lung cancers occur before age 40 and the contributions to lifetime risk are ignored after the person reaches age 85 [9]. In Gaza Strip, the median age of cancer in males was 60 years, and in females was 51 years [1].

2.3.2) Joint effect of Radon and smoking

The evidence from studies indicates that joint effect of Radon exposure and smoking on the risk of lung cancer is greater than additive. The main effect of choice of model is on how the risk is distributed between smokers and non-smokers [8]. In the other word, the number of cancers induced in ever-smokers by Radon is greater than one would expect from the additive effects of smoking alone and Radon alone. Nevertheless, the estimated 15,000 or 21,800 deaths attributed to Radon in combination with cigarette smoking and Radon alone in ever-smokers constitute an important public-health problem [16].

Smoking is the major cause of lung cancer, it is responsible for about 90% of all lung cancer deaths in males and 80% of lung cancer deaths in females [21]. In U.S. (1990), the risk of dying from lung cancer is 22 times higher among male smoking and 12 time higher among female smoking than among people

who have never smoked [22]. Table (2.1) shows that when 1,000 people are exposed to a certain Radon level over a lifetime**,** what is the expected number who will catch the lung cancer [23].

Radon level (pCi/l)	People smoke (people could get lung cancer)	People never smoke (people could get lung cancer)
20 (740 Bq/m^3)	~ 135	~ 8
10 (370 Bq/m^3)	~ 71	~ 4
8 (296 Bq/m^3)	~ 57	~ 3
4 (148 Bq/m^3)	~ 29	~ 2
2 (74 Bq/m^3)	~ 15	~ 1
1.4 (48.1 Bq/m^3)	~ 9	< 1
0.4 (14.8 Bq/m^3)	~ 3	< 1

Table (2.1) joint effect of Radon and smoking

2.3.3) Exposure rate

The exposure rate of Radon plays an important role of the risk of lung cancer. When an alpha particle damages a cell to make it cancerous, the onset of lung cancer takes a minimum of 5 years, but most often 15 to 30 years, and even longer. The decades-long decay of Radon progeny and the slow onset of cancer make it almost impossible to measure in a mobile population the increase in health rates caused by Radon [20].

2.4- Other health risks from Radon

It is generally assumed that inhaled Radon gas is quickly exhaled and has little time during its circulation through the body to deposit its radioactive products in human organs, tissue, or bones. But there is some evidence that Radon also cause leukemia (cancer of the blood) and other types of cancers. Animals exposed to high concentrations of Radon progeny display lung carcinoma, and other respiration and breathing diseases. However, the risk of other cancers is

much lower than the lung cancer risk [20]. Lung cancer is the most common of cancer death in the world for both men and women. In the United States alone, earlier studies estimated that 154,900 people expected to die from lung cancer in 2002. In comparison, 126,800 people are expected to die from colon, breast and prostate cancer combined in 2002 [24].

2.5- Radon concentrations in different countries

There is no doubt about Radon being a lung carcinogen for humans. All major international organizations that have examined the health risks of Radon agree that it is a lung carcinogenic. For instance, in the U.S.A., the Environmental Protection Agency (EPA) and the National Cancer Institute (NCI) have independently placed that numbers at about 15,000 lung cancer deaths each year are attributed to Radon. Because of the health risks of Radon and its decay products, many scientists examined Radon concentrations in different places in overall the world. They used various experimental and technical possibilities that are available to measure the Radon concentrations indoors. These procedures will be discussed later. Recent surveys in a number of countries in the European Communities (EC) have shown that the average Radon level ranges from about 20 to 50 Bq/m^3, with some countries having Radon levels of several hundred to a few thousand Bq/m^3 [8]. This depends strongly on the factors of Radon concentrations. On the other hand many countries set (action levels) based on the Radon concentration alone. An action level is the maximum concentration of Radon permitted, before some action is deemed necessary to reduce the concentration. For example, the EC (1990) has recommended the following action levels: 200 Bq/m^3 for new homes and 400 Bq/m^3 for existing homes. EPA in U.S. (1987) recommended that if a short-term screening measurement result is above 140 Bq/m^3, a follow-up measurement is needed to determine the long-term average concentration. If the long-term average is still above 150 Bq/m^3, action is recommended to lower the concentration [25]. The Radon concentration was found mainly to depend on the ventilation rate. Variation of the inverse of the ventilation rate

with the concentration of Radon daughters in the different high-rise buildings. In Jordan (340 dwellings in Irbid region), it has been found that Radon levels vary between 3.0 to 163.9 Bq/m^3 with an average value of 33.28 Bq/m^3. Also measurements indicated that the highest Radon concentration is found to be in basement floor and in the bedrooms [17]. Muhsiz, et al. (1993) have measured indoors average Radon concentrations in more than 400 houses in Istanbul City in Turkey. The average Radon concentrations vary between 10 to 260 Bq/m^3 and the mean value was 50 Bq/m^3. They reported that the bedrooms have relatively higher Radon concentrations than living rooms and Radon concentrations in the basement floors were higher than those in the upper floors. This was attributed to elevated level in bedrooms to the exhaled Radon of the sleeping person and poor ventilation of the bedroom [26]. In a survey made in Singapore, 100 detectors were used for measure Radon concentrations of the living room and the bedroom to show that Radon concentration in the two rooms could be different due to variation in the ventilation rate. Radon concentration ranges from 2.4 to 54.89 Bq/m^3 and arithmetic mean was found to be 11.95Bq/m^3 [25]. Measurements were made in 55,000 randomly selected houses in 38 states divided into 225 regions in Unites States, to identify houses with screening level of Radon. 24 regions were identified as having the highest Radon concentration: with 78.4% above 74 Bq/m^3; 57.3% above 148 Bq/m^3; 31.7% above 296 Bq/m^3; and 8.6% above 740 Bq/m^3. An extremely high Radon level, exceeding 410 kBq/m^3, has been measured in the basement of a house in Prescott in the state of Arizona [8]. Some locations in Brazil have been recognized worldwide as high level natural radiation areas. However, Radon concentration was ranging from 600 to 900 Bq/m^3 in living areas and bedrooms. The high values obtained from indoor Radon concentrations can be attributed to the combination of local geology, building materials used, and type of structure and nature of ventilation used in some houses [27]. In Ireland dwellings, the Radon measurements were carried out in 11,319 houses throughout the country. The Radon levels varied from 10 to

1924 Bq/m^3, with average indoor Radon concentrations of 89 Bq/m^3. It can be estimated that approximately 91,000 houses throughout the country have indoor levels in excess of 200 Bq/m^3 [28].

Recently primary survey of Radon concentrations was carried out throughout North Gaza Strip dwellings by Yassin, 1999, the measurements show that Radon concentration ranges from 22 to 43 Bq/m^3 with arithmetic mean 34 Bq/m^3. It is therefore noted that the main reason for the differences in Radon concentrations present is actually the ventilation condition [27]. This motivated me to pursue this survey throughout different region in Gaza.

CHAPTER (3)

EXPERIMENTAL TECHNIQUES FOR MEASURING RADON

3.1- Introduction

Humans lack the special sense to detect ionizing radiation as a result they have to rely on specialized instrumentation for identification and quantification of ionizing radiation. Radiation detectors come in many different types, but they are all based on the same fundamental principle. There are a number of ways through which radiation transfers its energy to detector, charge particles for example generally interacts through direct collisions with atomic electrons thus causing excitation or ionizing of the atoms. The form in which the converted energy is seen generally depends on the type of detector and design of detection system [29].

3.2- Fundamental characteristics of detectors

The fundamental characteristics of detectors are:

3.2.1) Sensitivity

The sensitivity of a detector can be viewed as the capability to produce a useful signal for a particular radiation and its energy. Detectors are usually designed to be sensitive to a specific type of radiation within a given energy range. It therefore follows that there is no detector that can be sensitive to all types of radiation and all energies. Some of the parameters that influence the sensitivity of a detector are the detector mass and the cross section which determine the probability that an incident radiation will transfer energy to the detector in the form of ionization. For charged particles, even detectors of low density and small volume will usually have some ionization produced in its sensitive volume [29].

3.2.2) Efficiency (e)

Generally the efficiency related the actual registered events by the detector to the events emitted by the source. Radiation detection is generally divided into **two** types:

- Absolute efficiency (ε_{abs}), is the fraction of events emitted by source that is actually events by the detector (det.),

.

$$e_{abs} = \frac{Events\ recorded\ by\ \det.}{Events\ emitted\ by\ source} \qquad (3.1)$$

This efficiency is dependent on the properties of the detector and the design of the counting geometry,

-The intrinsic detection efficiency (ε_{int}), is defined as the fraction of the events actually incident on the detector that are recorded.

$$e_{int} = \frac{Events\ recorded}{Events\ imping\ on\ the\ \det.} \qquad (3.2)$$

This efficiency is a basic parameter of the detector. It is independent of the source and detector geometry. Also, it is a function of the type of radiation, detector material, and the physical thickness of the detector in the direction of the incident radiation [29].

3.3- Identifying and controlling Radon concentrations

In order to determine whether a particular house has elevated Radon levels, measurements of Radon and Radon progeny in the house air are required. A variety of methods exist for measuring Radon or Radon progeny levels. Some methods involve simple to use devices which homeowners can buy and use by themselves, other methods require a professional with specialized equipment visits the house. These measurements of Radon concentration can be divided into two major classes namely **passive method;** when the Radon concentrations are measured under natural conditions, Radon entering the detection volume by more diffusion, or **active method**, which involves the pumping of gas into or through a detecting instrument [8]. Radon tests fall into two categories: short-term tests (screening) which are for a period less than three months and long-term tests which are covering periods longer than three months. The two most popular, commercially available Radon detectors are the charcoal type and alpha track detector. The charcoal type is always a short-term test but alpha track detector may be either short or long-term. Both kinds are designed to be exposed to the air inside home for a specific period of time. Then, they are sent to a laboratory for analysis [14].

Let us now examine the various experimental and technical methods of measuring Radon concentration in the environment.

3.3.1- Passive devices

The passive method has several advantages over the active method. The passive technique is now widely used by scientists and researchers on large scale. This technique has also attained the status of commercial use throughout the world. In the case of direct measurement of the radiation, the detection sensor is usually placed inside a container (dosimeter) that has an opening to let Radon enter it. The container is used meantime to protect the detector and to make room around the detector for a sensitive volume large enough so as to have as many alpha particles produced and detected in as short time as possible usually for several months. The various detectors that can be used for Radon concentration measurements are:

3.3.1.1) Solid State Nuclear Track Detectors (SSNTDs)

SSNTDs are passive, low cost, long term method, most widely used for measuring Radon and can be used for site assessment both indoors and outdoors. SSNTDs are sensitive to alpha particles in the energy range of the particles emitted by Radon. SSNTDs are largely insensitive to beta and gamma rays. In other word, $\beta-$ and γ-rays do not produce etchable individual tracks. SSNTDs also have the advantage to be mostly unaffected by humidity, low temperatures, moderate heating and light. They of course do not require an energy source to be operated since their detecting property is an intrinsic quality of the material they are made of [8].

Two types of commercially available SSNTDs are:

a) Allyl-diglycol-carbonate ($C_{12}H_{18}O_7$) known as CR-39
b) Cellulose nitrate ($C_6H_8O_8N_2$) known as CN-85

The detectors SSNTDs placed inside the dosimeters. Detectors are usually exposed for 3 to 12 months. When alpha particles from the decay of Radon and its progeny strike the detector, they cause damage tracks. At the end of

exposure, the detector is chemically treated and the numbers of tracks over area counted by a microscope and Radon concentration is determined [9].

They have been compared in different types of SSNTDs based passive dosimeters. The different shapes of dosimeters using SSNTDs have been designed to measure Radon concentrations in houses. Relative performances of a set of dosimeters were studied by Khalid Jamil, et al.1997 [30]. The dosimeters were consisting of (1) box-type, (2) pen-type, (3) tube-type, (4) Karlsruhe Diffusion Chamber (KDC)-type, and (5) bare-type dosimeters. Sketches of these dosimeters are shown in figure (3.1). The positions to mount CR-39 or CN-85 are shown in each type of dosimeter [30].

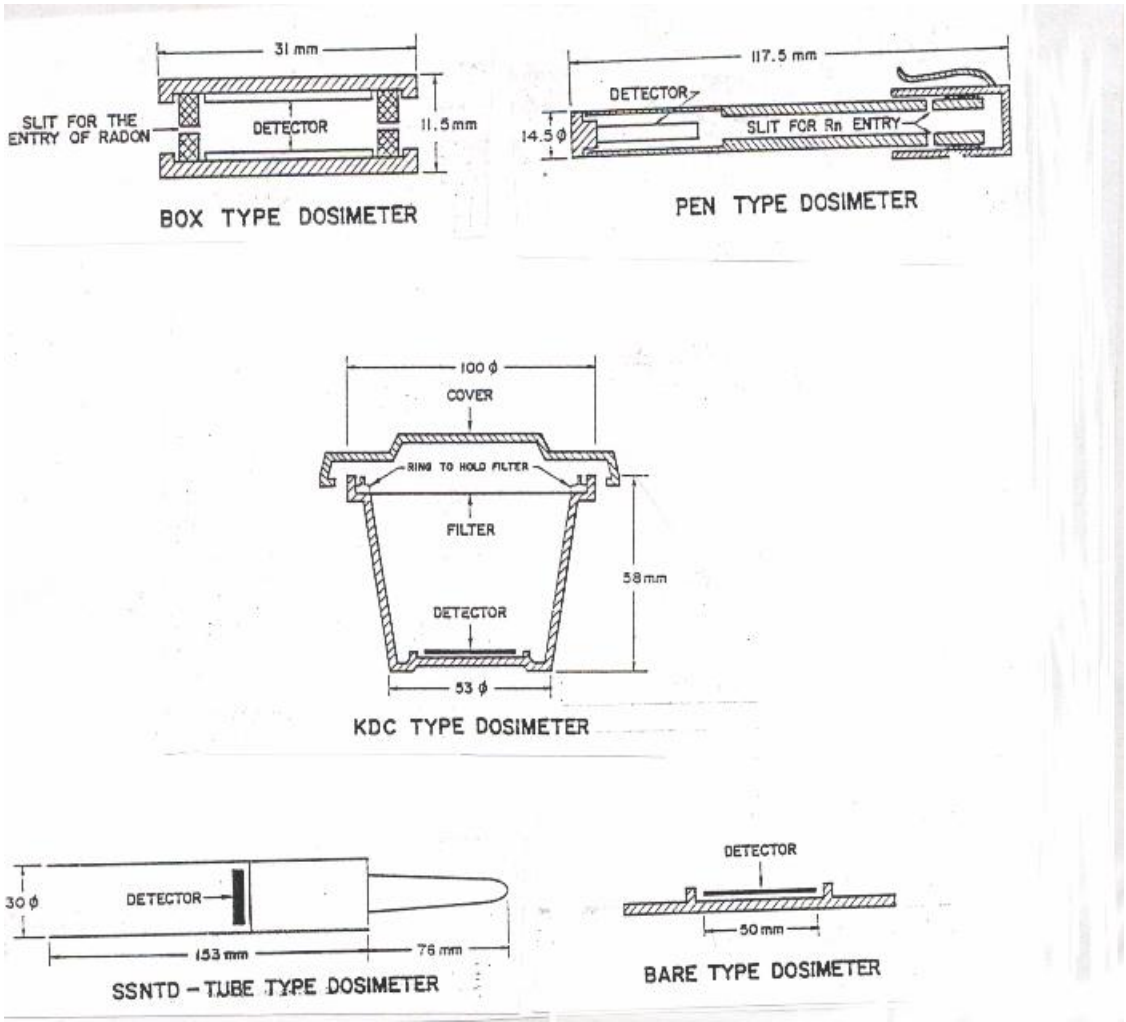


Figure (3.1) sketches of various types of dosimeters

The track densities due to alpha particles from Radon and its progeny from both types (CR-39, CN-85) of SSNTDs were determined and results are presented in table (3.1). Since all dosimeters were exposed for 30 days in a chamber where Radon concentrations was the same. The detectors are then collected, chemically etched and the tracks are counted microscopically.

Dosimeters	Calibration (CR-39) $(Bq/m^3)/(track\ per\ cm^2)$	Calibration (CN-85) $(Bq/m^3)/(track\ per\ cm^2)$
Box-type	$(78.2\pm8.6)\times10^3$	$(70.5\pm8.1)\times10^3$
Pen-type	$(27.4\pm3.3)\times10^3$	$(22.8\pm2.7)\times10^3$
Tube-type	$(142.4\pm14.3)\times10^3$	$(129.0\pm16.7)\times10^3$
KDC-type	$(204.2\pm24.5)\times10^3$	$(182.6\pm22.1)\times10^3$
Bare-type	$(273.2\pm32.7)\times10^3$	$(248.2\pm32.2)\times10^3$

Table (3.1) intercalibration factors for different types of SSNTDs

Bare-type dosimeters are the most efficient dosimeter, but given inaccurate Radon concentrations. For this reason the KDC type dosimeters are preferred where SSNTDs are enclosed in a container to avoid the aerosol particles containing Radon progeny. It is found that the track detection efficiency of CR-39 for alpha particles was found about 10% higher than track detection of CN-85 for various shapes of dosimeters. This observed change in detection efficiencies is due to different chemical composition of the two kinds of plastics. It is concluded that KDC-type of dosimeter is found the most efficient and practically useful. Also, CR-39 is a better detector as compared to CN-85 used for Radon concentration measurement [30].

This is due to the fact of the advantages of the detector of CR-39 of measuring the Radon concentration which is cheap and can be easily obtained. Therefore, this type of detectors have been used throughout our work so that a reasonable result can be obtained.

3.3.1.2) Electret detectors

Electret detector has the ability to store information over relatively long periods of time, it is independent of humidity in its environment, and is easy for reading. Electret detector is a piece of dielectric that exhibits a permanent electrical charge. This charge produces a strong electrostatic field, which is able to collect ions of the opposite sign and the total charges of the electret decrease. An electret dosimeter is made of a steel can, on the inside top of which the electret detector is fixed. At the bottom of the can a small inlet allows the Radon gas to enter the assembly through a filter. When Radon decays it produces ionizing particles that in turn produce ions within the can. These ions and the total charges of the electret detector are collected. The charge deposited is calculated from which Radon concentrations can be determined. But its response curve does not efficiently cover the very low or very high dose, also it is sensitive to normal gamma radiation background [8].

3.3.1.3) Charcoal adsorption detectors

Radon, like a number of other gasses, can be adsorbed on charcoal. This property has been used to develop a practical detection system in which Radon gas is accumulated in a bed of charcoal then the gamma ray activity from the decay of Radon daughters is counted [9]. Charcoal adsorption detector is a passive low cost screening method for measuring indoor Radon concentrations. For this method, an airtight container with charcoal is opened in the area to be sampled and Radon in the air adsorbs into the charcoal adsorption detector by diffusion. The detector is deployed for 2 to 7 days. At the end of the sampling period, the container is sealed and sent to a laboratory for analysis. After exposure, scintillation fluid is added to the vial and Radon concentrations is determined by the alpha and beta decay of Radon and progeny when counted in a liquid scintillation spectrometer. But charcoal adsorption detectors are sensitive to drafts, temperature and humidity [31].

3.3.1.4) Thermoluminescent Detectors (TLDs)

Ionizing radiation can cause atomic or molecular disturbance in some materials such that material emits light when heated. TLDs for ionizing radiation are based on this property. TLD chip is exposed to α and β particles and gamma rays that are emitted by the Radon and its decay product [9].

In the case of Radon detector, Radon is allowed to enter a detector volume containing the TLD. A metallic plate is placed at a short distance in front of the TLD. This plate can either be electrically charged for better collection efficiency, or not. Radon daughters deposit on the plate and ultimately decay, thus producing energy storage in the TLD. After proper exposure to Radon rich atmosphere, the TLD is recovered and read in a TLD apparatus. But the data analysis is not always very simple, depending on the type of used TLDs. In commercially available devices the data analysis is made automatically [8].

3.3.2- Active devices

The active part for detecting Radon, or Radon daughter products, is an electrical or electronic device in general. Measurement technique is usually either pumped from the environment or extracted by means of a gas or liquid, sampling achieved by the suction action of pumps, syringes, pistons, etc. Where, Radon is pumped, the gas flow passes through the electronic meter to the outside of the equipment. Direct scintillation can also be used for measuring Radon levels by means of forcing air through the detector. The air is bubbled through liquid scintillation solvent where the Radon is dissolved and air passes through. Radon concentration is thus continuously measured [8]

In this method Radon concentration measured over shorter periods. However, the measurements are not valid tests for whole house Radon concentrations and should not be used to make mitigation decisions [15].

3.4- Tracks registrations

Track registration detectors: record the presence of alpha particles through small pits (tracks) in the surface of a clear plastic chip. The track density (tracks/area) is proportional to total number of alpha particles that struck the chip surface. To use the track etch detectors would normally require calibration to determine the calibration constant in units of tracks.

3.4.1) Tracks formations

Heavy ionizing particles passing through detectors (CR-39) leave narrow trails of damage. The means by which heavy ions lose energy as it is shown in the next section and rest in solids to understand the track formation [29]. In fact, the most important characteristics of damage tracks detectors are that, there is a minimum density of damage along the core of the track that will permit the track to be enlarged by etching. The whole of the energy loss does not contribute of this damage. The existence of threshold is one of the most valuable characteristics of damage track detectors, since particles whose primary ionization rate is below the critical value of a given material will not be registered. This explains its ability to differentiate against large fluxes of higher energetic particles, electrons, gamma rays, and etc [8]. So, the CR-39 can be conveniently used for registration of alpha particles only.

3.4.2) Tracks etching characteristics

The shape and diameter of each pit (track) depend basically on two parameters: the etching characteristics of given detector, signified by its "bulk etching velocity" V_B for etchant used under the given etching conditions such as the type, molarity and temperature of the etchant. And the characteristics of the charged-particle interaction with detector, signified by the "track etching velocity" V_T along the trajectory of the particle, it's value where is a function of type and energy of charged particle, and V_T can be many times V_B [8].

The chemistry of track etching has not been studied extensively. More intensive studies have concentrated on track shape geometry, and on the effects of environmental conditions on track etching. The ratio of V_B/V_T is an

important parameter that is very useful in determining the registration properties of charged particles in dielectric media. Also for tracks to be made visible it is very important that the angle (θ) between the detector surface and incident particle is larger than a critical angle $\theta_c = \sin^{-1}(V_B/V_T)$. Where θ_c is an angle at the time that etchant travel a distance V_B vertically into the boy of the detectors as shown in figure (3.2) [29].

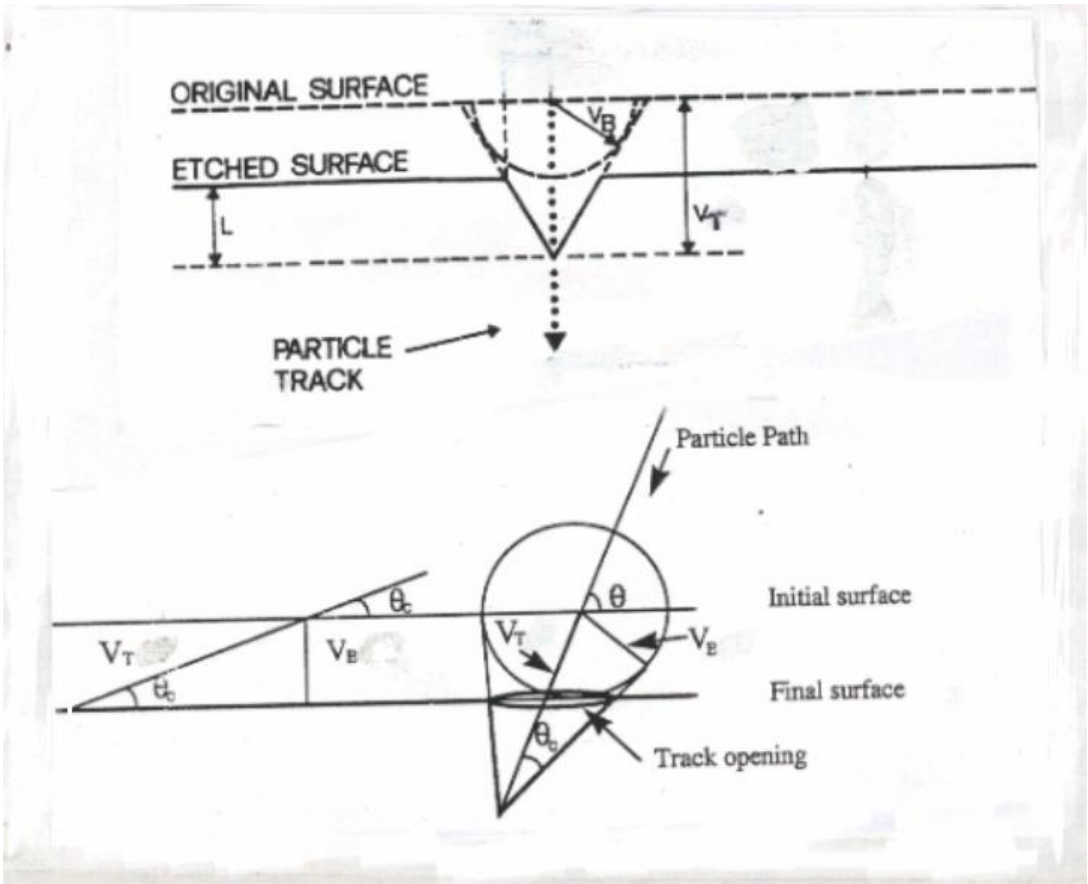


Figure (3.2) model of track etching on CR-39 detectors

3.4.3) Tracks chemical etching

The molarity of the etchant and temperature of etching are important parameters of the etching conditions, also the etching time varies according to the etching conditions. To determine these parameters, use of the suitable chemical etching for detectors were exposed to Radon source. Chemical etching is usually carried out the detectors in a thermostatically controlled bath

of temperatures ranging from 40 to 70^0c. The common etchant is an aqueous solution of (NaOH) or (KOH) in concentration ranging between 1 to 12 M (molarity) [29]. The detectors are immersed in the etching solution, without rotation inside beakers, which are placed in constant temperature water bath for a certain period of time. At the end of etching, the detectors are removed, washed in running water. After drying the detectors are ready to count under an optical microscope [8].

3.4.4) Tracks counting

The main requirement generally is simply to count etched tracks on a detector. Etch pit "track" sizes and shapes will of course vary: vertically incident alpha particles will form circular etch pits. While the majority of etch pits will be elliptical resulting from alpha particles incident on the detector surface of shallower dip angles. Then consistently ignore any smaller etch pits and any scratches are easily discounted. The genuine track etch pit may be identified by slowly moving the fine focus of microscope up and down and looking for a bright point of internally reflected light at bottom tip of the etch-pit cone as shown in figure (3.3) [8].

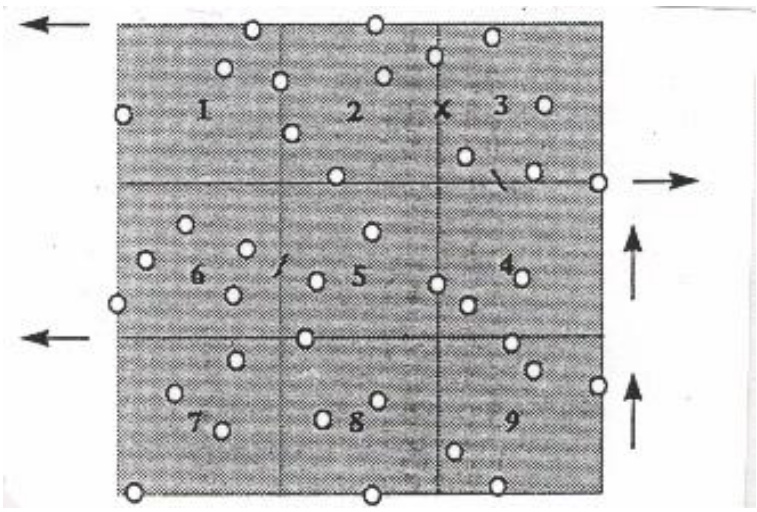


Figure (3.3) tracks formation on CR-39 detectors after chemical etching

3.5- Measurement technique

The most common device for the measurement of Radon concentration inside houses and potential alpha energy concentration (PAEC) is the passive diffusion Radon dosimeter containing solid state nuclear track detector (SSNTD) CR-39. This type of detector is used throughout the present work. The dosimeter is composed of a plastic cup with a circular hole of diameter d in the center of the lid and depth h (d=7cm, h=4.5cm) as shown in the figure (3.4). The hole is covered by a piece of sponge sealed into the interior surface of the lid. A piece of dimension (L=2.5cm,W=1.3cm) of CR-39 is fixed to the bottom of the cup.

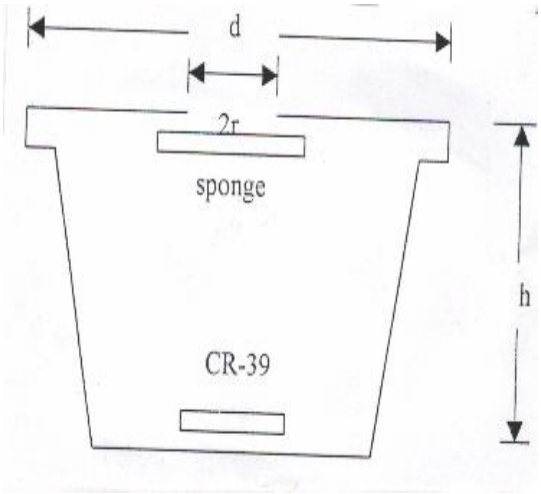


Figure (3.4) passive diffusion Radon dosimeter

This detector is exposed to indoor environment of a house for a period of time. The detectors are then collected from the houses and chemically etched. Then number of tracks per unit area are observed and counted under a microscope. Finally, from the track density the Radon concentration in (Bq/m^3) is determined.

3.6- Distribution technique

Five hundreds (500) dosimeters, were prepared and distributed inside the houses of the middle region of Gaza strip. These houses are chosen to be representative of the whole region. Our sampling strategy was to distribute the dosimeters in houses located at different geographic parts of the region.

Moreover, houses built of different materials (see appendix B). Like (stones and concrete), (stone and zinc) and (stone and spostos) were selected: a first group of 100 dosimeters was distributed inside Nuseirat camp (N), a second group of 100 dosimeters placed inside Bureij camp (B), a third group of 100 dosimeters located inside Maghazi camp (M), a fourth group of 100 dosimeters distributed inside Deiralbalah camp (D), a fifth group of 50 dosimeters distributed inside Abraj An- Nuseirat (A), finally a group of 50 dosimeters distributed inside Zahra City (Z). The detectors were placed in a room so as to avoid contribution of ^{220}Rn and its progeny, where the occupants of the house spend most of their time. The detectors were either hung on an interior surface or placed on a horizontal surface so that it was exposed to room air. They were not installed near any heat or air conditioning source and were not dusted. It has been pointed out that strong and uncontrolled variation in efficiency for detectors of alpha particles emitted by Radon and its decay products were observed in detectors exposed to solar light. Therefore, the detectors must be protected from sunlight.

The detectors were left in the houses for a period of four months, (from August to December of 2001). Only 433 dosimeters were found in place and collected, while the remaining 67 dosimeters were considered lost, mistreated or damaged. The collected detectors were chemically etched using a 20% solution of KOH, at a temperature of $(70\pm.0.5)^0$ C, for 5 hours according to a calibration made in our laboratory. The detectors immersed in the etching solution, in a small container inside a water bath. At the end of the etching process, the detectors were washed thoroughly with distilled water and then left to dry. Each detector was counted visually using an optical microscope with power of (40×10). Tracks in 9 distinct regions were observed, through the area ($1cm^2$) the average number of tracks/cm^2 was determined.

3.7- Calibration technique

Images of tracks can be enhanced by special techniques. For applications where only the measurement of track density is required, high contrast

techniques have been developed which usually enlarge the track images. The etchant most often used for CR-39 are aqueous solution of KOH or NaOH. In the present work, we have chosen KOH was chosen as aqueous solution.

Somogyi and Gulyas (1972) have first shown that KOH solution increases etching speed. A large variety of data available in published papers has studied the experimental etching parameters for CR-39 detectors. In practice, the most important parameters for control of the etching speed of the detectors are temperature, concentration of the etchant and time etching, as indicated in figure (3.5) [8].

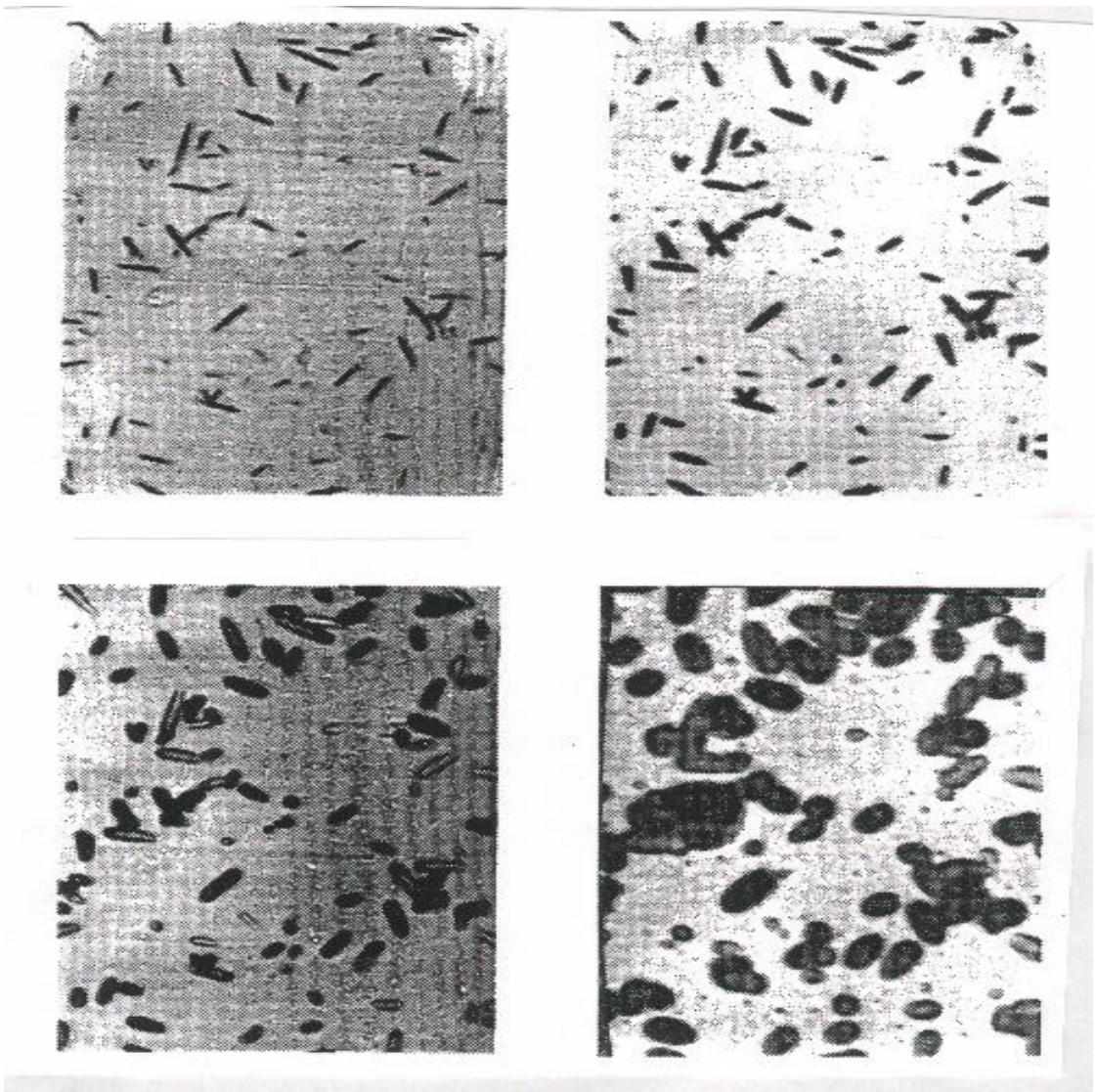


Figure (3.5) track induced fission fragment for different etching

Firstly, to find, suitable molarity of KOH (concentration of the etchant), eighteen (18) dosimeters were exposed to ^{226}Ra (Radon source) of activity concentration 800 Bq/m^3 for twelve (12) days. Then the collected detectors were chemically etched using different values of molarity of KOH at constant temperature (70^0c) and constant etching time (5 hours). The numbers of tracks per unit area of $1cm^2$ were counted using an optical microscope with power of (40×10). Figure (3.6) shows that the variation of the track density (number of track/cm^2) as a molarity function of KOH. The maximum numbers of track density was found at 20% molarity of KOH, where a clear track observed. As the molarity of KOH increased greater than 35%, the detectors were found not valid for track counting and dissolved. The variation of tracks diameters for the same detectors as function of the molarity of KOH is also illustrated in figure (3.7). It is indicated that the 20% molarity of KOH is reasonable solution.

Secondly, to find, suitable etching time, another eighteen (18) dosimeters were exposed to ^{226}Ra (Radon source) of activity concentration 800 Bq/m^3 for twelve (12) days. Then the collected detectors were chemically etched using 20% of molarity of KOH at constant temperature (70^0c) and different etching times. The numbers of tracks per unit area of $1cm^2$ were counted by using an optical microscope with power of (40×10). Figure (3.8) shows that the number of tracks increases when the time etching increases. But as the etching time increased greater than 7 hours, the detectors were found not valid for track counting and dissolved.

The shape of diameter tracks change drastically with prolonged etching time as shown in figure (3.9). The diameter of the track keeps increasing, but once the track has lost its pointed shape it becomes less clear and more difficult to differentiate from background pits (tracks). Also, from the two figures (3.8, 3.9), it is concluded that 5 hours time etching is reasonable for chemical etching of clear tracks.

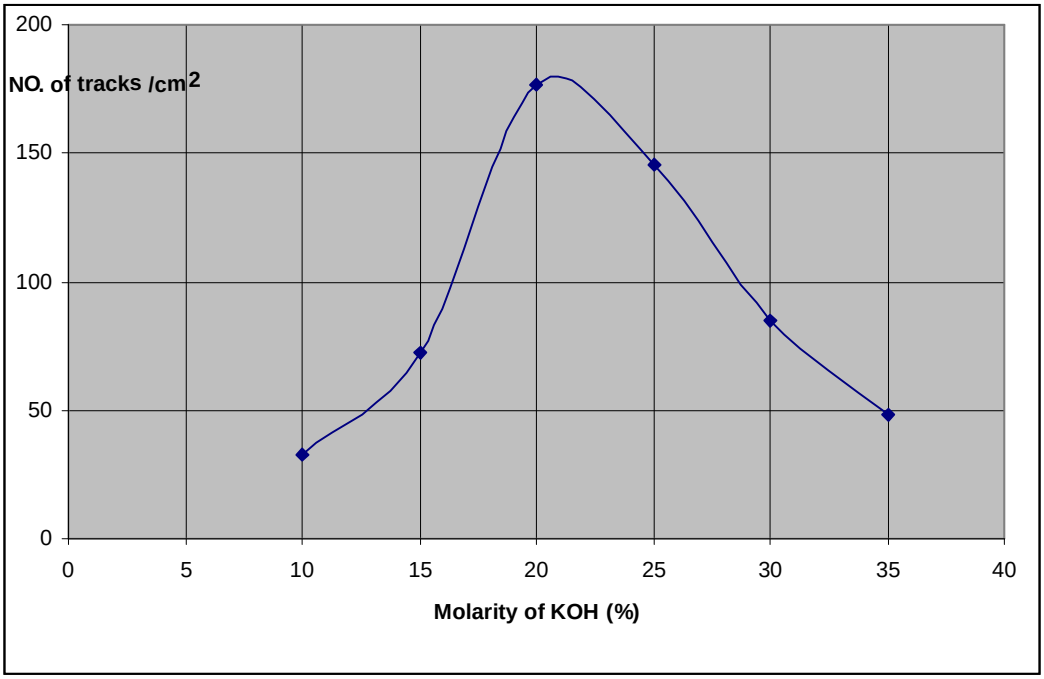


Figure (3.6) relationship between track density and molarity

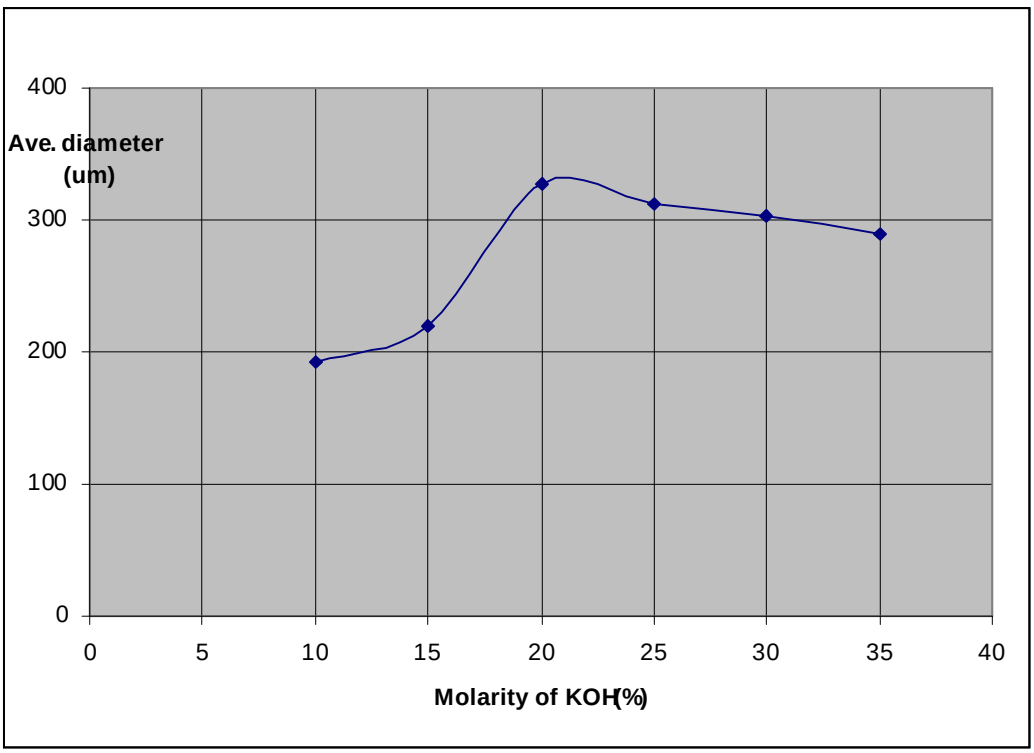


Figure (3.7) relationship between average diameter and molarity.

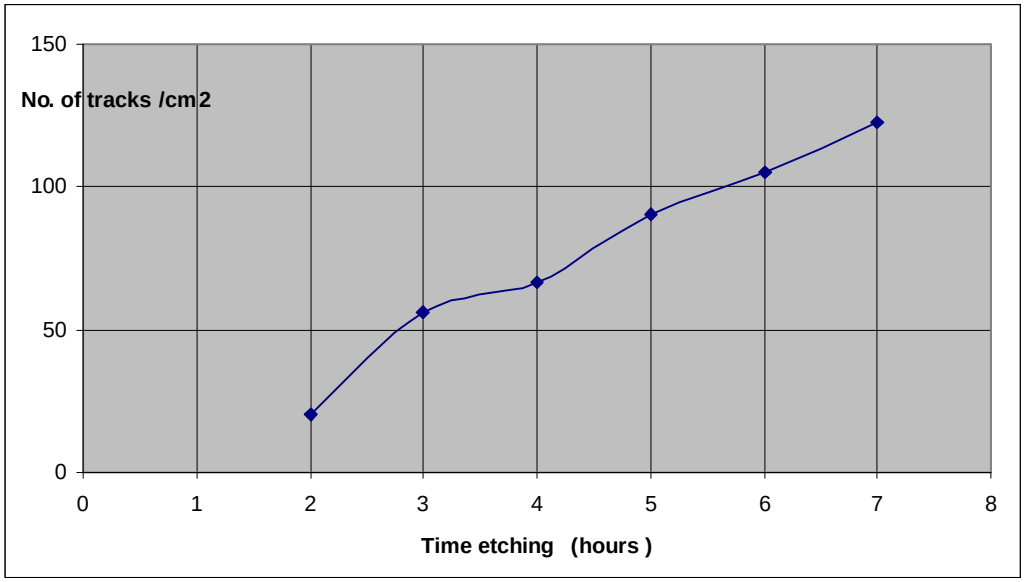


Figure (3.8) relationship between track density and etching time.

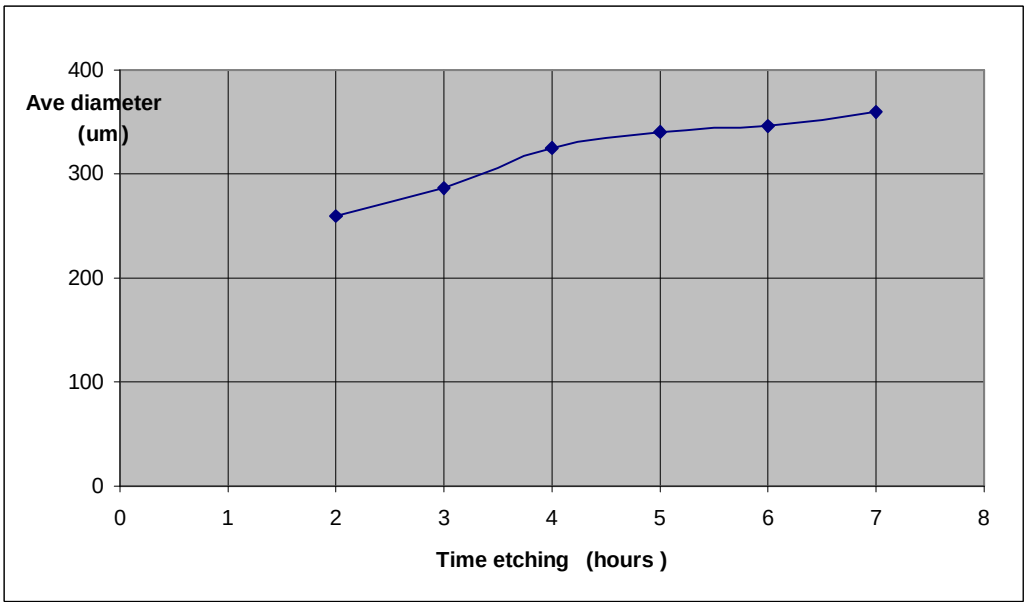


Figure (3.9) relationship between average diameter and etching time.

3.8- Determination of Radon concentration

The solid state nuclear track detector technique is one of the most often used technique for the measurement of Radon. Radon concentration (C) in surrounding air is measured in terms of Bq/m^3, since the most regulatory reference levels are specified in these unit.

Determination of Radon and its daughter's concentrations (C) throughout Gaza Strip are carried out by the following equation [32]

$$C(Bq/m^3) = \frac{C_O\left(Bq.d/m^3\right)}{r_0}\left\{\frac{r}{t}\right\}_{\text{det.}} \qquad (3.3)$$

Where,

C_0=the total exposure of ^{226}Ra (Radon source) in term $Bq.d/m^3$,

ρ_0=track density (number of tracks/cm^2) of detectors exposed to ^{226}Ra,

ρ=track density (number of tracks/cm^2) of distributed detectors,

t= exposure time (days) of distributed detectors.

Simply, a number of dosimeters were exposed to a known dose of ^{226}Ra (Radon source) for a period of time. Then those dosimeters were collected and treated chemically etching. The average numbers of tracks/m^2 were observed. These detectors were considered as a calibration standard [32].

Similar method is also obtained for track detectors techniques to determine the calibration constant (factor). This is derived by dividing the track density by the total exposure of Radon source. Then the equation (3.3) for Radon exposure becomes as follows [33].

$$C(Bq/m^3) = \frac{1}{k}\left\{\frac{r}{t}\right\}_{\text{det.}} \qquad (3.4)$$

where k is called the calibration factor in terms of (track.cm^{-2}/Bq.d.m^{-3}), or a calibration coefficient was determined experimentally.

Calibration factor (k)

The calibration process for dosimeters used in this survey was prepared and carried out by Yassin [27]. Four dosimeters were exposed for 30 days of ^{226}Ra (Radon source) of activity concentration 800 Bq/m^3. It gives 572 pCi.d/l

(2.12×10^4 Bq.d/m^3) concentration for the total exposure. The room's Radon gases monitor was a NITON RAD7. 2500 number of tracks/cm^2 were found in these calibration detectors, then reversed calibration constant (1/k) was found to be (8.45 Bq.d.m^{-3}/track.cm^{-2}), the overall uncertainty in this calibration was estimated to be ±10% [27]. Substituting reversed calibration constant in equation (3.4) then,

$$C(Bq/m^3) = 8.45\left\{\frac{r}{t}\right\}_{\text{det.}} \qquad (3.5)$$

The above equation was used to determine the Radon concentration (C) throughout the present work.

For example, consider that there are 400 tracks/cm^2 (average value), where the dosimeter exposed for a time period of 100 days. So the Radon concentration would be:

$$C = (8.45)\ (400/100) = 33.8\ Bq/m^3$$

So, the observed 400 tracks/cm^2 corresponds ≈34 Bq/m^3 Radon concentration.

CHAPTER (4)

RESULTS AND DISCUSSIONS

4.1- Introduction

Passive diffusion Radon dosimeters containing CR-39 solid state nuclear track detectors of good quality were used in this survey. A pair of two dosimeters was distributed to houses that were randomly selected. One dosimeter was placed in a bedroom and another in a living room or a kitchen. Our sampling strategy was to distribute the dosimeters in the camps located at different geographic parts of the region. Radon concentration inside the house changes from one place to another depending on houses built of different material like (stone and zinc), (stone and spostos) and (stone and concrete) were selected (see appendix B). Also, the Radon concentration depends on the high level of the houses. From the public health point of view, such cumulative Radon exposure conditions could be important, since they occur in a period when most people are resting at home. This information is valuable based on these choices, however, the selected houses in the present survey can be considered representative of the middle region of Gaza.

4.2- General results

The collected detectors were chemically etched (see previous section 3.7). Each detector was counted visually using an optical microscope with power of (40×10). Tracks in 9 distinct regions were observed, through the area ($1cm^2$), then average number of tracks/cm^2 was found. By using equation (3.5) the Radon concentrations were determined over the different camps in the study region of this survey. Table (4.1) indicates that the numbers of dosimeters collected from the groups of camps and the minimum and maximum concentrations of Radon in the camps of each group measured in Bq/m^3. The table also shows the average Radon concentrations (C) and the standard deviation (S. D.) for each camp in location of the survey.

The arithmetic mean of all measurements of Radon concentration performed at all camps of middle region of Gaza was 37.83 Bq/m^3 (1.02 pCi/l) with a range of values between 13.36 and 83.82 Bq/m^3 (0.361 and 2.265 pCi/l) and a maximum value of 97.06 Bq/m^3 (2.62 pCi/l) with average standard deviation

of 11.23. The overall uncertainty of these measurements was estimated to be ±10%. In most cases, only one measurement per building was made. However, it should also be taken into account that one result from a certain floor rooms dose not necessarily represents the main Radon level of whole building.

Location	No. of detectors	Ave. C(Bq/m^3)	Max. C(Bq/m^3)	Min. C(Bq/m^3)	S. D. Bq/m^3
Nuseirat (N)	84	37.5	79.5	16.3	13.4
Bureij (B)	91	45.0	97.1	17.2	12.6
Maghazi (M)	90	38.0	87.1	8.6	12.3
Deiralbalah (D)	85	44.5	93.3	15.5	9.9
Abraj Al Nuseirat (A)	43	28.8	64.3	14.9	8.2
Zahra City (Z)	40	17.5	56.3	3.2	7.3
Ave. value	Sum 433	37.8	83.8	13.4	11.2

Table (4.1) Radon concentrations in each camp and S. D.

Figure (4.1) shows the average Radon concentrations of B and D camps were higher than M and N camps, but very higher than A and Z that are new Cities. Also, the result indicates that the difference between the minimum and maximum Radon concentrations in each camp is very high. This large variation in Radon concentrations inside these camps is due mainly to the difference in the ventilation methods used, difference type of these locations building (bedroom, living room, … etc) and difference in locations height above the ground (basement, first floor, …etc). Different materials will have different influence on Radon emanation rates that determine the indoor concentration, like the building was built stone and spostos, stone and concrete…. etc.

Most of buildings in middle region of Gaza Strip are low-rise level and made of concrete or spostos and stone. While some of the buildings have their windows closed all the time, most of them have the windows open for a few hours a day. In our sample of the camps, about 70% have their windows open for more 7 hours per day. However these effects have been found to be small when compared with those caused by different ventilation conditions. This indicates that the difference in Radon concentration is due to different ventilation in the camps. Other factors may also affect the Radon concentration, such as the air exchange rate. Therefore, it is assumed that the main reason for concentration difference is ventilation conditions. In the next sections these factors that affect on the Radon concentration will be discussed.

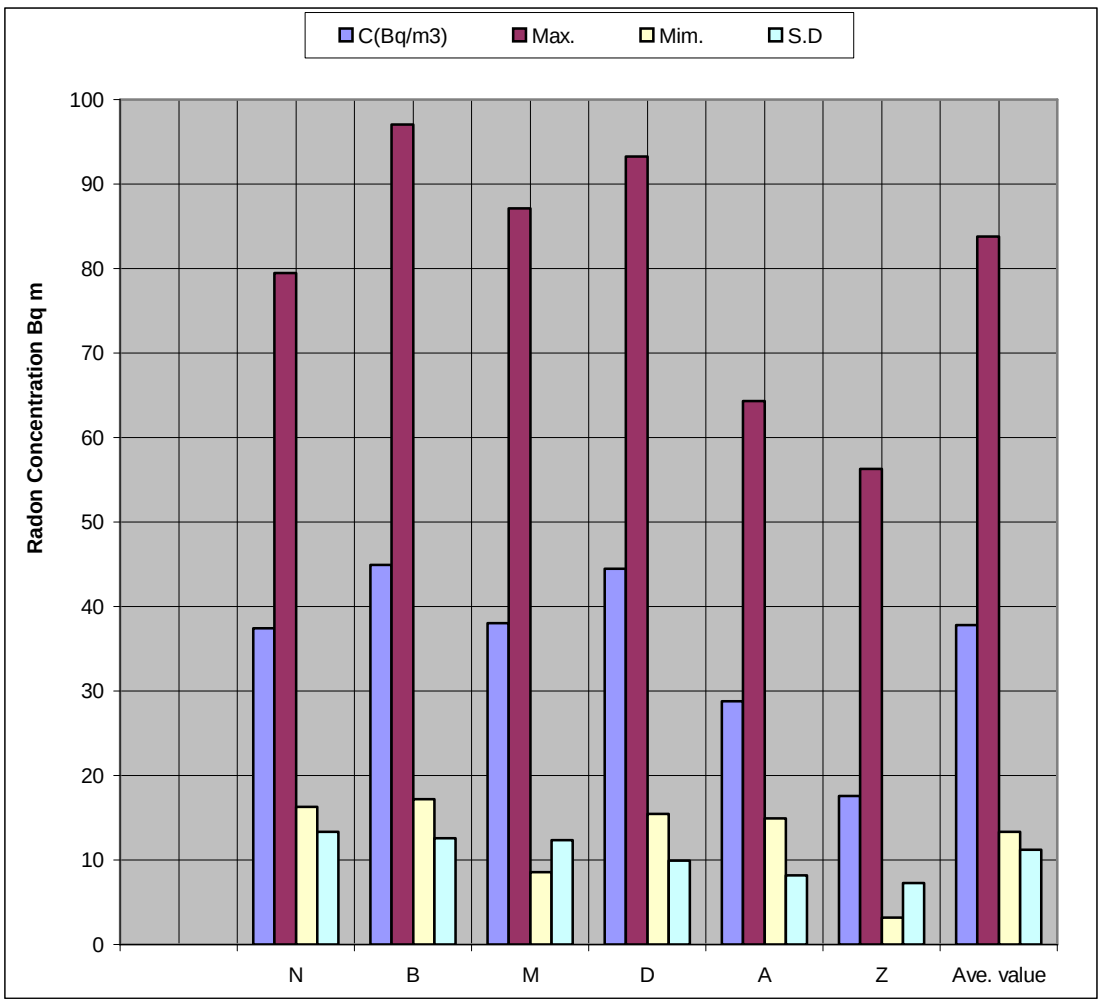


Figure (4.1) Radon concentrations in each camp and S. D.

4.3- The variation of Radon concentrations with the high level of the houses

In both camps, the Radon concentration is, due to the geological and radiometric characteristics of the soil, significantly increased. Deep fissures in carbonate rocks result in conditions of easy transport of Radon from deeper layers into overlying soil, from where the Radon enters the high level of the houses through cracks in the floor or walls which come into contact with the soil. The Radon concentrations vary with the height above the ground of building the houses locations were built from stone and concrete.

Location	Basement C(Bq/m^3)	1st C(Bq/m^3)	2nd C(Bq/m^3)	3rd C(Bq/m^3)	4th C(Bq/m^3)	5th C(Bq/m^3)	6th C(Bq/m^3)	7th C(Bq/m^3)
N	34.7	28.7	27.1	-	-	-	-	-
B	41.3	38.3	31.0	25.7	-	-	-	-
M	38.1	32.5	22.5	-	-	-	-	-
D	42.4	32.7	26.8	22.3	-	-	-	-
A	37.6	-	30.6	31.2	26.2	24.3	27.4	21.7
Z	32.9	19.6	15.9	11.2	13.6	-	-	-
No. of Det.	92	53	46	23	17	5	4	4
Ave. value	38.8	31.0	24.6	21.8	21.1	24.3	27.4	21.7

Table (4.2) Radon concentrations vary high level of the houses

As shown in table (4.2) the Radon concentrations vary from one building to another within the same height as in, for examples, A and Z. It is also different from one floor to other within the same height. Table (4.2) shows that the basements are the highest Radon concentrations in the all locations, to demonstrate this dependence of Radon levels on the floor height for vary floors of the N, B, M, D, A and Z buildings. In these results, the Radon concentrations determined are mostly due to the contribution from the soil located under the building, and ventilation. The highest Radon concentration values were observed in the basement of D camp, and lowest were observed in

the 3rd of Z new city due to increase in air movement. Figure (4.2) describes the histograms of Radon concentrations for various floors in these building locations. It can be seen that Radon levels inside the basement floors of the D and B are much higher than the Radon levels in the other floors of the other building camps. The rooms in these basement floors have small windows or no opening windows and their ventilation is very poor, while rooms in the other floor building camps buildings have large windows and are ventilated well. This ventilation effect is strongly pronounced when the 7th floor of A building is considered, where the Radon level drops rapidly owing to the excellent ventilation and increased height of the floor. It can be concluded that Radon concentrations in the basement floors were higher than in the upper floors. Thus, Radon concentrations cannot be predicated merely on the basic of values for soil gas Radon concentrations, which can vary drastically even over distance of a few meters.

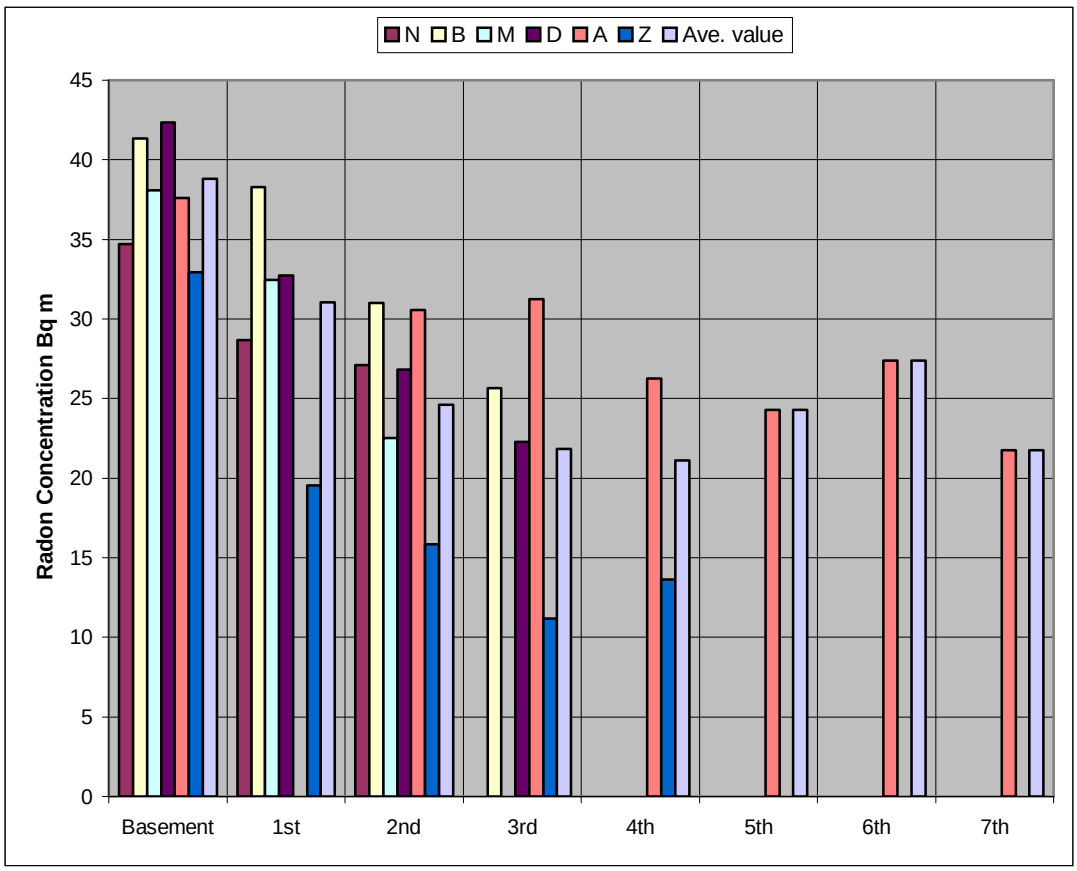


Figure (4.2) Radon concentrations vary high level of the houses

4.4- The variation of Radon concentrations with materials of the houses

The determination of Radon concentration and its decay products in indoor air has become very important, since the main level of these measurements carried out in the different building material of detached built houses. The data describing the characteristics of the selected houses in only four camps (N, B, M, and D) are as follows: the building are constructed of stone and zinc, stone and spostos, and stone and concrete as shown in table (4.3). Since the building materials (stone and concrete) used in the construction of the other two houses locations (A and Z) are most identical.

Location	Stone and zinc C(Bq/m^3)	Stone and spostos C(Bq/m^3)	Stone and concrete C(Bq/m^3)	No. of detectors
N	44.5	43.8	31.9	84
B	63.9	50.9	39.4	91
M	46.4	44.3	32.4	90
D	-	58.2	35.4	85
No. Of Det.	15	137	198	Sum(350)
Ave. value	52.7	49.1	35.0	-

Table (4.3) Radon concentrations versus material of house

Also the table indicates that the main values of Radon concentration in houses range between 34.97 and 52.74 Bq/m^3. These representing to houses built of spostos and stone were 1.4 times higher than of houses built of concrete and stone. The highest values were found in houses where the building substructure consisted of stone and zinc. Figure (4.3) shows that in D camp houses were built of stone and spostos where Radon concentration were higher than 1.32 times of these in N camp. Also the figure (4.3) indicates that the higher Radon concentrations of D and B houses built of stone and spostos than N and M houses built of stone and concrete. Houses built of stone and

concrete had low Radon concentrations in all house locations. The ventilation method in these buildings can be understood to be better than other buildings. Figure (4.4) indicates that the Radon along with its daughter products in air deliver the highest contribution to overall exposure of the building materials (stone and spostos 36%, stone and concrete 26% and stone and zinc 38%). Also figure (4.4) reviews that greater percentage of Radon concentrations of the houses built of (stone and zinc), and (stone and spostos) than that built of (stone and concrete). Since few houses are constructed of stone and zinc in the middle region of Gaza, it is concluded that the highest Radon concentrations were found in houses where the building substructure consisted of stone and spostos. The concentrations of Radon inside a house are varying in accordance with constructional characteristics of their foundations and by the type of ventilation system in use. Since the building materials used in the construction of detached houses are different of Radon concentration. This indicates that the different materials of houses are important parameters in determining Radon concentrations.

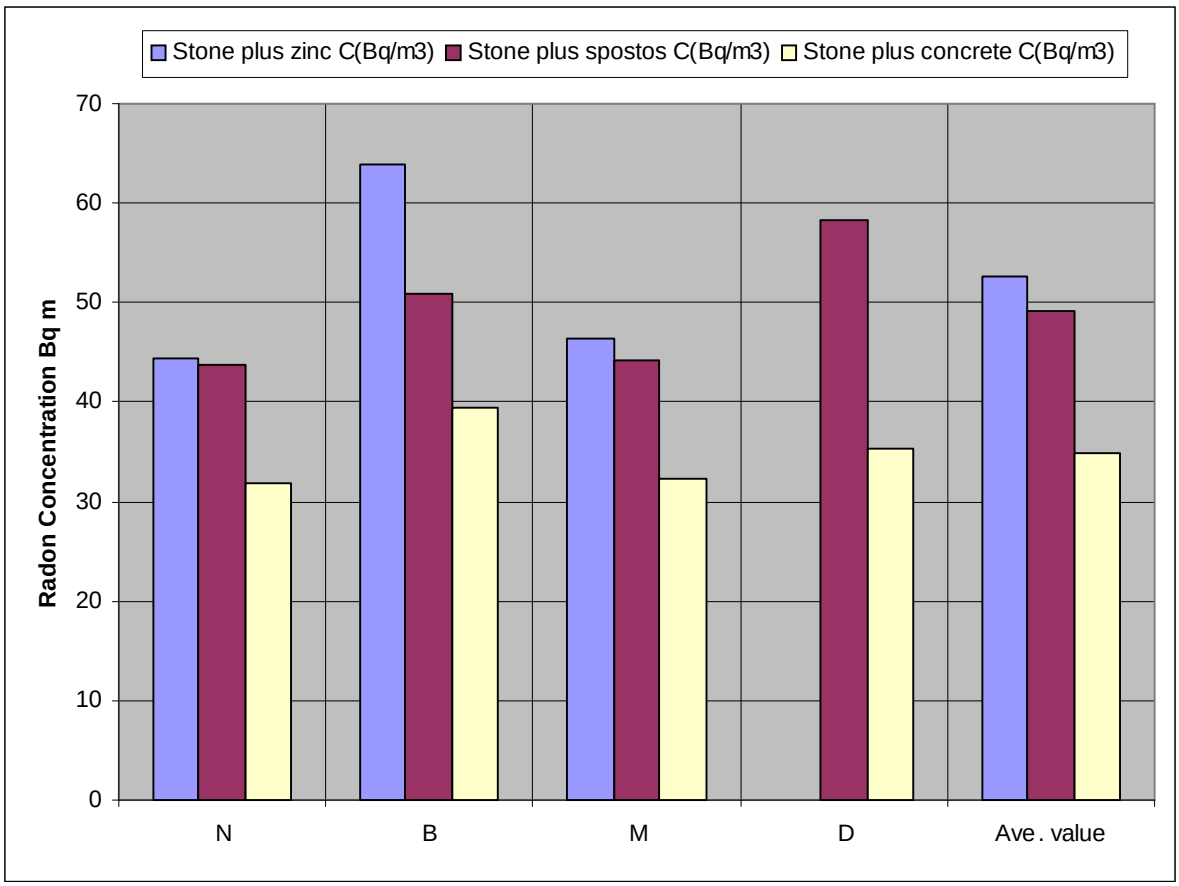


Figure (4.3) Radon concentrations versus with material of the house

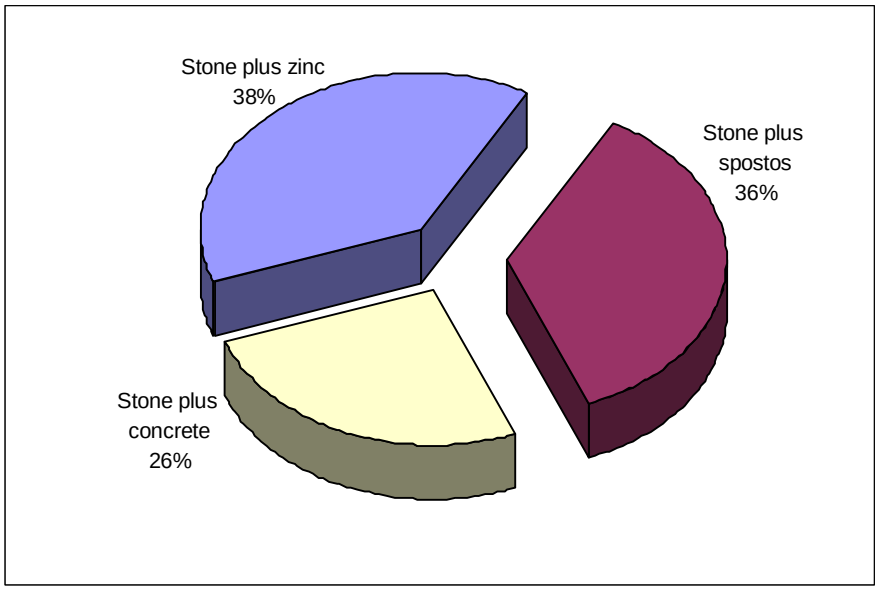


Figure (4.4) percentage Radon concentrations versus material of the house

4.5- The variation of Radon concentrations in different rooms of the house

These results for work places (rooms) show that Radon concentrations are vary from room to another room in the same house.

4.5.1) The variation of Radon concentrations in different rooms of the house built from (stone and concrete)

Although the Radon source is often concentrated in one room or in one part of the house, as the gas streams into the other parts of the house, mainly because of the ventilation rate. Table (4.4) shows the Radon concentrations versus the different part (storage of Pharmacy, shop, bedroom, living room…etc) of house built from (stone and concrete).

Location	Pharmacy C(Bq/m^3)	Shop C(Bq/m^3)	Bedroom C(Bq/m^3)	Living room C(Bq/m^3)	Kitchen C(Bq/m^3)	No. of detectors
N	38.6	33.0	33.7	25.2	31.9	45
B	48.8	47.9	42.0	34.4	54.7	54
M	31.6	27.4	32.3	24.1	44.1	48
D	49.9	32.1	34.3	24.3	43.3	51
A	-	-	30.9	19.0	34.1	43
Z	-	-	18.5	11.9	15.8	40
No. of Det.	16	21	171	39	34	Sum(281)
Ave.value	40.7	34.3	31.7	24.8	37.8	-

Table (4.4) Radon concentrations versus different rooms of the house built from (stone and concrete)

One of the most important results of the previous analysis and evolutions was confirmation that Radon concentration values correlate very well with the different rooms in a house. Form the results of measurements performed in each room selected in the middle region of Gaza houses, the average Radon concentration were found to range from a minimum value of 24.76 Bq/m^3 determined in living rooms to maximum value of 40.69Bq/m^3 determined in

storage of Pharmacy. The high Radon levels inside storage of Pharmacy are due to the relatively low ventilation, since there are no windows or they are closed most of the time. Figure (4.5) describes that Radon concentration versus the different rooms in a house. The storage of Pharmacy normally has the lowest air exchange rate and is also nearest to the ground (basement), where the basements have the highest Radon concentrations. Also shown in figure (4.5) that the highest Radon concentration was found in the kitchen and bedroom in B camp. While the living rooms have about lowest Radon concentrations in A and Z new cities. Figure (4.6) indicates that the variation of Radon concentration percentage according to different rooms in the middle region of Gaza houses as following: (storage of Pharmacy 24%, kitchen 22%, shop 20%, bedroom 19% and living room 15%.). On the other hand, the kitchen in this section has Radon level higher than the bedroom. Where bedroom has larger area than the kitchen in general of the house built of stone plus concrete. The kitchen has poor ventilation, because it has small window.

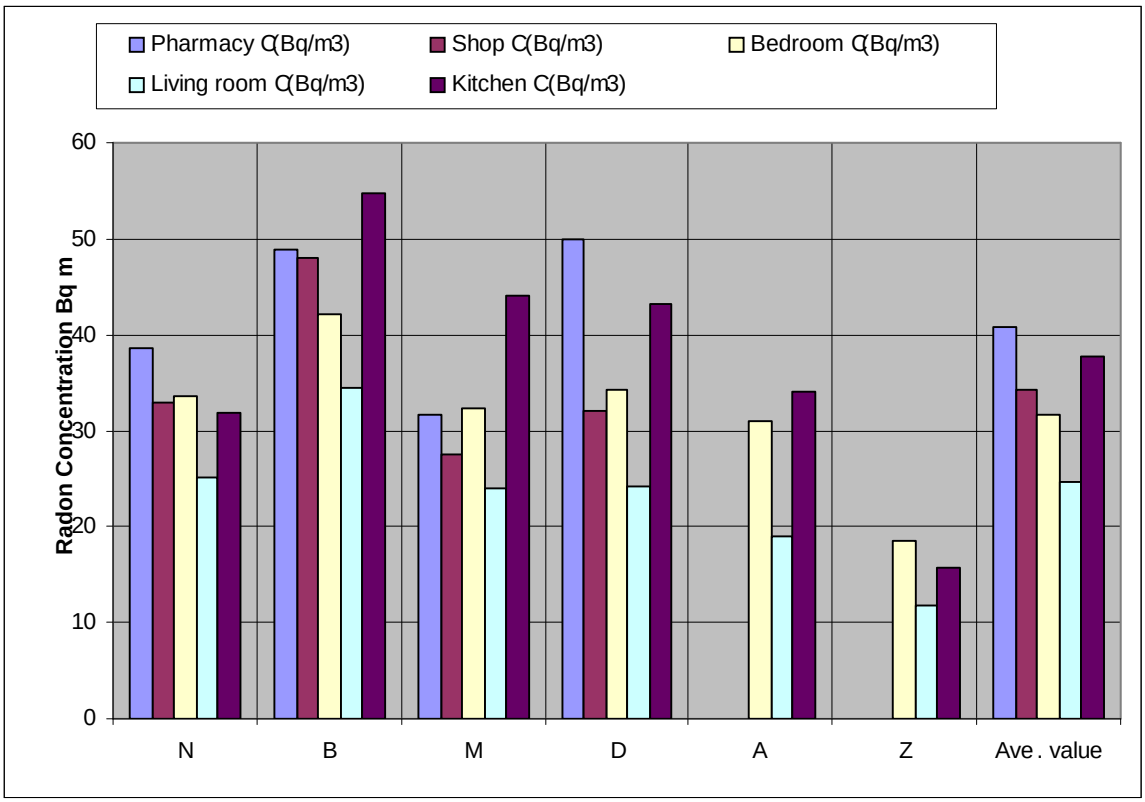


Figure (4.5) Radon concentrations versus different rooms of the house built from (stone and concrete)

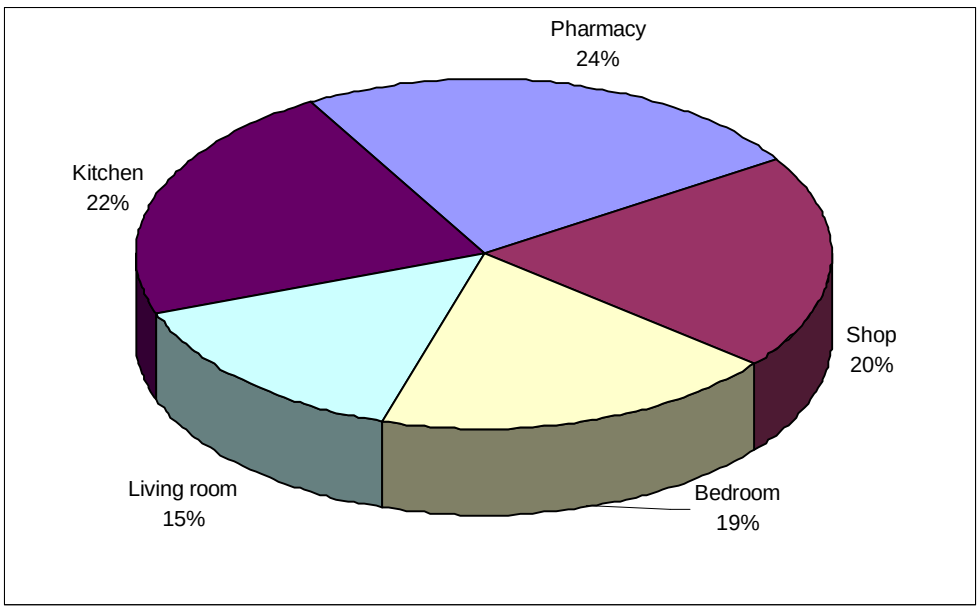


Figure (4.6) percentage of Radon concentrations versus different rooms of the house built from (stone and concrete)

4.5.2) The variation of Radon concentration in different rooms of the house built from (stone and spostos)

A single door kept open or closed continuously is enough to affect the Radon transport within the house. Table (4.5) reviews that the Radon concentrations versus the different house rooms (bedroom, living room, and kitchen) was built from (stone and spostos).

Location	Bedroom C(Bq/m^3)	Living room C(Bq/m^3)	Kitchen C(Bq/m^3)	No. of detectors
N	46.1	32.0	47.4	34
B	51.6	38.2	43.0	31
M	50.3	29.5	-	38
D	62.8	37.0	-	34
No. of Det.	96	30	11	Sum(137)
Ave. value	53.2	33.6	45.0	-

Table (4.5) Radon concentrations versus different rooms of the house built from (stone and spostos)

Table (4.5) also indicates that the main values of Radon concentration in houses range between 33.60 and 53.16 Bq/m^3. These represent houses were built of (spostos and stone) and basement floor, so that the Radon can escape from the ground to the house and cause highest Radon concentrations.

Figure (4.7) shows that the highest Radon concentrations were in bedrooms of D camp, and the lowest were in living rooms in M camp. It is obvious that the bedrooms have relatively higher Radon concentrations than the kitchens and living rooms. This may be due to exhaled Radon of the sleeping person and also poor ventilation of bedrooms. While living rooms of the houses have large windows, front of open area and ventilation as well. Figure (4.8) shows that highest percentage of Radon concentration was found in the bedrooms 41%, while kitchen 34% and living rooms 25%, within the same housing

complex, have about the some Radon levels. The high Radon levels inside bedrooms are due also to the relatively low ventilation.

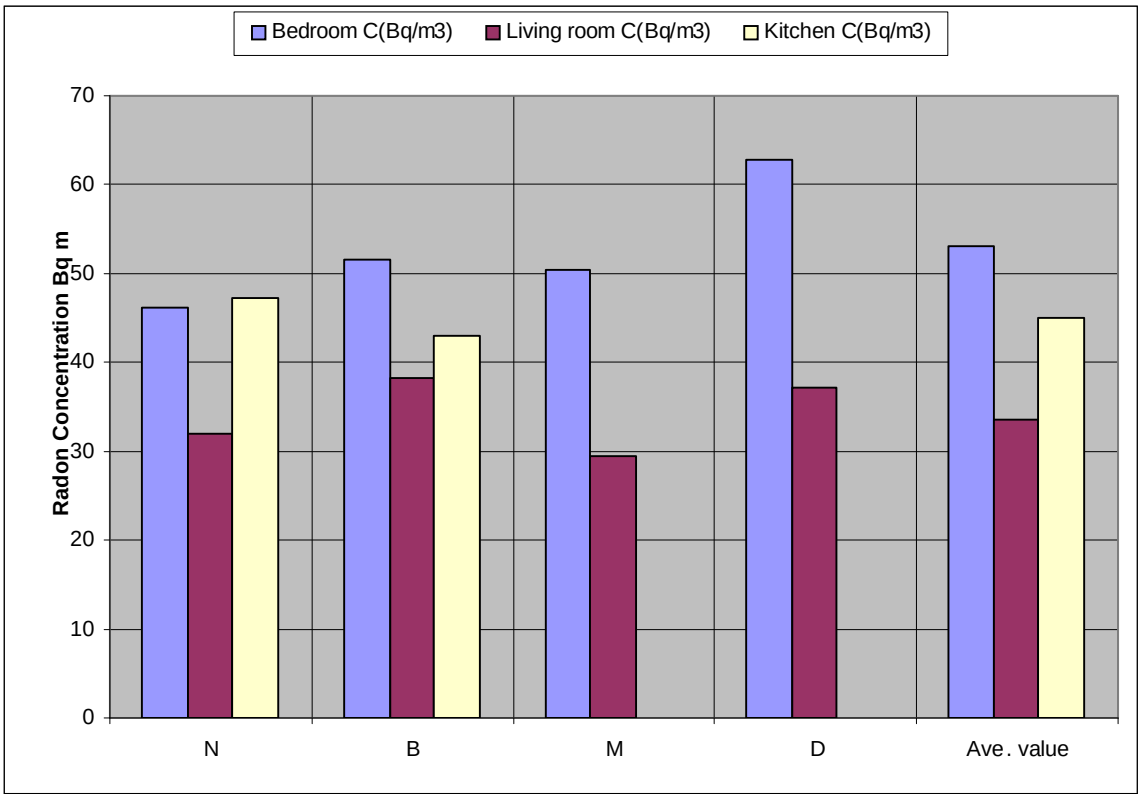


Figure (4.7) Radon concentrations versus different rooms of the house built from (stone and spostos)

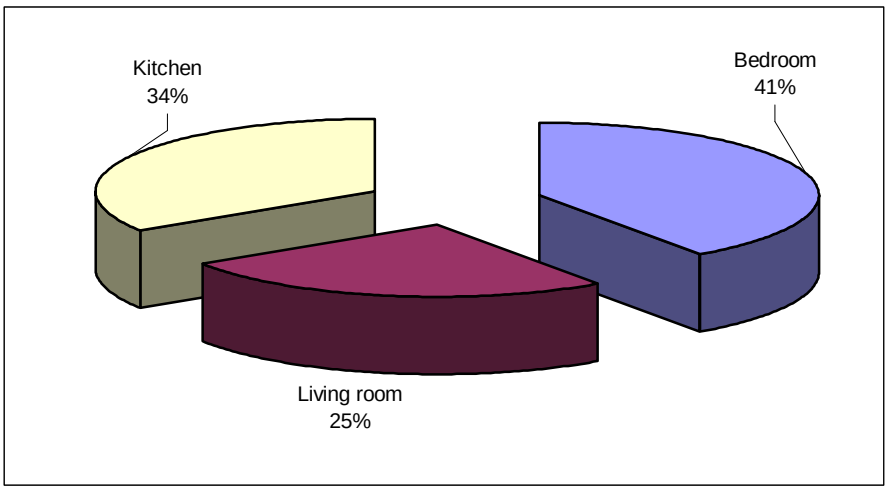


Figure (4.8) percentage of Radon concentrations versus different rooms of the house built from (stone and spostos)

4.6- The smoking effect

4.6.1) The smoking effect of the houses built from (stone and concrete)

It is necessary to focus on an important environmental problem, which is smoking. The risk of smoking, as everyone knows, is duration dependent and cumulative. Exposure to Radon and smoke cigarettes may combine to increase the risk of lung cancer. Research has compared the cancer rate in smoking and non-smoking uranium miners. Results indicate that smoking increases earlier development of lung cancers that may have been caused by the Radon [21]. In addition, there is an interactive effect between the Radon exposure and smoke cigarettes. Two agents have really causing and developing of lung cancer. On the other hand, the risk of lung cancer caused by smoking is much higher than caused by indoor Radon [22].

The results obtained in table (4.6) of every camp in the region study, show that variation of Radon concentration is independent of smoking status.

Location	Smoking C(Bq/m^3)	Light smoking C(Bq/m^3)	No smoking C(Bq/m^3)	No. of detectors
N	31.6	37.1	29.7	45
B	42.7	41.0	44.4	54
M	28.1	39.0	30.3	48
D	32.3	-	40.6	51
A	24.8	-	30.5	43
Z	17.6	-	17.4	40
No. of Det.	129	23	129	Sum(281)
Ave. value	28.8	38.7	34.3	-

Table (4.6) smoking effect of the houses built from (stone and concrete)

Table (4.6) exhibits that the variation of the average Radon concentration according to smoking status (light smoking 38.68 Bq/m^3, non-smoking 34.34

Bq/m^3 and smoking 28.75 Bq/m^3). Where light smoking was the highest average Radon concentration.

Also table (4.6) indicates that in B and D camps non-smoking people have the highest Radon concentration comparing to other camps. In M camp the non-smoking people have higher Radon concentration than smoking people.

Figure (4.9) shows that Radon concentration of smoking people in B camp is very high comparing to other camps. Thus, higher Radon concentration and smoking together caused risk lung cancer.

Smokers should keep their exposure to Radon as low as possible. Smokers have many times the risk from Radon than non-smokers. If the house was tested in a frequently used basement, it may have measured a Radon level that is higher than actual level, stop smoking and spend most of your time upstairs.

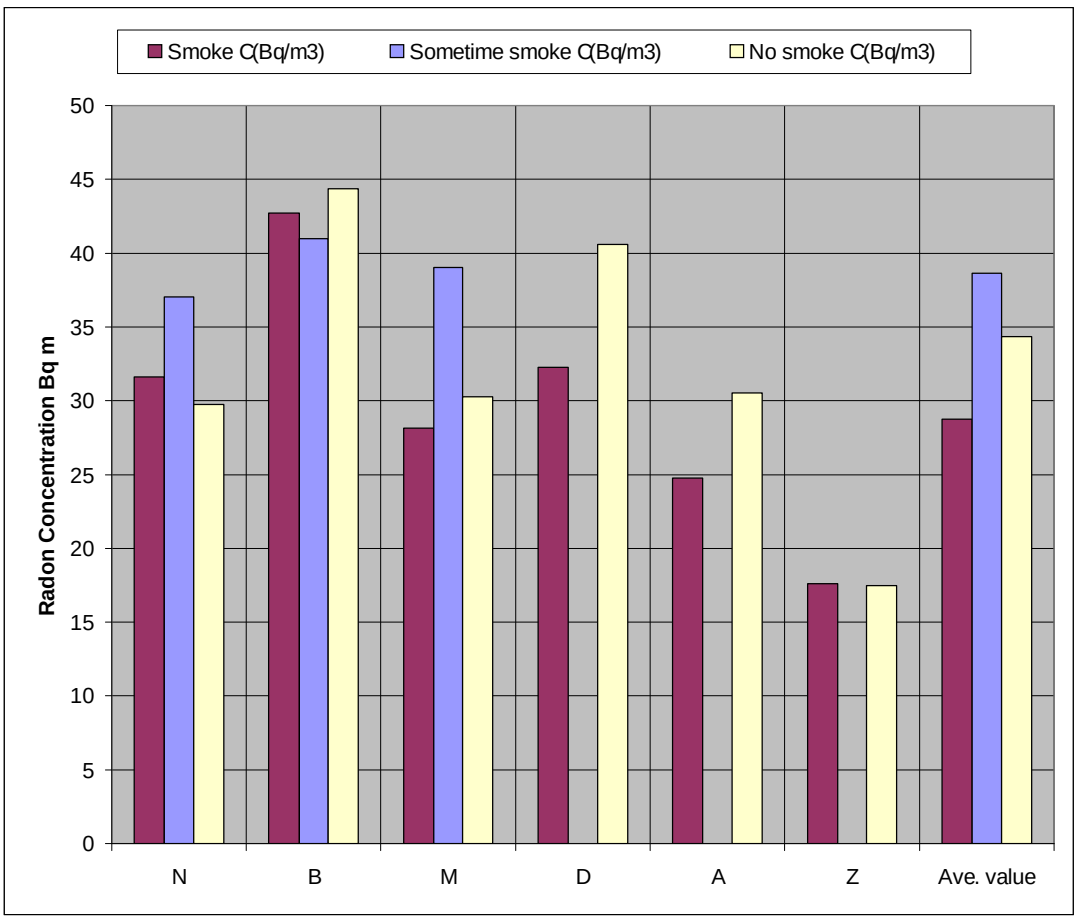


Figure (4.9) smoking effect of the houses built from (stone and concrete)

4.6.2) The smoking effect of the houses built from (stone and spostos)

Table (4.7) indicates that the average Radon concentration of smokers are greater than of non-smokers.

Location	Smoking C(Bq/m^3)	No smoking C(Bq/m^3)	No. of detectors
N	47.1	41.7	34
B	44.6	47.1	31
M	49.7	38.5	38
D	62.2	55.1	34
No. of Det	71	66	Sum(137)
Ave. value	51.3	45.0	-

Table (4.7) smoking effect of the houses built from (stone and spostos)

Figurer (4.10) shows that D camp of smokers has the highest Radon concentration, and the M camp of non-smokers has the lowest Radon concentration. These represent houses were built of (spostos and stone) greater in Radon concentrations than another houses were built of (concrete and stone), and represent to basement floor cause highest Radon concentrations.

Thus, the impact of Radon and smoking together may be greater than the sum of their individual impacts. A given increase in the Radon concentration would then lead to a greater increase in the lung cancer rate among smokers than non-smokers, and concern over Radon would become intertwined the broader concern over smoking. In contrast to clear trend of increased risk of lung cancer with increasing smoking in each Radon exposure category.

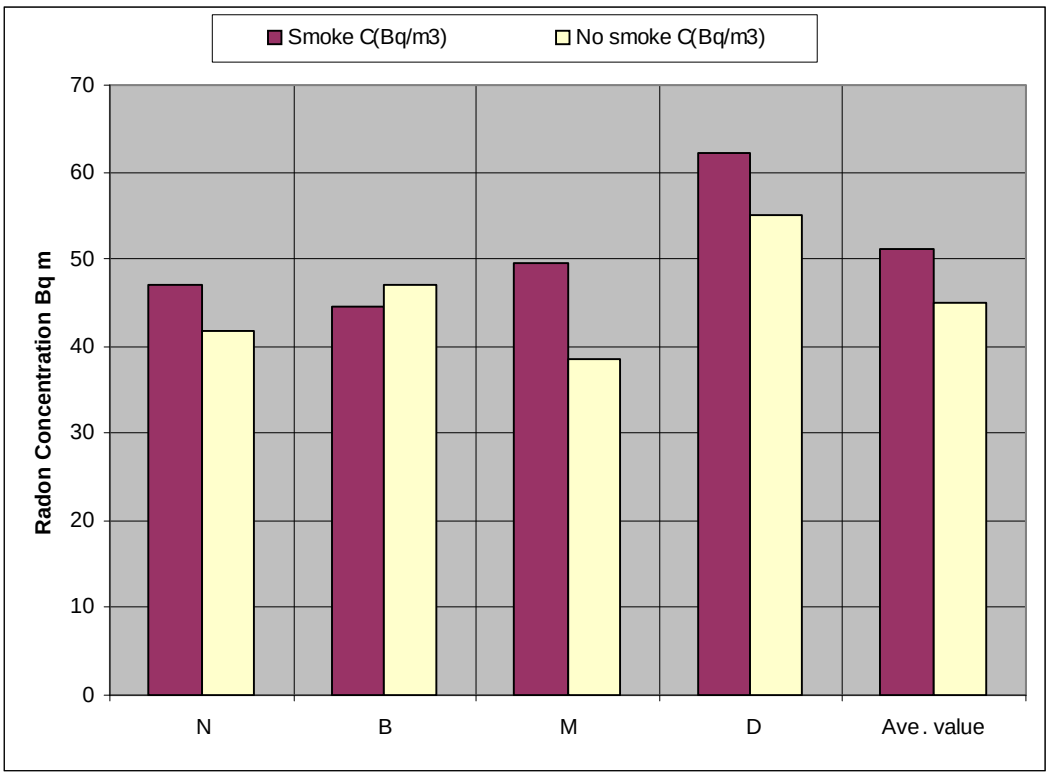


Figure (4.10) smoking effect of the houses built from (stone and spostos)

CHAPTER (5)

CONCLUSIONS AND RECOMMENDATIONS

5.1- Conclusions

At present, changes in living conditions among the population, and the significant increase and differences of sources of pollution in the environment produce a significant effect on the health of the population. One source of such health problem of pollution is indoor Radon. The inhalation of Radon and its short-lived daughter products represents the main source of exposure to natural radiation. Radon is now believed to be the most important source of ionizing radiation in our environment. Radon is a gas that is produced naturally in the ground and seeps into most houses. The study purpose was to find out an approximate mean and range of Radon and Radon progeny concentrations in the houses in order to estimate the possible health hazards from Radon in the middle region of Gaza. Inhalation of Radon, or more specifically the Radon daughters, leads to deposition of radioactive atoms on the walls of the lung, especially in the bronchial region. In the decay of these atoms, alpha particles are emitted which irradiate the cells of the lung tissue through which they pass. These irradiated cells may become cancerous.

In the present work, we have distributed five hundreds dosimeters of detectors (solid state nuclear track detectors CR-39) were distributed inside the houses of the middle region of Gaza strip. The dosimeters were distributed in houses located at differences, level of the house above the ground (basemen, 1^{st}, 2^{nd} …etc), houses built from different materials like (stones and concrete, stone and spestos, .. etc), and different rooms of the house were selected (bedroom, living room, …etc).The detectors were left in the houses for a period of four months, (from August to December of 2001). The collected detectors were chemically etched using a 20% solution of KOH, at a temperature of 70^0 C, for 5 hours. The detectors were then washed thoroughly with distilled water and left to dry. Each detector was counted visually using an optical microscope with power of (40×10). Tracks in 9 distinct regions were observed; through the area ($1cm^2$) the average number of tracks/cm^2 was determined. It have been concluded that from survey data, Radon and its daughter's concentrations

throughout Gaza strip over six locations in the middle region of Gaza tend to follow four months distribution varied between 13.36 to 83.82 Bq/m^3 and maximum value of 97.06 Bq/m^3. The average Radon and its daughter's concentration was 37.83 Bq/m^3 with average standard deviation of 11.23. As a result of the measurements, it was found that the Radon concentrations in several houses were less than the limited value for U. S. and EPA recommendations (148 Bq/m^3). This indicates that most of the camps have Radon concentration below average levels.

-It is also evident that each house has its own level of Radon concentration. Therefore, it is not possible to generalize and say that it is enough to measure the Radon level in one house and believe that neighboring houses have the same Radon level.

-Other characteristic is the different levels of Radon in different rooms in a house, which means that it is not enough to use only one detector for the estimation of the Radon levels in a house.

-The seasonal variation of the indoor Radon levels means that the Radon level may be a factor of two higher in one season winter in comparison with another season summer. This implies that the mean value of the measured Radon in the house has uncertainty not caused by the technique of measurement but by the nature of Radon.

-Despite all the work that has been accomplished to the present, it well to keep in mind that strategies for controlling the indoor entry of Radon rate still in research stage and some techniques indicated as useful in the past have since been shown to be ineffective.

-Finally, it is not as yet possible to use reported epidemiological studies of the general population to determine lung cancer incidence due to Radon, although there is hope for future.

Although there were a small number of studied buildings, the results provide a framework for future studies that include a larger, broader survey of Radon concentrations indoor and outdoors in Gaza. Substantial research efforts are

also required to the other parts of Gaza to estimate the average Radon concentration of the whole country. These primary results also provide a basis for an extensive survey programs covering major cities and locations of high interest.

5.2- Recommendations

The measurement of indoor Radon levels is an important factor in the evaluation of impacts on public health. Radon concentrations in indoor air may increase in the future, as a result of the utilization of new building materials, the implementation of energy conserving measures, and the change in living condition. These factors may thus lead in the future to an increase in the levels of indoor radiation exposure to the population. Without testing, it is impossible to tell which particular houses in a given area that may have high Radon levels. Radon levels vary widely not only from area to area, but even from house to house. Efforts to control Radon concentrations in houses may be achieved by a number of ways directed towards reducing Radon entry, including:

1) Removing Radon source

-Removing contaminated soil and building materials, since it was known that the cinderblock walls are usually more porous than ordinary concrete or stone.

-In these cases, the entire source can be isolated.

2) Preventing Radon entry to the house

-Fixing the openings in the house basement by elimination of cracks in the walls and other entry channels in the basement.

-Ventilating the soil to divert soil gas away from the house.

-Adjusting the pressures inside the house to reduce or eliminate the driving force for soil gas entry.

-Treating the well water entering the house.

3) Removing Radon from the house after entry including

-House ventilation, increased ventilation of the house with use of air-to-air heat exchangers or by opening windows on two or more sides of lower level of the house (and on upper levels if these are the primary living areas).

-Air cleaning techniques, Radon can be removed from the environment by a filtration device made up of fans used to direct air through a mechanical filter.

It is apparent that if the Radon is removed the progeny will not exist in the indoor air. Consequently, removing the Radon is sufficient to remove the health risk associated with Radon progeny.

- Since Radon concentration tend to be greater on the lower levels of a house. Spending the most times in the living rooms and ventilation the bedrooms “that location in the upper floor”.
- Scientific evidence indicates that smoking may increase the risk of exposure to Radon. Stopping smoking and discouraging smoking in your home should reduce the risk that you or member of your family will develop lung cancer from inhalation of Radon.

GLOSSARY [9]

Alpha particle: The nucleus of the helium isotope of mass 4 u; emitted in the decay of some heavy radioactive nuclei.

Atomic mass unit (u): Nuclear masses are measured in term of the unified atomic mass unit, u, defined such that the mass of an atom of ^{12}C is exactly 12u. 1 u = 931.502 MeV/c^2 = 1.660566×10^{-27} kg.

Becqueral (Bq): The S. I. Unit of rate of radioactive decay; 1 Bq equals 1 disintegration per second.

BEIR reports: A series of reports by the Committee on the Biological Effects of Ionizing Radiation of the National Academy of Science.

Beta particle: An electron (with either negative or positive charge); emitted in the decay of some radioactive nuclei.

Cosmic rays: High-energy radiations arriving at the earth from space. These radiations originate both from the sun and from beyond the solar system.

Curie (Ci): A unit of rates radioactive decays; Curie is measure of the number of atoms disintegrating per second in radioactive material. One Ci is equal to 3.7×10^{10} disintegrations per second.

Daughter: The atom produced by the decay of a radioactive parent atom.

Decay chain: A radioactive isotope and the series of radioactive daughter, which are generated from it through a succession of radioactive decays. The chain ends when one of the daughters is non-radioactive.

Electron volts (eV): Amount of kinetic energy acquired by an electron (or other particle carrying the same charge) when it is accelerated through a potential difference of one volt.

Emanation: The gas emitted from a solid or liquid. Radon was originally called (emanation) since it was emitted by radium.

Gamma ray: Radiation, similar to x-ray and light, emitted the decay of some radioactive nuclei.

Gray: The S. I. unit of physical dose, i.e., the unit of deposition of energy in material due to the passage radiation; 1 Gray equals 1 joule per kilogram.

Ground water: The free water located within the soil and rocks that is not combined as water of hydration in minerals.

Half-life time ($t_{1/2}$): The time required for the number of radioactive nuclei present at any instant of time to be reduced by a factor of two, due to radioactive decay.

ICRP: The International Commission on Radiological Protection; international group of experts who recommend limits for exposure to ionizing radiation to the international community.

Ionization radiation: Radiation with the ability to interact with and remove electrons from the atoms of material, leaving the atom ionized.

NCRP: The National Council on Radiation Protection and Measurements; a Congressionally chartered group of experts who are charged with studying the effects of exposure to ionizing radiation and recommending protective measures.

Noble gas: A noble gas is gaseous element with negligible chemical reactivity. Helium, neon, argon, krypton, xenon and Radon are noble gases. Radon is the only radioactive noble gas.

NRC: Nuclear Regulatory Commission; also National Research Council.

Potential alpha energy: The amount of alpha-particle kinetic energy that can be dissipated within an atmosphere containing some particular mixture of short-lived daughters of Radon, if they all decay there.

Rad (rad): A traditional unit of physical radiation dose, i.e., the unit of deposition of energy in material due to the passage of ionizing radiation; 1 rad equals 100 ergs per gram.

Radioactivity: The process by which an atom changes spontaneously into a different atom by the emission of an energetic particle from its nucleus.

Radium: A naturally occurring radioactive element whose decay produces Radon. Radium is a number of the decay chain of uranium.

Radon daughters: The term (Radon daughters) usually refers to the short-lived radioisotopes in the decay chain of Radon down to Lead-210. These are Polonium-218, Lead-214, Bismuth-214 and Polonium-214.

Radon: Radon-222, radioactive noble gas generated by the decay of radium.

Relative risk: A risk of an adverse health effect due to some injury which is proportional both to the magnitude of the injury and to the usual rate of occurrence of the adverse health effect in the population at risk.

Rem (rem): A traditional unit of dose equivalent used to express on a common basis the health hazard from different kinds of radiation; the dose equivalent in rem is equals to the product of quality factor (other modifying factors, if used) and the physical dose in rad. (1 rem $= 10^{-2}$ sieverts).

Sievert (Sv): The S. I. Unit of dose equivalent is used to express on a common basis the health hazard from different kinds of radiation; the dose equivalent in sieverts is equals to the product of quality factor and the physical dose in grays. (1 Sv = 100 rem).

Specific activity: The amount of activity in a unit amount of material. Usually specified as amount of activity per unit mass, e.g., pCi/g.

Working level (WL): One working level is that amount of potential alpha-particle energy dissipated in air by the short-lived daughters in equilibrium with 101.3 pCi/l of Radon. One WL is equal to 130000 MeV of alpha-particle energy deposited per liter of air.

X-ray: Radiation similar to gamma rays and light emitted during rearrangements of the inner electrons surrounding an atom.

APPENDIX (A)

The Properties of Common Radionuclides Physical Characteristics

Isotope name	Half-time $t_{1/2}$	Decay modes and energy (MeV)
Uranium-238 (^{238}U)	2.47×10^{9} years	α, 4.198 (77 %), 4.149 (23 %)
Thorium-234 (^{234}Th)	24.1 days	β, 0.198 (72 %)
Protactinium (^{234}Pa)	1.17 minutes	β, 2.29 (98 %)
Uranium-234 (^{234}U)	2.45×10^{5} years	α, 4.773 (72 %), 4.721 (27 %)
Thorium-230 (^{230}Th)	7.57×10^{4} years	α, 4.688 (76 %), 4.621 (23 %)
Radium-226 (^{226}Ra)	1.60×10^{3} years	α, 4.785 (94 %), 4.602 (6 %);
Radon-222 (^{222}Rn)	3.8235 days	α, 5.49 (99.9 %)
Polonium-218 (^{218}Po)	3.11 minutes	α, 6.003 (100 %)
Lead-214 (^{214}Pb)	26.8 minutes	β, 0.65 (50 %); γ, 0.295 (19 %), 0.352 (37 %)
Bismuth-214 (^{214}Bi)	19.9 minutes	β, up to 3.26 MeV; γ, 0.609 (46 %), 1.120 (15 %), 1.765 (16 %)
Polonium-214 (^{214}Po)	1.64×10^{-4} seconds	α, 7.687 (100 %)
Lead-210 (^{210}Pb)	23.34 years	β, 0.015 (81 %)
Bismuth-210 (^{210}Bi)	5.01 days	β, 1.161 (100 %)

Isotope Name	Half-time $t_{1/2}$	Decay modes and energy (MeV)
Polonium-210 (^{210}Po)	138 days	α, 5.297 (100%)
Lead-206 (^{206}Pb)	stable	none
Thorium-232 (^{232}Th)	1.39×10^{10} years	α, 4.01 (77.8 %), 3.95 (22.1 %); γ, 0.0638 (0.267 %)
Uranium-235 (^{235}U)	7.038×10^{8} years	α, 4.22 (5.7 %), 4.32(4.4 %), 4.40 (55 %), 4.56 (4.2 %), 4.37(17 %); γ, 0.196 (61 %)

Retention is described by (Nuclear Energy Agency {NEA} 1985).

APPENDIX (B)

Survey Questionnaire for Sierra Radon Study

Measurement of Radon and Its Daughter's Concentrations

In Indoor and Outdoor throughout Gaza Strip

The Name: - ----------, Detector Serial No.: ----------

Family No.: - ----------, Area of the Location: ----------m^2

The Location: - N---------, B--------, M---------, D--------, A---------, Z---------

The Type of Location: -

- House----------
- Bedroom-------, Living room-------, Kitchen-------, Others-------
- Shop----------, Pharmacy----------, Others----------

The Nature of Building: -

- Stone and Concrete--------, Stone and Spestos----------, Zinc--------, Others---------

The Building Level: -

- Basement-------, 1^{st} Flor------, 2^{nd} Floor-------, 3^{rd} Floor---------,
  4^{th} Floor-------, 5^{th} Floor-------, Others-------

The Ventilation rates: -

- No. of Doors----------, No. of Windows----------
- Period---------Hours. , Humidity----------
- Smoking-------, No Smoking--------, Sometimes Smoking---------

Usage of Building: ----------

Date of Distribution: ----------

Date of Collection: ----------

Comments: ----------

Average of No. of tracks/cm^2 :----------, S. D.:----------

-Concentration of the Radon-222: ----------Bq/m^3

Nsuirat (N), Buraij (B), Maghazi (M), Deiralbalah (D), Abrag Al-Nsuirat (A), Zahra (Z).

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