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Study of the chronic radiation exposure situation in Gaza

By

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

سورة المجادلة أية (11).

DEDICATION

TO

MY PARENTS

MY BROTHERS

MY SISTERS

MY WIFE

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 supervisor, Dr. S. S. Yassin, for useful discussions, kind help and guidance throughout this work.

Special thanks and appreciatation to staff members of physics department for their great advice, kind help and endless support. I would also like to express my gratitude to my parents for their patience that kept me stable and productive during the years of studying and writing this thesis.

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ABSTRACT

Passive diffusion Radon dosimeters containing CR-39 solid state nuclear track detectors of good quality were used to measure Radon and its daughter's concentrations throughout Gaza city. Our sampling strategy was to distribute the dosimeters in houses in Gaza city (Ziton, Sapra, Remal, Shegaea, Shekh Radwan, Darage, Beach Camp and Nazla). These dosimeters were randomly distributed in bedroom, living room and kitchen. The (180) detectors were left for about two months during the period from March to June of 2006. The collected detectors were chemically etched by using NaOH of 30% concentration. Each detector was counted visually using an optical microscope with power of (40×10). Tracks in the six distinct regions of Gaza city were observed, through the area ($1cm^2$), then average number of tracks/cm^2 was detected at all the regions was 39 Bq/m^3 (1.1 pCi/l) with a range of values between 9.5 and 80.5 Bq/m^3 (0.24 and 2.18 pCi/l), a maximum value of 105 Bq/m^3 (2.8 pCi/l) and average standard deviation of 17.01Bq/m3. The results obtained in this work are quite limited and should only be considered as indicative of the variability in radon concentration that expected in normal building in Gaza. However, in spite of this limitation, certainly this study provides an extrapolations about radiation concentration in general form in Gaza City, and a dresses the health effects that radiation might cause in future, especially from environmental point of view.

.

ملخص

دراسة حالات التعرض المزمن للأشعاع فى غزة

لقد تم في هذه الأطروحة قياس تركيز غاز الرادون-222 ومشتقاته في الهواء داخل وخارج منازل مدينةغزة، وذلك باستخدام كاشف الحالة الصلبة (مجراع الرادون السلبي) للمسارات النووية والمعروف تجارياً باسم CR-39. تم توزيع 180 مجراعاً حسب الموقع الجغرافي لمنطقة غزة وهي: الزيتون، معسكر الشاطئ، الرمال، الشجاعية،الشيخ رضوان ،الدرج، النزلة، الصبرة.

بعد مرور ستين يوم جمعت المجراعات وعولجت كيميائيا باستخدام محلول هيدروكسيد البوتاسيوم (NaOH) المخفف بالماء المقطر بتركيز 30% 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) عبر6 مناطق واضحة على الكاشف.

وجد أ ن تركيز الرادون في أماكن الدراسة يتراوح بين 9.5 Bq/m^3 و80.5 Bq/m^3، وأن القيمة العظمى لتركيز الرادون هي105Bq/m^3 . وتبين أن القيمة المتوسطة لتركيز الرادون ومشتقاته في المنطقة الوسطى تساوي 39 Bq/m^3، مع متوسط الانحراف المعياري يساوي 17.01 Bq/m^3. ووجد أن تركيز الرادون ومشتقاته في كل موقع كالتالي: الزيتون40 Bq/m^3 ، معسكر الشاطئ 38 Bq/m^3 ، الرمال36 Bq/m^3 ، الشجاعية35 Bq/m^3،الشيخ رضوان 46 Bq/m^3،الدرج 42 Bq/m^3، النزلة34 Bq/m^3، الصبرة42 Bq/m^3 .

رغم أن النتائج التى تم الحصول عليها محدودة نوعا ما، لكنها تشير إلى تغير تركيز غاز الرادون فى مبانى مدينة غزة ، وبالتأكيد إن مثل هذة الدراسة تزودنا بمعرفة تركيز الإشعاع بشكل عام فى مدينة غزة ، والأخطار الصحية الناجمة عنها و معلومات مستقبلية عن الإشعاع تكون ذات فائدة من وجة النظرالبيئية.

CHAPTER (1)

Background radiation

1.1- Introduction:

The aim of this research is to study the chronic radiation exposure situation in Gaza strip, mainly, natural radiation sources. That is to evaluate the effect of the life style on the overall radiation exposure situations in Gaza.

This was carried out throughout the knowledge of medical treatment that given in health situations and the special case of Radon exposure which is considered as the most valnerable to chronic radiation exposure.

The source, collective effective doses, the resulting radiation, induced fatal cancer and sever hereditary effects was evaluated. This provides data, static information and brief description of the study area, Gaza. This highlights the sources of ionizing radiation, with the emphasis on the natural sources, the radiation induced health effects that results a chronic radiation exposure situations. Remedial measures will be presented in view of the results that could be helpful to the environmental point of view part of this work. In fact remarkable increases of many diseases are spreading in the country, and these include acute and chronic respiratory disease as well as the lung and blood cancer. This has been reported in cancer 2000 report of the Ministry of Health [20].

Therefore, radioactive pollution monitoring system should be established in Gaza to avoid more possible radioactive risks since chronic dose from natural sources have been increasing concern world wide.

Since we believe that the naturally occurring radiation sources such as radon would contribute in the annual effective dose of the general public, contribution from man-made radiation sources and radiological medical treatment will also be discussed. Our main interest is to investigate approaches, measures, and detection both of natural and radiological background radiation, since no serious study has been received in the past.

1.2- Background radiation:

Radiation is amount of energy release as particles or electromagnetic waves that come from radioactive elements. These elements will attempt to reach stability by emitting radiation [1].

The radiation travel through space or matter and they divide into two types ionizing radiation and non ionizing radiation.

1.2.1- Ionizing radiation:

The radiation concerning pollution is ionizing, radiation of sufficiently enough energy to ionize atoms and molecules. They consist of both particles and electromagnetic waves that can be produced from unstable atoms and by high voltage devices, the particles are electrons, protons, neutrons and alpha particles, depending on the type of atom structure. The electromagnetic radiations for this type have enough energy to break chemical bonds. The most common forms of ionizing radiation are alpha particles, beta particles and gamma rays.

i) Alpha particles:

Particles consist of two protons and two neutrons bound together to form nucleus of helium atom.

It has a positive charge +2 and carries kinetic energy always in the range of 4 to 8 Mev. Alpha particles do not penetrate far into material and can be stopped easily. Alpha particles have harmful effects within a human when they absorbed rather than an external hazard [2].

All uranium atoms are in chain of successive decays of radioactive isotopes with radium and radon that result alpha particles[3].

ii) Beta radiation (particles):

Beta particles are electrons emitted from nucleus of radioactive atom and have a negative charge. It carries kinetic energy always from 0 to 2 Mev they can travel in high speed one meter in air but not in straight line and they can penetrate human skin. Beta particles can produce skin injury[2]. Beta particles will be harmful when deposited internally. However, beta particle with very low energy can be stopped by aluminum foil or thin wood.

The materials emit beta particle are as an examples: strontium 90, carbon-14, tritium and, sulfur-35- [3] .

iii) Neutrons particles:

Neurons are natural particles that are normally contained in the nucleus of all atoms and may be removed by many processes like collision and fission. The neutron has no electrical charge and have large mass and can be absorbed or scattered by a nucleus of an atom or interact with it. It has the potential to penetrate matter deeper than any other charged particles.

iv) Gamma radiation:

Gamma rays are photons packets of pure energy usually between 50 and 2000 Kev [2], and they are emitted from nucleus of an atom when it excites. They are not electrically charged particles and massless. Gamma rays usually have higher energies than x-rays and both can penetrate matter further than any particles. They can travel form 1 to hundreds of meters in air and can easily go right through a human tissue and they may be called "penetrating radiation" thus they cause hazard to humans. They can early detected by sodium iodide detector, for example of some atoms emitting γ-rays such as; technisume 99, iodine 131, and cesium 137[3].

v) X-rays:

X-rays are electromagnetic radiation or photons that can be emitted by machines or decay of radionuclide.

X-rays are able to travel many feet's in air and many inches in human tissue. They can penetrate most materials and called "penetrating radiation" and make external hazard on human. The dense material is used for shielding from x-ray and γ-ray [3].

1.2.2- Non ionizing radiation:

Non ionizing radiation refers to any type of electro magnetic radiation that does not carry enough energy to ionize material and remove an electron from an atom or molecule.

The composition of this type of radiation depends on what is it Visible light, near ultraviolet, infrared and radio waves which are all example of non ionizing radiation.

Non ionizing radiation ranges from extremely low frequency radiation, as micro wave. Extremely low frequency radiation in the range of 100 Hz or less [4]. Because it is lower energy radiation, the use of this type of radiation in medical fields and every day life poses fewer health risks than ionizing radiation in forms such as x-ray. Some studies have shown that long term exposure to low- frequency electromagnetic fields can pose health risk, through the radiation it self.

1.3- Units of radiation and radiation dose:

There are common units used to measure radiation and radiation dose. We will define most of these units in brief: Becquerel (Bq) and curie (Ci): are common units used for radioactivity. The (Bq) is defined as: one disintegrate per second. Curie is equal 3.7×10^{10} disintegrations per second. The (ci) is large unit so we usually use milli and micro curies or kilo and mega Becquerel's.

Due to that instruments which are not 100% efficient we are often use counts per unit time instead of disintegration [3].

i) Exposure: Any ionizing beam passing through air causes ionization of the gas molecules and the formation of an electric charge.

$$Exposure \qquad e = \frac{q}{m} \quad coulombs.kg^{-1} \tag{1.1}$$

Where q: is the total electric charge produced and m is the mass of air. The unit of exposure are coulombs per kilogram (c kg^{-1}); the old unit is roentgen [5].

ii) Exposure rate: Amount of exposure per unit time and the units of exposure rate is ckg^{-1}.s^{-1}[5] .

iii) Kerma: The amount of energy loss in a small air volume and the unit of kerma is Gray.

Kerma used only for high energy photons which is an important measure for radiation therapy and is not commonly used in diagnostic radiology[5] .

iv) Absorbed dose D: Is measure of the energy absorbed by a volume of material (air or tissue)

$$D = \frac{E}{M} \tag{1.2}$$

Absorbed dose in air may be identical to tissue because the average atomic number of air 7.6 which is very close to water and soft tissue and the absorbed dose measured by J Kg $^{-1}$ or gray (Gy) [5] .

The probability of tissue radiation damage depends not only on the absorbed dose but also on the type and energy of radiation.

The effect of radiation type introduced as a radiation weighting factor w_R. The value of radiation weighting factor has been selected by the ICRP to represent of the relative biological effectiveness for inducing stochastic effects at law doses. The value of w_R are presented in the table (1.1)[5] .

	Type and energy range	w_R
1	X –and gamma - rays	1
2	Electrons and betas	1
3	Neutrons	5 - 20
4	Alphas and fission fragments	20

Table (1.1): The value of radiation weighting factor w_R

v) Equivalent dose H_T :

The equivalent dose is the absorbed dose averaged over a tissue or organ and weighted according to the radiation type.

Equivalent dose H_T : is the equivalent dose in tissue T for an absorbed dose D_T from a radiation having a weighting factor w_R is;

$$H_T = \sum D_T \times W_R \tag{1.3}$$

The equivalent dose is measured in savert (sv) [5] .

vi) Effective dose equivalent:

This quantity expresses the overall measure of health detriment associated with each irradiated tissue as a whole body dose. It's calculated by the relation

$$E = H_T \times W_T \tag{1.4}$$

A value of Effective dose equivalent is the over all risk per (Sv) of irradiating the whole body. The sum of the effective doses.

$$E = \sum H_T \times W_T \tag{1.5}$$

However for radiation dose we use many units to measure radiation absorbed dose, dose equivalent and exposure [5] .

vii) Roentgen: Is a unit used to measure exposure in air and only for x-rays and Gamma rays.

One Roentgen has energy to produce 0.000258 coulombs of charge by ionization in dry air. The Roentgen is limited in use at present, because roentgen is used only for gamma and x-rays and only in air[6].

viii) Gray and rad: is a units used to measure absorbed dose relates to a mount of energy absorbed by material and used for any type of radiation and any type of material, where 1 rad is equal to 100 ergs per gram and 1 Gray is equal 100 rad. These units are not used to describe the biological effects [6, 7] .

ix) Severt and rem:

It is a unit used to measure a quantity called equivalent dose and this relates the absorbed dose in human tissue to the effective biological damage of radiation. Note that not all radiation has the same biological effect if the tissue has the same amount of radiation; S v depends on the quality factor (Q):

1 rem = 1 rad x Q (1.6)

1 Sv = 100 rem (1.7)

So rem or Sv are units of biological risk [6, 8] .

1.4- Tissue weighting factor W_T :

The probability of tissue radiation damage depends not only on absorbed dose and type of radiation but also on the type of tissue. So there was a need to find a relation to combine type of tissue and probability of damage when exposed to the same equivalent dose. The weighting factor for important tissues is listed in table (1.2). [5] .

	Tissue or organ	w_T
1	Gonads	0.20
3	Bone marrow	0.12
3	Colon	0.12
4	Lung	0.12
5	Stomach	0.12
6	Bladder	0.05
7	Breast	0.05
8	liver	0.05
9	Esophagus	0.05
10	Thyroid	0.05
11	Skin	0.01
12	Bone surface	0.01
13	Remainder	0.05
14	Whole body	1.0

Table (1.2): The value of weighting factor w_T

1.5- Radiation sources: There are different types of radiation; some are more energetic than others. Radiation is produced naturally when unstable elements try to stabilize themselves and give off excess energy in the process.

We can divide radiation sources into two categories natural sources and man-made sources. Natural background radiations that are found naturally in air, water and soil. They are even found in us, being that we are products of our environment. Every day, we ingest and inhale radionuclides in our air, food, and the water. Natural radioactivity is common in the rocks and soil that make up our planet, in water and oceans, and in our building materials and homes. There is nowhere on Earth that you can not find Natural radioactivity.

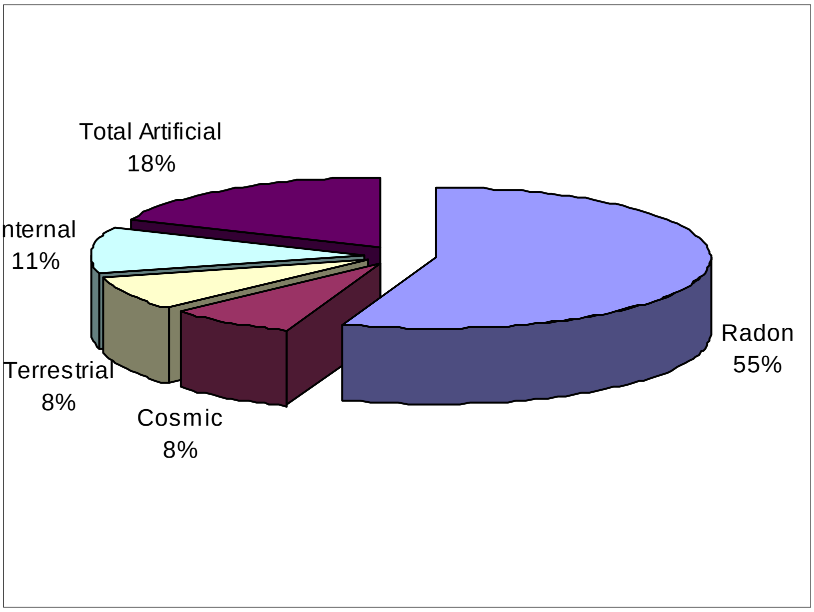


Figure (1.1): annual effective dose equivalent[12]

1.5.1- Radon

Radon is a gaseous radioactive element having symbol Rn, the atomic mass number is 222, a melting point of -71^0C, a boiling point -62^0C. There are between 20 and 25 isotopes, it is an extremely toxic, colorless and odorless. Radon's isotopes, all of which are radioactive, include mass number ranging from 200-226. Rn 222, formed in the U238 decay chain (see appendix II), is the most important isotope because of its relatively long half life of 3.82 days, the short half life beta and gamma – emitting decay products of Rn222 achieve equilibrium with the parent isotope within several hours.[3,9]

i) Radon source in homes

Radon222 is present in the natural environment because of radioactive decay of U238. For intermediate decay a product follow the decay of U238 and produce Rn226, is the direct source of radon 222.

Because Rn222 is a gas, it can readily travel through several meters of permeable soil before decaying.

The major sources of Rn222 in indoor air are:

- Soil gas emanations from soils and rocks.
- Off-gassing of water born Rn222 into indoor air.
- Building materials.
- Outdoor air.

Building materials generally contribute only a small percentage of indoor air Rn222 concentration. However, building materials may impart a greater Rn222 contribution when waste products from uranium mining were used to make concrete, concrete bulk. In some area with a high geologic Rn222 source outdoor Rn222 gas concentration exceed several pci/l for short period [9]

ii) Health risk of radon

If you inhaled radon atom, the atom can disintegrate while it is in your lungs. When it disintegrates, it becomes polonium 218, which is a metal. This metal atom can settle in your lungs, and over the next hour or so it will emit number of alpha particles, beta particles and gamma rays. It eventually turns into lead-210 with a half-life of 22-years, which is fairly stable in this context. But now you have an atom of lead in your system, which cause its own problems. When an alpha particle strikes the chromosomes in a lung cell, it could alter the way that cell reproduces. Our bodies' immune system should recognize and destroy these mutant cells before they can multiply over the next 10 to 20 years into a recognizable cancerous growth.

Some peoples immune system is better than others, Because of these inherent differences, radon doesn't affect everyone the same [01,11]

iii) Factors affecting indoor radon concentrations:

The indoor concentration of radon and its decay products, or of any other air born pollutant, depends on many factors as temperature variations, seasonal variation, humidity, geography place, high rise levels of building and ventilation rate.

1.5.2- Cosmic radiation:

The cosmic radiation is produced from our solar system (interstellar space and sun). It composed to very wide range from high speed heavy particles to high energy photons and muons. When radiation comes from space and sun, it penetrates atmosphere and interact with and produce radioactive nuclides as in table (1.3) , and other radionuclides ^{10} Be, ^{26}Al, ^{36}Cl, ^{20}Kr, ^{14}C,^{32}Sl,^{39}Ar,^{22}Na,^{35}S, ^{37}Ar……

Nuclide	Symbol	Half-life	Source	Natural Activity
Carbon 14	^{14}C	5730 yr	Cosmic-ray interactions, $^{14}N(n,p)^{14}C$	6 pCi/g (0.22 Bq/g) in organic material
Hydrogen 3 (Tritium)	^{3}H	12.3 yr	Cosmic-ray interactions with N and O, spallation from cosmic-rays, $^{6}Li(n, alpha)^{3}H$	0.032 pCi/kg (1.2 x 10^{-3} Bq/kg)
Beryllium 7	^{7}Be	53.28 days	Cosmic-ray interactions with N and O	0.27 pCi/kg (0.01 Bq/kg)

Table (1.3): radiation products due to cosmic rays

Cosmic radiation is classified as primary and secondary type, primary radiation have high energy particle and mostly large particles, and comes from the sun and outer space. Little of this type reaches to earth surface and other radiation interact with atmosphere. When it interacts with atmosphere, it produces the secondary type of cosmic radiation with lower energy in the form of photons, electrons, neutrons and muons, which arrive to earth surface. Therefore we can say that atmosphere is a shield, so that the rate at sea- level is less than at high a altitudes. Magnetic field is the other factor affects reaching radiations to earth also, the rate of radiation on pole to the equator decreases a bout 10% [12,13] .

1.5.3- Radiation from terrestrial:

When the universe is created the radionuclides were found in it. Earth has some radionuclide in rocks, soil, ocean water, air and vegetation. It is in small quantities. Terrestrial radiation varies depending on some factors such as half lives of the radionuclides and the type of the rock. These radionuclide is decreasing in its activity because it's decreasing to half value after certain time, the radiation varies from sandstone limestone and granite [5, 8, 13] .

1.5.4- Human Produced Nuclides:

Humans have used radioactivity for one hundred years, and through its use, added to the natural inventories. The amounts are small compared to the natural amounts discussed above. Due to the shorter half-lives of many of the nuclides, there is a marked decrease since the halting of above ground testing of nuclear weapons. Here are a few human produced or enhanced nuclides:

Human Produced Nuclides			
Nuclide	**Symbol**	**Half-life**	**Source**
Tritium	^{3}H	12.3 yr	Produced from weapons testing and fission reactors; reprocessing facilities, nuclear weapons manufacturing
Iodine 131	^{131}I	8.04 days	Fission product produced from weapons testing and fission reactors, used in medical treatment of thyroid problems
Iodine 129	^{129}I	1.57×10^{7} yr	Fission product produced from

			weapons testing and fission reactors
Cesium 137	^{137}Cs	30.17 yr	Fission product produced from weapons testing and fission reactors
Strontium 90	^{90}Sr	28.78 yr	Fission product produced from weapons testing and fission reactors
Technetium 99	^{99}Tc	2.11×10^{5} yr	Decay product of ^{99}Mo, used in medical diagnosis
Plutonium 239	^{239}Pu	2.41×10^{4} yr	Produced by neutron bombardment of ^{238}U (^{238}U + n--> ^{239}U--> ^{239}Np +ß--> ^{239}Pu+ß)

Table (1.4): Human Produced Nuclides

1.5.5- Man-made radiation:

Natural and artificial radiation sources are identical in their nature and their effects. The most significant source of man-made radiation exposure to the general public is from medical procedures, such as diagnostic x-rays nuclear medicine and radiation therapy. Some of the major isotopes used would be I-131, Tc-99m, Co-60, Ir-192,Cs-137,and others [13] .

In our region of study we have only diagnostic x-ray.

i) X-ray chest:-

A chest x- ray is a radiology test that involves exposing the chest briefly to radiation to produce an image of the chest and the internal organs of the chest. An x-ray film is positioned against the body opposite the camera, which sends out a very small dose of radiation beam. As the radiation penetrates the body, it is absorbed in varying amounts by different body tissues. Bones, for example, absorbe much of the x- ray radiation while lung tissue absorbs very little, allowing most of the x-ray beam to pass through the lung. Due to the differences in their composition (and, therefore, varying degrees of penetration of the x-ray beam). The lungs, heart, aorta, and bones of the chest each can be distinctly visualized. The x-ray film records these differences to produce an image of body tissue structures.

The effective radiation dose from this procedure is about 0.1 mSv, which is about the same as the average person receives from background radiation in 10 days [14].

ii) CT scan

A "CT" or "CAT" Scan is the term used to describe a radiologic test known as "computerized tomography" or "computed axial tomography" uses special x-ray equipment to obtain image data from different angles around the body and then uses computer processing of the information to show a cross- section of body tissue and organs.

CT can see inside the brain and other parts of the body in to areas that cannot be seen by regular x- ray examinations.

CT makes it possible to diagnose certain disease earlier and more accurately than with other imaging tools.

The effective radiation dose from this procedure is about 10 mSv, Which is about the same as the average person receives from background radiation in three years, a special care is taken to keep the radiation dose to an absolute minimum for all patients [15].

iii) Mammography

Mammography, of an x- ray of the breast, is the most accurate method of breast cancer detection. While these examination doses use radiation, the exposure is minimal [15].

1.6- Objectives

The present work is intended to study the chronic radiation exposure situations in Gaza since we believe that naturally occurring radiation sources such as radon would contribute in the annual effective dose of general public.

Contribution from man-made radiation sources and radiological medical treatment is considered, however, we get difficultly to reach the people who are in concern. Radon concentration is the main source of natural radiation.

The aim of this study is to evaluate the effect of radiation exposure particularly radon concentrations in different area of Gaza, We have distributed about 180 detectors in eight regions in Gaza. These are Ziton, Sapra, Remal, Shegaea, Shekh Radwan, Darage, Beach Camp and Nazla.

Such a survey will provide the basic data for any future planning from environmental point of view, and enable us to identify the problems concerning radiation hazards. This would also advance of public awareness and develop the management model of ecologic studies, especially for remediation of radiation hazards.

CHAPTER (2)

HEALTH
AND
RISK EFFECT
OF RADIATION

2.1- Radiation interaction with tissue (damage):

There was a short time between the discovery of x-rays and reported cases of radiation damage from their use. When alpha and beta particles and electromagnetic radiation lose their energy by electrical interaction with outer electron of atoms in tissue, these two types produce ionizing event. The damage may be represented by:

Charged particles → electrical interaction → tissue ionization → chemical changes → biological damage (cancer)

It is known that human biology consists of about 80% water and about 17% of the body is protein and nucleic acid [16].

Deoxyribonucleic acid DNA (The DNA contains all the hereditary information representing a cell) may be directly be damaged by radiation causing a break in a chain [5].

2.2- Radiosensitivity:

2.2.1- Physical factor affecting:

i) Linear energy transfer (LET): is the energy transferred from ionizing radiation to soft tissue over its path length expressed in kev m $^{-1}$.

The values of LET explain that heavy charged particles have high LET values and the ability to produce biological damage are shown in table (2.1) [5].

	Ionizing radiation	$LET\ kev\mu\ m^{-1}$
1	X-rays, gammas, electrons	0.2-3.0
2	Low energy electrons	3.5-7.0
3	High energy proton, neutrons	23-50
4	Alpha particles	175-200

Table (2.1): The value of linear energy transfer

ii) Relative biologic effectiveness (RBE):

The biologic effect is differing on the tissue with radiation type although the absorbed dose is equal. So we use R.B.E to express the effect of radiation type on the tissue type [16].

$$\text{R.B.E} = \frac{\text{Dose of standard radiation necessary to produce a given effect}}{\text{Dose of test radiation necessary to produce the same effect}}$$

iii) Fractionation and protraction:

If a dose of radiation is delivered over along period of time rather than quickly, the effect of that dose will be less stated differently, if the time irradiation is lengthened, a higher dose will be required to produce the same effect, this lengthening of time can be accomplished in two ways.

If the dose is delivered continuously but at a lower dose rate, it is said to be protracted. For example 600 rad delivered in 3 minutes 200 rad/ min is lethal for mouse and when it delivered at the rate of 1 rad/min for a total time of 600 hr however the mouse will survive.

If 600 rad delivered at the same dose rate 200 rad/min but in 12 equal fractions of 50 rad each separated by 24 hr the mouse survives in this case the dose is 5 rad to be fractionated. Dose fraction is less effective because tissue repair and recovery occur between doses [16].

2.2.2- Biologic factors affecting radiosensitivity:

Factors that affecting radiosensitivity for tissue are such as oxygen effect, age, sex and other factors

i) Oxygen effect:

Tissue is more sensitive to radiation when irradiated in the oxygenated than in anoxic (without oxygen) or hypoxic (low-oxygen) condition [19].

ii) The age:

Age of tissue or cell also affects radiosensitivity. Humans are most sensitive before birth, the sensitivity then decreases until maturity, the time we are most resistant to radiation induced effects, in old age sensitivity increases as in figure (2.1)[16].

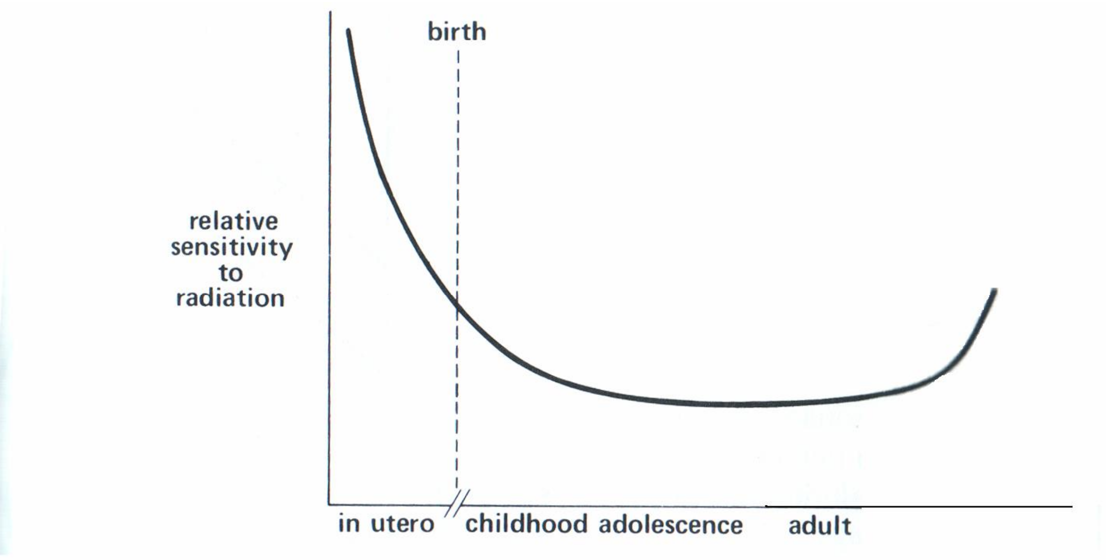


Figure (2.1): Radiosensitivity varies with age.

iii) Sex:

Females are less radio sensitive than males [16].

iv) Other factors as: state of health, body size, body weight and cell dividing activity all these factors have increased sensitivity to radiation exposure [16].

2.3- Radiation risks:

The risk for radiation exposure has been very widely studied to define and understand radiation related health effects; the risk for the indication of cancer by ionizing radiation is summarized in very wide number of reports from national and international committees. It's important to understand that radiation is very good cell killer, as demonstrated in it's wide use in cancer therapy. However, radiation is not very strong carcinogen, especially at low doses of radiation that this is a conservative assumption since the body has many repair mechanisms that can handle the damage induced by low doses of radiation.

the exposure to low levels of ionizing radiation cannot produce remarkable effect directly, however long term exposure would case cancer that depends on many factors [17].

i) Teratogenic:

Mutations result from the exposure of fetuses (unborn children) to radiation, they can include smaller head or brain size, poorly formed eyes, abnormally slow growth and mental retardation. Studies indicate that fetuses are most sensitive between about eight to fifteen weeks after conception, they remain some what less sensitive between six and twenty five weeks old.

The relationship between dose and mental retardation is not known exactly. However, scientists estimate that if 1,000 fetuses between eight and fifteen weeks old were exposed to one rem, four fetuses would become mentally retarded and If the fetuses were between sixteen and twenty five weeks old, it is estimated that one of them would be mentally retarded.

ii) Genetic effects: They are those that can be passed from parent to child-health physicists estimate that about fifty severe hereditary effects will occur in a group of one million live born children whose parents were both exposed to one rem.

In comparison, all other causes of genetic one million live-born children these genetic effects include those that occur spontaneously as well as those that have non radioactive causes. [18].

2.4- Area of study:

Gaza Strip is a narrow coastal region extending southeast along the Mediterranean Sea as shown in figure (2.2) at roughly 31^0 N latitude and 34^0 E longitude. It is 45km in length, and ranges from 5 to 12 km in width, with a surface area of $360\,Km^2$. The area is subject to a semiarid Mediterranean climate. Most of the strip is covered by Quaternary soil, with clayey material increasing towards the border with Israel.

The Gaza strip is heavily populated and its density among the highest in the world. Air quality is considerably bad due to pollution from several sources, where this believed to be responsible for many diseases spreading in the Gaza strip.

Figure (2.2): map of Gaza strip

2.4.1- Geology:-

The surface of the Gaza strip is simple and exposures are limited. It is formed of a series of alternating ridges. These ridges consist of clayey sands stone and silt which referred to as continental kurkar or Jarwal . The coastal 1-4 km wide along the Mediterranean sea is covered with calcareous sand dunes.

2.4.2- Geography:- It is bordered on the south by the Sinai desert, on the east by the Naqab desert. It has an 11 Km border with Egypt, near the city of Rafah, and a 51 Km border with Israel on the north and east it also has a 40 Km coast line on the Mediterranean Sea on the west. Gaza strip has a temperate climate, with mild winter, and dry, hot summer. The terrain is flat or rolling, with dunes near the coast, the highest point is about 105 meters above sea level. Natural resources include arable land which is mostly irrigated and natural gas which was discovered recently. Gaza strip faces many problems related to environmental issues such as desertification, water desalination, sewage treatment, soil degradation and depletion and contamination of under ground water resources [19].

In general, natural radiation may be one of the most dangerous pollutants in our environment. Also, all building material, in Gaza strip, is imported through occupied Palestine and have never been monitored to ensure compliance with relevant standards. In addition, building designs do not take radon risk into consideration and no public awareness exists. Moreover, no serious attention has been given to health risks due to radiation exposure.

Extensive measurements have been done in the world showing that radiation in homes increases Lung- cancer risk for general population, especially, those who spend a majority of their time at home. Here in Gaza we have no information about radiation concentrations. Where women and children under six years old (25% of the total population) spent more than 90% of their time at home. The birth rate will increase the problem in the future. Our main interest of our current research is to find out the relationship between radiation concentration and health risks of lung cancer…

2.4.3- Demographics:

Around 1.37 million Palestinians live in the Gaza strip where the majority of the population are direct descendants of refugees who flat or were expelled from Palestine during the 1948 Arab Israel war. The population had grown about six times, and the population has continued to increase.

The population is growing by around 4% a year and the population distribute in cites, small villages and eight refuges camps that contain two thirds of the population [19].

2.4.4- Gaza statistics:

In Gaza strip about 3.646 cases of cancer reported in 1995-2000, 1750 in male and 1896 cases in female. The incidence rate per 100,000 population was, 59.9 in general population 316 cases from the total number of cancer is lung cancer, about 251 deaths were reported: 206 in male and 45 in female. The deaths is distributed on Gaza strip as: north Gaza 39 death, Gaza city 107 deaths, midpoint 35 death: Khan younis 44 deaths and Rafah 26 death. In male bronchus and lung cancer is the first leading cause of cancer mortality 19.9% of all cancer mortality, the main reason to cause Lung cancer is smoking and radon gas [20].

CHAPTER (3)

EXPERIMENTAL TECHNIQUES FOR MEASURING RADON

3.1-Measurement Device Location Selection

3.1.1 Passive devices:

Passive radon testing devices do not need power to function. They include radon detectors such as charcoal canisters, alpha-track detectors, and charcoal liquid scintillation devices. They are exposed to the air in the home for a specified period of time and then sent to a laboratory for analysis. Both short-term and long-term passive devices are generally inexpensive. Some of these devices may have features that offer more resistance to test interference or disturbance than other passive devices. Professional radon testers may use any of these devices to measure the radon concentration such as:

i) Electrets Ion Chamber Radon Detectors (EC or ES, EL) to Measure Indoor Radon Concentrations:

Short-term (ES) and long-term (EL) ECs that require no power, and function as true integrating detectors, measuring the average concentration during the measurement period.

The EC contains charged electrets (an electro statically-charged disk of Teflon^{R}) which collect ions formed in the chamber by radiation emitted from radon and radon decay products. When the device is exposed, radon diffuses into the chamber through filtered openings. Ions which are generated continuously by the decay of radon and radon decay products are drawn to the surface of the electret and reduce its surface voltage. The amount of voltage reduction is related directly to the average radon concentration and the duration of the exposure period. ECs can be deployed for exposure periods of two days (one day for research purposes) to 12 months, depending upon the thickness of the electret and the volume of the ion chamber chosen for use. These deployment periods are flexible, and valid measurements can be made with other deployment periods depending on the application.

The electret must be removed from the EC chamber and the electret voltage measured with a special surface voltmeter both before and after exposure. To determine the average radon concentration during the exposure period, the difference between the initial and final voltages is divided first by a calibration factor and then by the number of exposure days. A background radon concentration equivalent of ambient gamma radiation is subtracted to compute radon concentration. Electret voltage measurements can be made in a laboratory or in the field.

ii) Activated Charcoal Adsorption Devices (AC) to Measure Indoor Radon Concentrations:

ACs are passive devices requiring no power to function. The passive nature of the activated charcoal allows continual adsorption and absorption of radon.

The AC technique, device used commonly by several research groups consists of a circular, six- to 10-centimeter (cm) diameter container that is approximately 2.5 cm deep and filled with 25 to 100 grams of activated charcoal. One side of the container is fitted with a screen that keeps the charcoal in but allows air to diffuse into the charcoal.

In some cases, the charcoal container has a diffusion barrier over the opening. For longer exposures, this barrier improves the uniformity of response to variations of radon concentration with time.

Another variation of the charcoal container has charcoal packaged inside a sealed bag, allowing the radon to diffuse through the bag. All ACs are sealed with a radon-proof cover or outer container after preparation.

The measurement is initiated by removing the cover to allow radon-laden air to diffuse into the charcoal bed where the radon is adsorbed onto the charcoal. At the end of a measurement period, the device is resealed securely and returned to a laboratory for analysis.

iii) Charcoal Liquid Scintillation (LS) Devices to Measure Indoor Radon Concentration:

Several companies now provide a type of LS device that is a capped, 20-ml liquid scintillation vial that is approximately 25 mm in diameter by 60 mm and contains one to three grams of charcoal (other designs are also feasible). In some cases, the vial contains a diffusion barrier over the charcoal which improves the uniformity of response of the device to variations of radon concentration with time, particularly for longer exposures. Some LS devices include a few grams of desiccant which reduces interference from moisture adsorption by the charcoal. All LS devices are sealed with a radon-proof closure after preparation.

A measurement with the LS device is initiated by removing the radon-proof closure to allow radon-laden air to diffuse into the charcoal where the radon is adsorbed. At the end of the exposure (typically two to seven days), the device is resealed securely and returned to the laboratory for analysis.

At the laboratory, the devices are prepared for analysis by radon absorption techniques. This technique transfers reproducibly a major fraction of the radon adsorbed on the charcoal into a vial of liquid scintillation fluid. The vials of liquid scintillation fluid containing the dissolved radon are placed in a liquid scintillation counter and counted for a specified number of minutes (e.g., 10 minutes) or until the standard deviation of the count is acceptable (e.g., less than 10 percent).

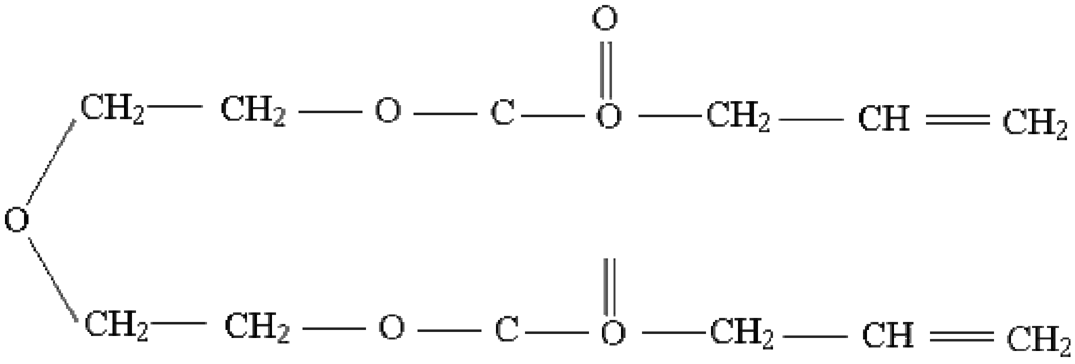
iv) Alpha track detectors (AT): Alpha track detectors, manufactured in various forms (CR39, LR115,…), use a thin section of plastic, or film, mounted inside a plastic or metal container. A filter permits radon atoms to diffuse into the container, but denies entrance to airborne radon decay products. Some alpha particles emitted by radon and radon progeny inside the container strike the plastic, or film, causing damage. In the lab, an etching process makes damaged regions more visible. They can relate the number of tracks to the radon levels in the room where the detector was exposed. Alpha track detectors are typically exposed from one to twelve months (twelve months is generally recommended).

In our study, we have used CR39 detectors to measure the radon concentration.

CR39 is a plastic made by the polymerization of the oxydi-2, 1-ethanediyl di-2-propenyl ester of carbonic acid. The monomer is an allyl resin which means that it contains the following functional group:

$[CH2 = CH - CH_2 -]$

The monomer itself contains two of these functional groups and has the following structure:



CR-39, is a clear, stable plastic which is sensitive to the tracks of energetic protons, alpha-particles and heavier nuclei. Each particle creates a sub microscopic crater which can be enlarged by etching the plastic in the hot NaOH. After that the craters become observable through an ordinary microscope.

Cut plastics: may be of any size, rectangular, circular or of more complex shape. Scribed features include rectangular boxes, circles, incrementing numbers, dot codes, titles and drilled holes.

- Alpha Track test is the best way to determine exposure to radon during different seasons and living conditions in home, providing a better estimate of actual risk. The alpha track radon test kit remains in home for more than 90 days, allowing you to measure the radon level under normal living conditions. An alpha track detector takes into account all the changes in weather that occur during the radon gas test period, as well as the changes in house under differing weather conditions. Weather conditions and ventilation habits can influence the radon level in the house.

Inside the unit is a piece of film that records the impacts (tracks) of alpha particles produced by the decay of radon and its decay by-product, polonium. At the end of the radon gas test period, the radon testing kit is sent to the laboratory, where counts the alpha tracks on the film, and reports the analysis [21].

3.1.2- Active devices:

Active radon testing devices require power to function. Active radon detectors such as continuous radon monitors and continuous working level monitors require operation by trained testers. They work by continuously measuring and recording the amount of radon or its decay products in the air of the home. Many of these devices provide a report of this information which can reveal any unusual or abnormal swings in the radon level during the test period. A professional tester can explain this report to you. In addition, some of these devices are specifically designed and detect test interference. Currently, some of the technically advanced active devices offer the most extensive device interference features. Although these tests may cost more, they may ensure a more reliable result [22].

3.2- locations of detector:

A position should be selected where the detector will not be disturbed during the measurement period and where there is adequate room for the device.

The measurement should not be made near drafts caused by heating, ventilating and air conditioning vents, doors, fans, and windows. Locations near excessive heat, such as fireplaces or in direct sunlight, and areas of high humidity should be avoided.

The measurement location should not be within 90 centimeters of windows or other potential openings in the exterior wall. If there are no potential openings (e.g., windows) in the exterior wall, then the measurement location should not be within 30 centimeters of the exterior walls of the building.

The detector should be at least 50 centimeters from the floor, and at least 10 centimeters from other objects. For those detectors that may be suspended, an optimal height for placement is in the general breathing zone, such as 2 to 2.5 meters from the floor [23].

3.3- Distribution of dosimeters:

Passive diffusion radon dosimeter containing CR39 nuclear track detectors of super grade quality which used in this survey is similar to that used by M. Rsass (2001)[27]. The structure of the passive dosimeter is a plastic cup 7 cm high, 7 cm diameter at one end, and 4 cm at the other end as in figure (3.1), where a plastic solid state nuclear track detector (SSNTD) with 1x1 cm2 was fixed. The end of the cup opposite to the detector is either covered with a plastic with a hole which covered by a piece of sponge into the interior surface.

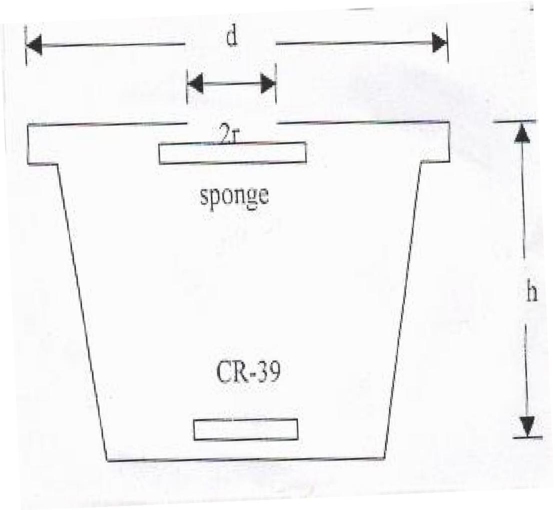


Figure (3.1) passive diffusion Radon dosimeter

For the purpose of this search 180 dosimeters were prepared and distributed in the Gaza city of Gaza strip. Our sampling strategy was to distribute the dosimeters in dwellings located at different region. Moreover , dwellings were built of different materials, like stone and concrete, bricks ,stone spestos and stone zinc .A group of 40 dosimeters was distributed in El- Remal region(R) , second a group of 20 dosimeters was distributed in El-Shate camp(B), third group of 20 dosimeters was distributed in El-Sheikh Rdwan region(SR) , a forth group of 20 dosimeters was distributed in El-Sabra region(SB), a fifth group of 20 dosimeters was distributed in El-Shejaia region(SH) , a sixth group of 20 dosimeters was distributed in El-Darge region (D), a seventh group of 20 dosimeters was distributed in Nazla region(J), an eighth group of 20 dosimeters was distributed in Ziton region(J) .

The detector was located in Kitchen, bed room and living room.

The detectors were left in the dwellings for a period of two months, (from March to June of 2006). Only 154 dosimeters were found in place and collected, while the remaining 26 dosimeters were considered lost, mistreated or damaged. The collected detectors were chemically etched using a 30% solution of NaOH, at a temperature of $(70\pm.0.5)^0$ C, for 6 hours according to a calibration made in laboratory in physics department of Islamic University Gaza. 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. After each detector dry they were counted visually using an optical microscope with power of (40×10). Tracks in 6 distinct regions were observed; through the area ($1cm^2$) the average number of tracks/cm^2 was determined.

3.4- The calibration

The calibration experiments were carried out to evaluate the relationship between track density recorded and the radon concentration, 16 dosimeter identical to the ones used in survey were prepared and put in the radioactive source of activity concentration 800Bq/m^3 for 28 days, after that the dosimeters were etched and the average number of tracks in cm^2 was found 119 tracks/m^2 which is the calibration standard. From this calibration, it was found that 19 tracks/cm^2 on the CR39 detectors, inside our cup dosimeter correspond to a concentration of 1 Bq/m3 for the activity of radon gas.

3.5- Track chemical etching

Each particle creates a sub microscopic crater which can be enlarged by etching the plastic in the hot NaOH. Until craters become observable through an ordinary microscope. For control of the etching speed of the detector we can change temperature, time and concentration as:

Firstly: to find the best concentration of aqueous solution NaOH, we use 12 detectors which were exposed to radon source of activity concentration

800Bq/m^3 for 30 days. Then we took them and allow them to be etched in different concentration of NaOH solution at constant temperature (70 c) and constant time (6 hours). Then we washed them in distilled water. The numbers of tracks per unit area of 1cm^2 were counted by using optical microscope with power of (40x10). The best field and reading track was at 30%NaOH concentration.

Secondly:

To find the best temperature, we use 16 detectors which were exposed to radon source of activity concentration 800Bq/m3 for 30 days. Then we took them and allowed them to be etched in different temperature, constant concentration of NaOH solution (30%), and constant time (6 hours), then we washed them in distilled water. The numbers of tracks per unit area of 1cm^2 were counted by using optical microscope with power of (40x10), the best field and reading track was at temperature 70 c.

After these two steps we took the temperature at 70 c, concentration of NaOH 30% and time 6 hours as the best factor for chemical etching.

3.6- Determination of Radon concentration

The solid state nuclear track detector technique is one of the most often used techniques 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 this unit.

Determination of Radon and its daughter's concentrations (C) throughout Gaza

$$C(Bq/m^3) = \frac{C_O\left(Bq.d/m^3\right)}{\rho_0}\left\{\frac{\rho}{t}\right\}_{\det.} \qquad (3.1)$$

Strip are carried out using the following equation [24]

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 to chemically etching. The average numbers of tracks/m^2 were observed. These detectors were considered as a calibration standard [24].

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 (3.2) for Radon exposure becomes as follows [25],

$$C(Bq/m^3) = \frac{1}{k}\left\{\frac{\rho}{t}\right\}_{\det.} \qquad (3.2)$$

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

3.7- Calibration factor (k)

The calibration process we made for dosimeters used in this survey prepared and exposed to radon source, eight dosimeters were exposed for 28 days of ^{226}Ra (Radon source) of activity concentration 800 Bq/m^3. The room's Radon gases monitor was 119 number of tracks/cm^2 were found in these calibration detectors, then reversed calibration constant (1/k) was found to be (18.85 Bq.d.m^{-3}/track.cm^{-2}), the overall uncertainty in this calibration was estimated to be ±10% [26]. Substituting reversed calibration constant in equation (3.4) then,

The above equation was used to determine the Radon concentration (C)

$$C(Bq/m^3) = 18.85\left\{\frac{\rho}{t}\right\}_{\det.} \qquad (3.3)$$

throughout the present work.

For example, consider that there are 250 tracks/cm^2 (average value), where the dosimeter exposed for a time period of 65 days. So the Radon concentration would be:

$C = (18.85)\ (250/65) = 72.5\ \text{Bq/m}^3$

So, the observed 250 tracks/cm^2 corresponds ≈73 Bq/m^3 Radon concentrations.

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. The structure of passive dosimeter is similar to that used by M. Rsass (2001). Our sampling strategy was to distribute the dosimeters in the buildings in eight regions of Gaza city (Ziton, Sapra, Remal, Shegaea, Shekh Radwan, Darage, Beach Camp and Nazla). These dosimeters were randomly distributed in a bedroom, living room or kitchen. Moreover, buildings built of different material are considered in the present study like (stone and zinc), (stone and spestos) and (stone and concrete). High leveles of the buildings are also taken into account, where the radon concentrations is strongly dependent.

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 6 distinct regions were observed, through the area (1cm^2). The average number of tracks/cm^2 was found. By using equation (3.3) the Radon concentrations were determined over the different region in the study area of this survey. Table (4.1) illustrates the minimum and maximum concentrations of Radon that determined from different groups of regions. Standard deviation (S. D.) is also calculated and listed in the table.

The arithmetic mean of all measurements of Radon concentration performed at all the region of Gaza city was 39.12 Bq/m^3 (1.06 pCi/l) with a range of values between 9.5 and 80.5 Bq/m^3 (0.26 and 2.18 pCi/l) and a maximum value of 105 Bq/m^3 (2.83 pCi/l) with average standard deviation of 17.01,while M. Rsass found in his study(2001) that the radon concentration in the middle zone of Gaza Strip in all region 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[28],

A. Al-Janabi studied radon concentration in Irbid Governorate, Jordan. He found that radon concentration in the dwelling was about 38Bq/m3 in

Al-Rafeed Village[28]. The small difference is due to the different region, different ventilation rate and air exchange. 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 does 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
Ziton(z)	12	40	86	13	14.47
Shatea(b)	21	38.0	67	8	16.62
Remal (r)	40	36	105	3	19.94
Shegaea(sh)	21	35	97	14	16.62
Shekh Rawan(sr)	20	46	68	11	15.39
Darag(d)	14	42	83	8	21.05
Nazla(N)	15	34	55	13	13.31
Sabra(sb)	11	42	83	6	18.75
Ave. value	Sum=154	39.125	80.5	9.5	17.02

Table (4.1): Radon concentration in each region of present study and S. D.

Figure (4.1) shows that the average Radon concentrations of Remal and Shegaea regions are higher than others; also the results indicate that the difference between the minimum and maximum Radon concentrations in each region is very high. This large variation in this regions is mainly due to the difference in the ventilation volume, different types of these locations in building (bedroom, living room, kitchen) and hight level rise of building (basement, first floor, …etc), different materials of building like the stone and spostos, stone and concrete…. etc. Most of buildings in the region of study are made of concrete and few buildings of spostos and stone. While some of the buildings have their windows closed all the time, most of them have the windows opened for a few hours a day. In our sample of the region, about 55% have their windows opened for more 8 hours per day. This indicates that the difference in Radon concentration is due to different ventilation in the region of study.

Other factors may also affect the Radon concentration. But, it is assumed that the main reason for concentration difference is ventilation conditions.

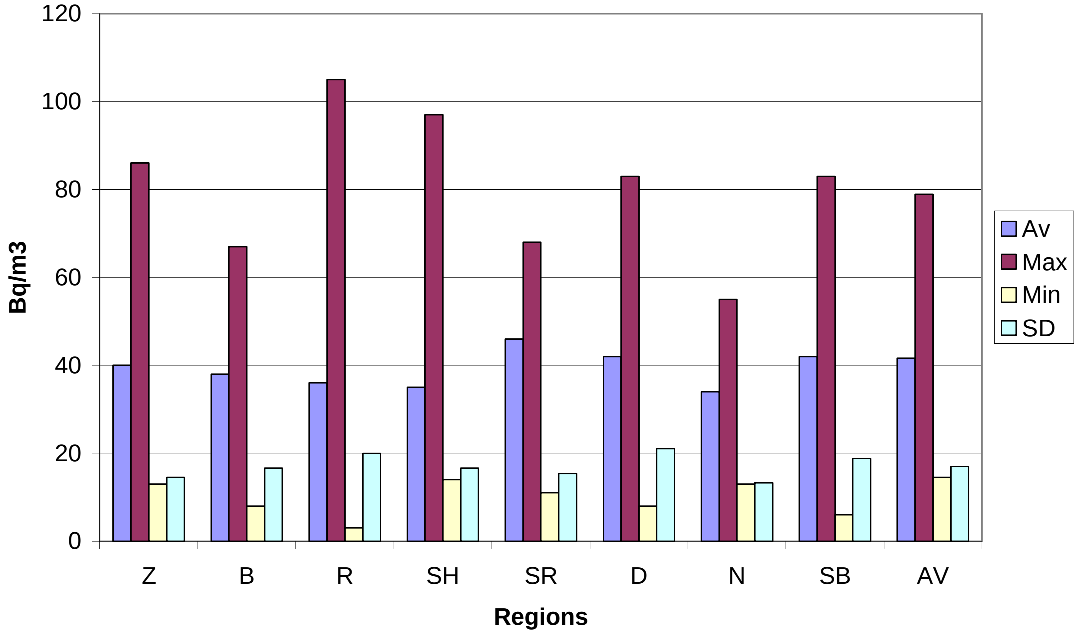


Figure (4.1): Radon concentrations in each region and S. D.

4.3- The variation of Radon concentrations with the high level rise of the building:

The dosimeters have distributed in different levels of buildings that built of different materials so that the radon concentration can be detected.

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)
Ziton(z)	41.28	27.7	32.11	-	-	-
Shatea(b)	42.09	34.80	-	29.60	-	-
Remal (r)	42.8	41.73	-	39.49	-	37.68
Shegaea(sh)	35.21	33.69	35.24	-	-	-
Shekh Rawan(sr)	52.05	38.43	30.07	-	27.25	-
Darag(d)	51.14	42.83	31.21	-	-	-
Nazla(N)	41.8	13.93	-	-	-	-
Sabra(sb)	43.77	31.98	-	-	-	-
No. Of Det	54	50	19	8	3	2
Ave. value	43.7675	33.13625	32.1575	34.545		

Table (4.2) Radon concentrations variation with the level of the houses

As shown in table (4.2) the Radon concentrations vary from one building to another within the same height. It is also different from one floor to another. Table (4.2) shows that the basements are the highest Radon concentrations in all locations. This dependence demonstrates that Radon levels vary from floor to floor of the Z, B, R, SH, SR, D, N and SB 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 SR and D region and lowest were observed in the 1st of N region 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 SR and D is the highest.

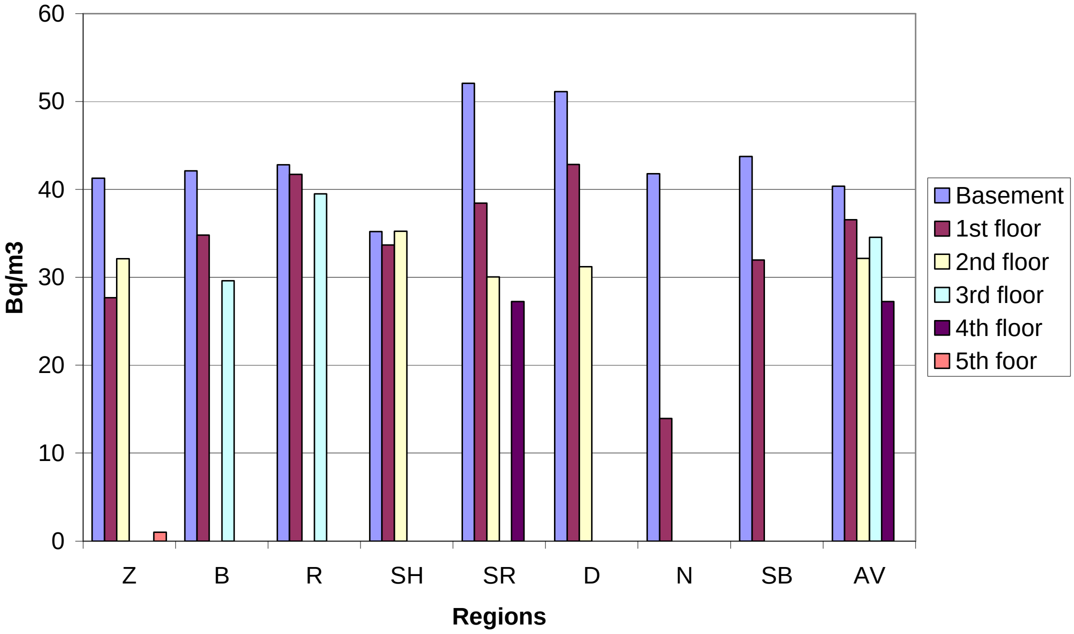


Figure (4.2): Radon concentrations variation with the level of the houses

The rooms in these basement floors have small windows or less opening windows and their ventilation is poor because the building are close to each other, while rooms in the other building floors have large windows and ventilated better than in basement. This was clear from questionnaire throughout survey of measurements.

This ventilation effect is strongly pronounced when the 5th floor is considered, where the Radon level drops rapidly to low values due to the excellent ventilation. It can be concluded that Radon concentrations in the basement floors were higher than in the upper floors.

This is attributed to that basement is the closest to the soil and the geological and radiometric characteristics play an important role in radon entering.

Radon can enter the basement or buildings throughout cracks in the floor or walls that in contact with soil.

4.4- The variation of Radon concentrations in different rooms

These results for work places (rooms) show that Radon concentrations vary from a room to another room.

Although the Radon source is often concentrated in one room or in one part of the buildings, the gas streams into the other parts of the buildings, mainly because of the ventilation rate. Table (4.3) shows the Radon concentrations versus the different part (bedroom, living room and kitchen) of different buildings.

Location	Bedroom C(Bq/m^3)	Living room C(Bq/m^3)	Kitchen C(Bq/m^3)
Ziton(z)	30.66	32.11	45
Shatea(b)	37.49	57.30	33.57
Remal (r)	50.82	41.8	41.97
Shegaea(sh)	37.29	25.66	39.06
Shekh Rawan(sr)	36.22	42.7	53.97
Darag(d)	31.82	48.21	40.68
Nazla(N)	16.15	27.23	46.23
Sabra(sb)	50.32	34.44	28.44
No. of Det	53	45	42
Ave. value	36.3465	38.68125	41.115

Table (4.3): Radon concentrations versus different rooms

One of the most important results of the previous analysis and evolutions was confirmed that Radon concentration values correlate very well with the different rooms. From the results of measurements performed in each room selected in the region of study, the average Radon concentrations were found to range from a minimum value of 16.15 Bq/m^3 determined in bedrooms to maximum value of 57.30 Bq/m^3 determined in living room. The high Radon level in this place is due to the relatively low ventilation, since there are small windows or they are closed most of the time. Figure (4.3) describes that Radon concentration for different rooms in different regions. In figure (4.3) it is also shown that the highest Radon concentration was found in the living room and kitchen in most regions. While the bedrooms have low Radon concentrations in most regions, and also shows Radon concentrations depending on ventilation more than on the location. This was clear from questionnaire throughout survey of the present work.

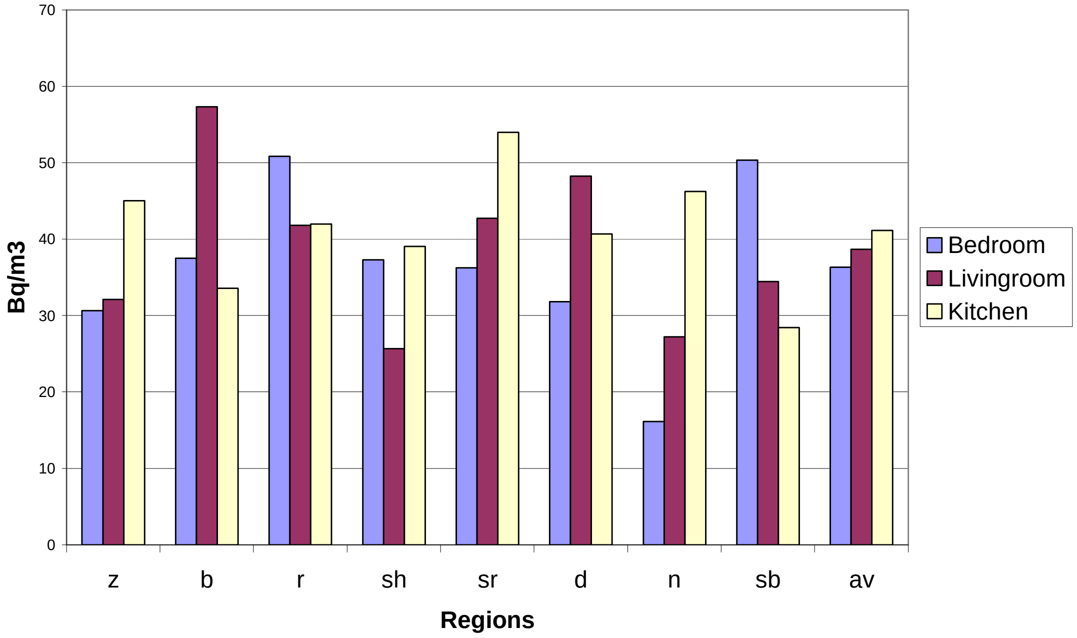


Figure (4.3): Radon concentrations in different rooms of the houses built of (stone and concrete)

Figure (4.4) indicates that the variation of Radon concentration percentage according to different rooms in the region of study of Gaza houses as following: (kitchen 36%, living room 33% and bedroom 31 %.). On the other hand, the kitchen in this section has the highest Radon level. Where the bedrooms have lowest Radon levels. The kitchen has poor ventilation; because it has small window this may be the reason that raises this radon level in kitchen.

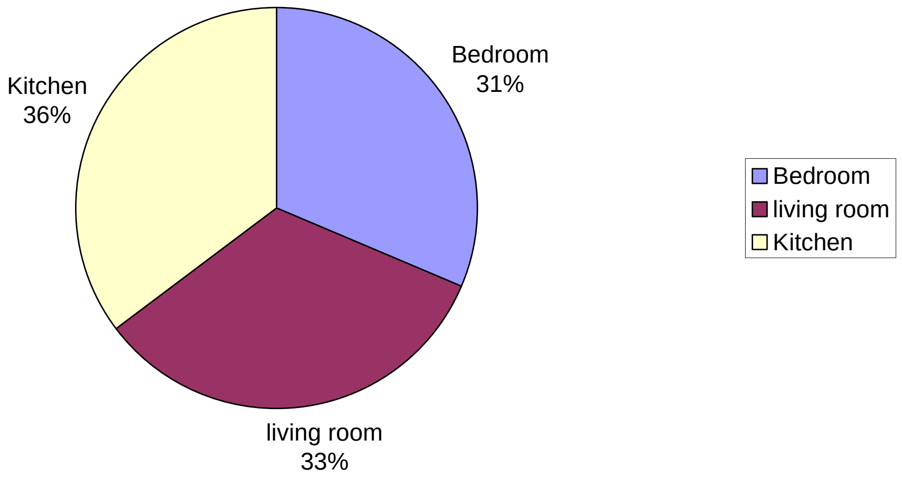


Figure (4.4): percentage of Radon concentrations in different rooms of the house.

4.5- The smoking effect

It is necessary to focus on an important environmental problem, that is smoking. The risk of smoking, as everyone knows, is duration dependent and cumulative. Exposure to Radon and cigarettes smoking 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 [18]. In addition, there is an interactive effect between the Radon exposure and cigarettes smoking. Two agents are really causing and developing of lung cancer. The risk of lung cancer caused by smoking is much higher than caused by indoor Radon [29].

The results obtained in table (4.4) of every region in the present work, shows that variation of Radon concentration is independent of smoking status. This was also obtained and analyzed from the questionnaires of buildings owner.

Location	Smoking C(Bq/m^3)	No smoking C(Bq/m^3)
Ziton(z)	33.43	34.24
Shatea(b)	39.65	49.46
Remal (r)	38.5	47.65
Shegaea(sh)	29.89	38.48
Shekh Rawan(sr)	42.4	38.34
Darag(d)	33.63	47.65
Nazla(N)	17.79	40.08
Sabra(sb)	32.69	44.35
No. Of Det	62	78
Ave. value	33.4975	42.53125

Table (4.4): smoking effect of the house

Table (4.4) exhibits that the variation of the average Radon concentration according to smoking status (non-smoking 42.5 Bq/m^3 and smoking 33.4Bq/m^3). Where nonsmoking was the highest average Radon concentration the reason may be due to that the smoker left the windows open for a long period of time when he smokes which rises the ventilation rate and air exchange.

Figure (4.5) shows that Radon concentration of nonsmoking people is higher compared with smoking people. Smokers should keep their exposure to Radon as low as possible.

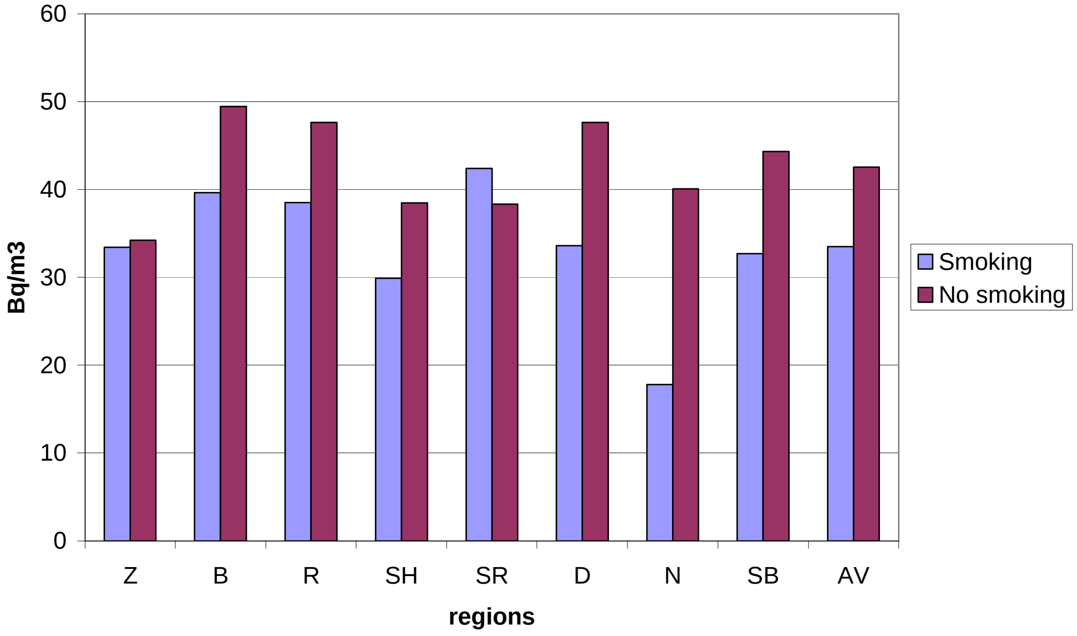


Figure (4.5): smoking effect of the houses built of (stone and concrete)

Figurer (4.6) shows that the variation of Radon concentration percentage according to smoking and non-smoking in the region of study of Gaza houses as following: (smoking 44%, non-smoking 56%). On the other hand, the non-smoking in this section has the higher Radon level.

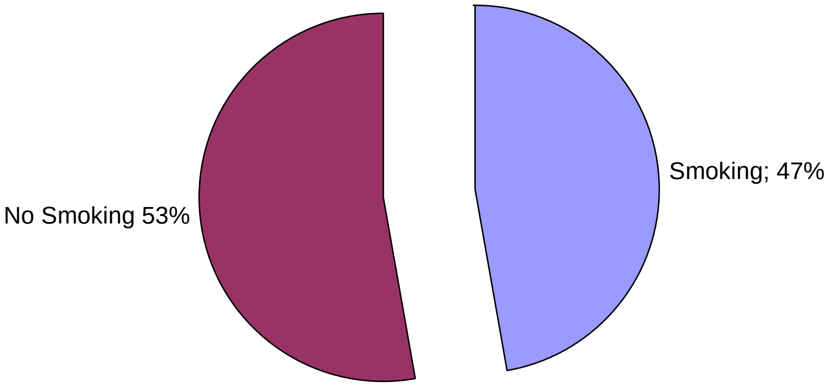


Figure (4.6): percentage of Radon concentrations versus smoking and non smoking.

4.6- The age of building effect

There is a slight age dependency, in our study we have divided the houses to five parts: less than 10 years old, from 10-20years old, from 20-30 years old, from 30-40 years old and 40-50 years old. We have seen the slight age dependency as shown in table (4.7). The old buildings have higher radon concentration than the newest buildings, this result contradicts the result found by J.K.C.Leung and others who found radon concentration in new buildings are higher than in old buildings. This depends on the building material content in new building [30]. However, in our region of study the difference may be due to the style of life, and high ventilation rate as well as to permanent air exchange in Gaza

Location	Age of building (0-10)year C(Bq/m^3)	Age of building (10-20)year C(Bq/m^3)	Age of building (20-30)year C(Bq/m^3)	Age of building (30-40)year C(Bq/m^3)	Age of building (40-50)year C(Bq/m^3)
Ziton(z)	35.39	32.93	-	-	45.36
Shatea(b)	40.17	41.44	44.62	43.47	43.42
Remal (r)	38.33	45.51	40.85	31.82	54.79
Shegaea(sh)	34.62	37.66	33.31	-	-
Shekh Radwan(sr)	39.74	37.82	45.86	-	-
Darag(d)	33.55	-	-	-	-
Nazla(N)	15.04	23.94	43.83	-	-
Sabra(sb)	38.30	42.93	-	-	-
No. Of Det	53	40	20	6	8
Ave. value	34.3925	37.4614	41.694	37.645	47.8566

Table (4.5): the age effect of the house

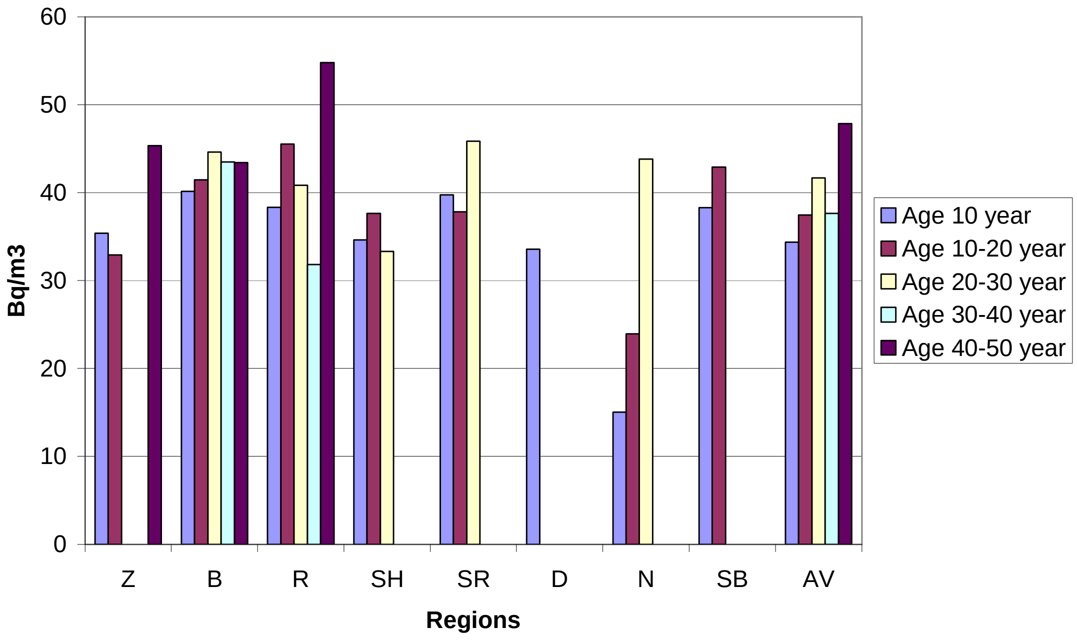


Figure (4.7): The age effect of the house on radon concentration

4.7- The ventilation rate:

The important factors affect the Radon concentration are the ventilation rate and air exchange. In this chapter no section haven't the ventilation as the reason of high or low Radon concentration. Therefore, we have divided the houses of study to three types of houses: bad ventilation, intermediate ventilation and good ventilation. Bad ventilation has small windows or windows left opened less than three hour a day, intermediate ventilation has left windows for three to eight hour daily and good ventilation has left windows opened more than eight hour a day. This has been observed from the questionnaire. From the results (table (4.6)) obtained from the area of study; it is found that Radon concentration is dependent of ventilation rate. That is in bad ventilation houses. Have the highest radon level is obtained and the lowest radon level in good ventilation. Thus the relation is inverse between radon level and ventilation rate. Table (4.6) also shows variation of radon concentrations with ventilation rate for different regions.

Location	Good ventilation C(Bq/m^3)	Intermediate ventilation C(Bq/m^3)	Bad ventilation C(Bq/m^3)
Ziton(z)	31.40	35.33	45.36
Shatea(b)	38.28	40.4	43.07
Remal (r)	39.6	44.09	44.11
Shegaea(sh)	24.65	37.26	42.40
Shekh Rawan(sr)	37.67	38.83	56.31
Darag(d)	35.33	51.22	76.98
Nazla(N)	27.01	49.71	-
Sabra(sb)	29.93	37.56	55.84
No. of Det	86	29	22
Ave. value	32.98	41.8	52.01

Table (4.6): Radon concentrations versus with ventilation rate

Figure (4.8) describes the histograms of Radon concentrations for various rates of ventilation in the buildings locations. It can be seen that Radon levels inside the bad ventilation are much higher than the Radon levels in the intermediate and good ventilation.

The rooms in the bad ventilation have small windows or less opened windows and their ventilation is poor because the buildings are close to each other, while rooms in the good ventilation have large windows and ventilated better than in the other.

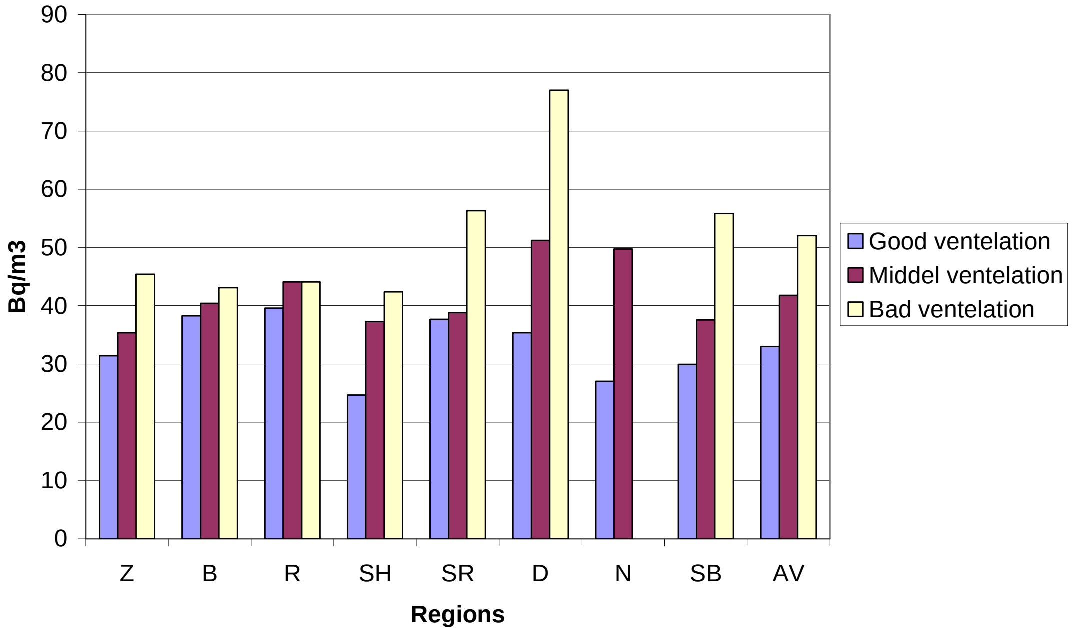


Figure (4.8) Radon concentrations versus with ventilation rate

Figurer (4.9) shows that the variation of Radon concentration percentage according to ventilation rate in the region of study of Gaza buildings as follows: (Good ventilation 29%, Middle ventilation 30% and Bad ventilation 41%). On the other hand, the Bad ventilation all over our current study has the higher Radon level and this due to less exchange of the air in it

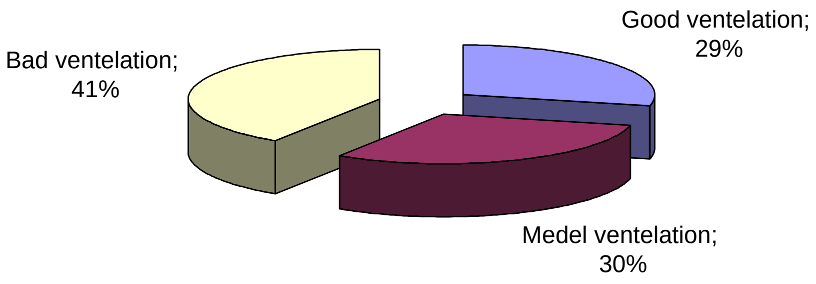


Figure (4.9): percentage of Radon concentrations versus with ventilation rate.

CHAPTER (5)

CONCLUSIONS AND FUTURE PLANS

Conclusion:

The current study is planned to determine the extent and severity of radon problems in the locations of Gaza City.

The plastic cup, containing CR39 detectors, are used for indoor radon monitoring.

The detectors are cut in small pieces (usually 1x1.5 cm) and fixed at the bottom of the plastic cup and the upper opening of the cup is covered with a polyethylene film to prevent Rn220 and Rn219 isotopes from entering the chamber and protect the detector surface from dust particles. The indoor radon levels have been estimated in 154 houses (eight locations) in Gaza City using integrating etched track detector. The eight regions were investigated and the radon level determined. This level in general is found that the ventilation is the key factor that affects the radon concentration, particularly in low level rise of building rather than the higher buildings. The devices are exposed to radon for a time period of two months, after which they are collected and the CR39 films were chemically etched using a 30% solution of NaOH, at a temperature of 70^0 C, for 6 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 6 distinct regions were observed; through the area ($1cm^2$) the average number of tracks/cm^2 was determined and analyzed. Surveys have been conducted in different types of houses in the region of study (Gaza City), houses built of different material like (stone and zinc), (stone and spestos) and (stone and concrete) which we know the Radon concentration depends, also Radon concentration depends on the height of the buildings and ventilation rate. These dosimeters were randomly distributed in bed in a bedroom, in a living room or in kitchen.

Generally, the result was found 39.12Bq/m^3 (1.05 pCi/l) with a range of values between 9.5 and 80.5 Bq/m^3 (0.26 and 2.18 pCi/l) and a maximum value of 105 Bq/m^3 (2.8 pCi/l) with average standard deviation of 17.01. M. Rsass [28]found that the radon concentration in the middle zone of Gaza Strip in all region 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, A. Al-Janabi[29] studied radon concentration in Irbid Governorate, Jordan and he found that radon concentration in the dwelling was about 38Bq/m3 in Al-Rafeed Village. The present work shows similar results for both M. Rsass and A. Aljanabi. This is attributed to the same geology and demography. The small difference is due to the different region, different ventilation rate and air exchange of buildings in Gaza city.

The result in Gaza City is lower than the level which made by EPA and ICRP. Despite the limited number of detectors used in this survey, the obtained results indicate a variability in radon concentration that expected in building of Gaza city. This would give a wider frame work for natural radiation measurement in Gaza that provide data specially from environmental point of view.

Future plans:

1- National Authorities should develop long-term action plans for addressing occupational radon exposures. These plans should include:

a- goals and targets;

b- Identification of stakeholders and contributors, assignment of responsibilities, and co-ordination of national authorities and resources;

c- Strategies, methods and tools for measuring radon levels, and for taking remedial actions; and the radiation protection community (e.g. regulators, advisory bodies, research establishments, etc) should acknowledge the assistance that other stakeholders can provide, and actively seek to develop links and working relationships, for example, with:

a- The wider Health and Safety Community;

b- Employer and employee organisations;

c- The building and work places; and

d- The media, and those with expertise in communication.

2- for radon risk

The effective provision of information on health risks from radon exposure, in a non-technical way, is essential to express the scale of the problem and the need for remedial action. Suggested approaches include:

a- Estimating the risk of cancer from workplace exposures, for example in terms of the numbers or ranges of fatal lung cancers predicted per year in each country or region;

b- Providing a comparison of these health risks, for example by including radon in a "Top 10" of hazardous (carcinogenic) workplace agent; and

3- Communication strategies

Experience in the effectiveness of different strategies used in radon action programmes is growing. These include advertising through various media, leaflets, websites, targeted mailshots, "roadshows" and inspection campaigns. There are many lessons to be learned, and it is recommended that this experience is analysed and shared . the recommend reach to puplic as:

a- Developing a website that provides information on radon/radon risks, as well as communication and protection strategies, as a resource to assist Member States in implementing National Action Plans.

b- National Authorities should also pay more attention to this subject, especially with a view to developing mutual trust with other stakeholders, for example by:

c- Engaging with credible, local information sources (e.g. medical or public health professionals) to ensure a common message;

d- Setting up stakeholder panels, national forums, etc.;

e- Making greater use of communication experts; and

f- Review the effectiveness of their own strategies and sharing this information with others.

4- Mapping radon-borne areas, by considering specific types of workplaces/work activities, and taking account of occupancy rates. The aim then is to develop regulatory programmes and measurement protocols to encourage radon surveys in these priority workplaces. As well as determining the need for remedial action in specific workplaces

5- For house

a- The design level be an effective dose equivalent of 10 mSv per annum, which for practical purposes, may be taken as quivalent to an annual average radon gas concentration of 200 Bq/m3;

b- Information be provided to those involved in the construction of new buildings, as relevant, on possible radon exposure levels, and on preventive measures which could be taken.

6- Because of diurnal and seasonal variations of indoor radon levels, radiation protection decisions should in general be based on the annually-averaged measurements of radon gas or daughters in affected buildings using integrating techniques. The competent authorities should ensure that the quality and reliability of measurements are adequate.

7- Criteria be developed for identifying regions, sites and building characteristics likely to be associated with high indoor radon levels. Investigation levels for the underlying parameters (i.e. activity in soil and building materials, permeability of ground, etc.) could be used to identify such exposure circumstances.

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 (I)

Questionnaire

- **For house**

The name:……………………………….. detector No:………………

- **Location**: R:☐, B: ☐, SH: ☐., N: ☐, D: ☐, SB: ☐, SR:☐, Z:☐.
- **Type of location**:

House: ☐

Bedroom: ☐, living room: ☐, kitchen: ☐.

Shop: ☐, Pharmacy: ☐, Others: ☐.

- **Belding construction**: stone and concrete: ☐,stone and spestose: ☐

Zinc: ☐, others: ☐.

- Year you began living in his residence:…………………..
- Year this building constructed:………………
- Primary source of water:……………………
- The level of the house
- Basement: ☐, 1st floor: ☐, 2nd floor: ☐, 3rdfloor: ☐, 4th floor: ☐,

5th floor: ☐, Others:…………………

- Type of heating systems had he uses:………………
- The type of heating fuel used in the house: natural gas: ☐, wood: ☐, electric: ☐, petrol: ☐.
- The time you spent in house:………………..
- Ventilation rate: very good: ☐, good: ☐, middle: ☐, bad: ☐.
- **For man**

- Age: …………………..
- Education rate: university: ☐, high school: ☐, primary school: ☐.
- Job:……………..
- Did you expose to any chemical substance in your job?yes: ☐, no: ☐
- Do you smoke? Yes: ☐, no: ☐.

Detector serial No.

Beginning date

Collective date

Location

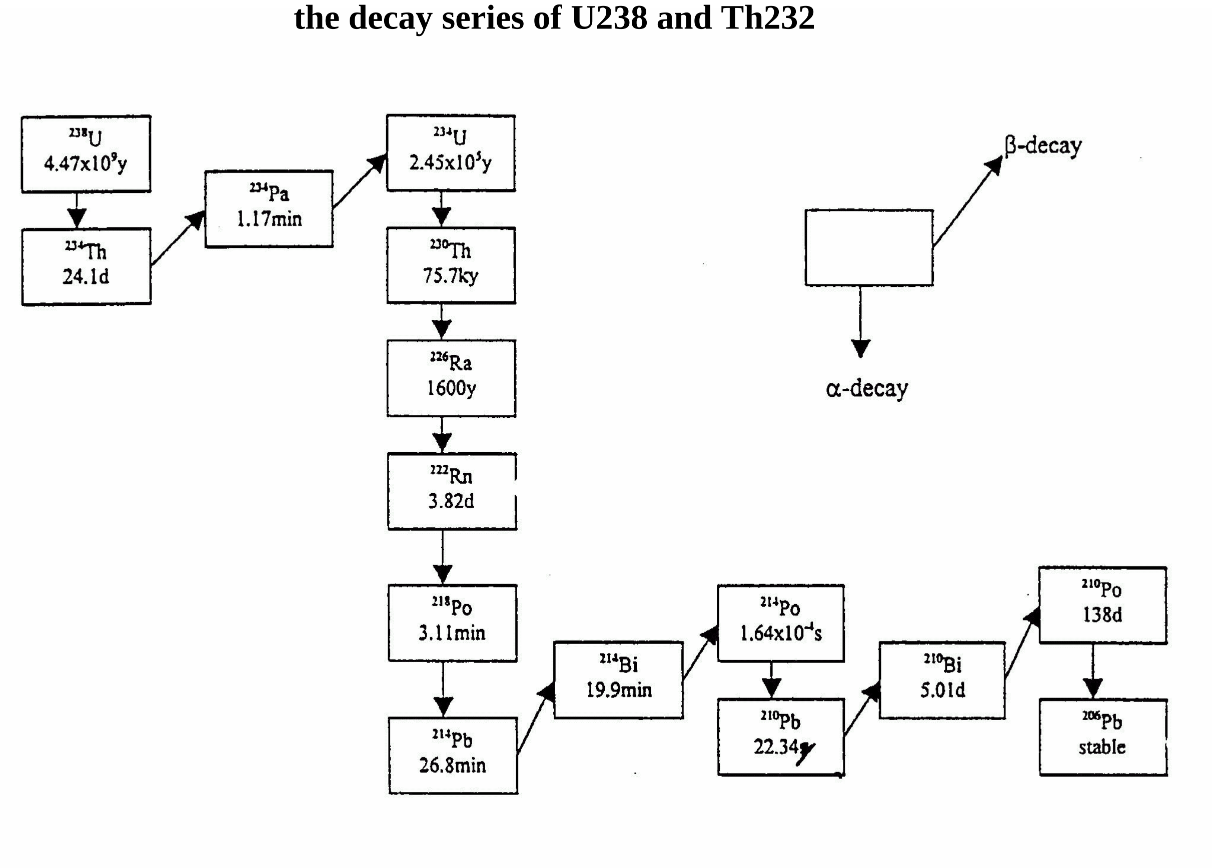
Type of location

Average no. of track /cm2

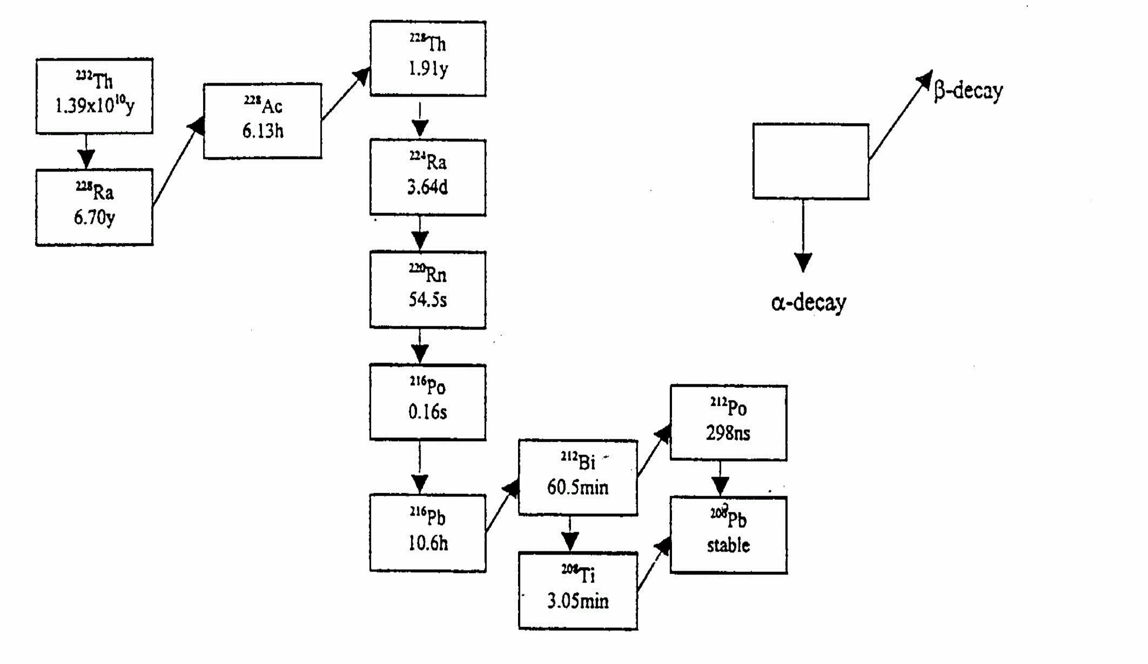
Concentration of radon

APPENDIX (II)

the decay series of U238 and Th232



The decay series of U ^{238}



The decay series of Th ^{232}

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