زانكۆی سەلاحەدین–هەولێر
Salahaddin University-Erbil

# Measurement of Radon Concentrations in Granite using RAD7

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

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**2022-2023**

## Supervisor Certificate

This research project has been written under my supervision and has been submitted for the award of the degree of BSc. in (Physics).

**Signature**
**Name: Hiwa Hamad Azeez**
**Date: / /2023**

I confirm that all requirements have been completed. Signature:

**Name:**
**Head of the Department of physics**
**Date: / /2023**

بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

قَالُواْ سُبْحَٰنَكَ

لَا عِلْمَ لَنَآ إِلَّا مَا عَلَّمْتَنَآ ۖ

إِنَّكَ أَنتَ ٱلْعَلِيمُ ٱلْحَكِيمُ



صَدَقَ اللَّهُ العَظِيم

**This project is dedicated to:**

Allah Almighty, my
Creator and my Master, My
great teacher and messenger,
Mohammed
(May Allah bless and grant him), who taught us the purpose of life,
My homeland Kurdistan, the warmest womb, The
Salahadin University; my second magnificent home;
My great parents, who never stop giving of themselves in countless ways,
My beloved brothers and sisters;
To all my family, the symbol of love and giving, My
friends who encourage and support me,
All the people in my life who touch my heart.

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# Chapter one

## 1-1 Introduction:

Radon Rn222 are radioactive gases produced by the disintegration of 22oRa, and 22Ra which are the decay products of U, is coming from the breakdown of naturally occurring uranium found within soil, rocks, and ground water. Radon is present in nature as the only( assad.h.ismail,2006 and cameron lawrence,2005) gas found in the natural *U radioactivite decay series, it is a direct progeny of 22Ra, has a half-life of 3.82 days, is colorless, inert, the major radon isotope, noble gas, which is the heaviest gaseous element and is soluble in water and highly soluble in organic solventsTwo other isotopes of radon exist in nature and are members of the 232Th and 235U natural radioactive decay series, they are 22Rn (which called Thoron) and 2Rn (which called Actinon) respectively. The half-life of 220Rn (55.6 Sec) and 2Rn (3.96 sec) are much shorter than of 222Rn. The 220Rn and 219Rn are emanates from soil and building materials, as well as, are in filtration from the ground and further migration are restricted to a few centimeters Radon and its progenies are proved to be a health hazard and they contribute around (50-55%) to the total radiation population exposure,Radon's primary transport through the environment is through soil and air where it can accumulate in living spaces and build up to dangerous levels. When radon is inhaled into the lungs, it decays by means of alphaemission, an alpha -particle is the nucleus of Helium atom, which causes ionization damage when it strikes the lung tissue. Over time, this damage causes lung cancer. Therefore, you can not see smell and taste radon, but it may be a problem in your home. That is because whenever you breathe air containing radon, you increase your risk of suffering from lung cancer People were not aware of its deadly health hazards. This invisible silent killer was pursuing the people in secret way so as to avoid being noticed, causing a plague of lung cancer In this regard, radon measurements are being pursued all over the world as at national level and extensive data are available in refs.The purpose of this chapter is to give an overview about history and discovery of radon gases; their physical and chemical properties, their isotopes and daughters, their risk and health effects, their exhalation, emanation and transport within medium material and their availability in indoor space and building materials.(nazaroff,w.w,nero,v.a,1988 and mansour h.h.,perkhar,abdulla 2005)

## 1-2 Physical and Chemical properties of Radon

Radon was the fifth radioactive element to be discovered, after uranium, thorium, radium and polonium, in 1900 by Friedrich Ernst Dorn A characteristic common to all natural radioactive series, unlike the artificially produced neptunium series, is the existence of radon isotopes. This element, with an atomic number of 86, is a colorless, odorless, tasteless and radioactive noble gas that generally lacks activity toward other chemical agents. It is the heaviest member of the rare gas group (-100 times heavier than hydrogen gas and ~7.5 times heavier than air). When cooled below its freezing point, radon exhibits brilliant phosphorescence that becomes yellow at lower temperatures and orange red at the temperature of the liquid air .The electronic structure of its atom suggests very limited chemical reactivity. However, according to its relatively low first-ionization potential of 10.7 eV, (shafe ur_rehman,2005 and khalil amgarou,phd thesis,2002)

some interactions might be possibl Because of its price and radioactivity, experimental chemical Reaserch is hardly performed of radon and as a reasult there are
very few reported compounds of radon, all either fluorides or oxides. Radon can be oxidized by a few powerful oxidizing agents such as (F), thus forming radon fluoride:

Rn (g) + 2 [$0_2$ ] + 2[SbF«] → [RnF]+[SbzF11]+ 2 O2 (g)
when the radon atoms are found within crystal lattices of certain hydrogenate compounds, RnF are formed. Radon is readily absorbed on charcoal, silica gel and similar substances. This property serves to separate it from other gases by collecting it on activated charcoal cooled to the temperature of solid $CO_2$ (78.2°C). Radon is released from charcoal by heating to 350°C. Another property of radon is its solubility in various liquids such as water or natural gas which may transport it over large distance Through the soil. (khalil amogrus,phd thesis,2002)

**Table(1-1): physical and chemical porperties of radon**
(khalil amogrus.phd thesis,2002)

| | |
|---|---|
| Density at 1 atm pressure and 0 **°C** | 9.73 g/L |
| Boiling point at 1 atm pressure | -62 **°C** |
| Crystal structure | Face-centered cubic |
| Specific heat capacity | (25**°C**)20.786 J/mol /K |
| Electrons per shell | 2,8,18,32,18,8 |
| Electron configuration | 4f^14 5d^10 6s^2 6p^6 |
| Standard atomic wight | (222)g/mol |
| Solubility in water at 1 atm pressure and 20**°C** | 230cm^3 /kg |

## 1-3 Radon Isotopes and Daughters

The three radon isotopes are produced from radium decay as steps in lengthy sequences of decays that originate from natural radioactive series: Rn (radon) from 238U, 220Rn (thoron) from 232Th and Rn (actinon) from U The relative importance of the isotopes increases with their half-life and relative abundance. Actinon is the shortest lived (T = 3.96 s) and is always practically produced in much smaller amounts than radon (t1/2 =3.82 days), since the natural 23U/23U ratio is (0.00719)(R.banjanac1, A.drgic1,B.grabez,2006).Radon (Rn) is the decay product of 22Ra and radon in turn decays by alpha emission to 218Po, which further decays to 21Pb, and the process continues down a long decay chain. The elements of radon are called progeny of radon known as radon daughters.(wilcot gohn speelman,2004) 222Rn decay Products are divided into two groups namely the short lived

(21spo, $21^{a}$pb, $^{21}$Bi, and 2Po) and the long-lived ($^{2o}$Po, 21°Pb, and 210Bi) daughters. Since the longest-lived element of the first group has a half-life of less than 27 min the whole sequence of decays can be completed before the human clearance processes can sweep them away. The long-lived Rn progeny contributes relatively little to lung exposure because the first nuclide, 20Pb, of this group has a large half-life (22.3 y) so that is utterly removed from the body before decaying. The case of 220Rn is somewhat different, firstly there is no long lived group of its daughters and secondly the most important radionuclide in its chain is the lead isotope 22Pb, which has a relatively long half-life of 10.64 h. In this way, a considerable fraction of this radionuclide deposited in the bronchial epithelium can be absorbed into blood; so that it may be carried to other organs and may produce a large biological impact(tufaid,M.matiullah and aziz,1988)

## 1-4 The aim of this stude

This study aims to measure the radon activity concentration, effective radium content, and exhalation rates of radon in eleven types of granit were collected from seven different sample of granit in Iraqi Kurdistan Region, using electronic RAD7 radon monitor as an active method. In addition to determining the annual effective dose of radon exhalation from these granit samples

# Chapter two

## 2-1 Source of Radon and Health Effect


Radon is the second leading cause of lung cancer after cigarette smoking. If you smoke and live in a home with high radon levels, you increase your risk of developing lung cancer. Having your home tested is the only effective way to determine whether you and your family are at risk of high radon exposure. Radon is a radioactive gas that forms naturally when uranium, thorium, or radium, which are radioactive metals break down in rocks, soil and groundwater. People can be exposed to radon primarily from breathing radon in air that comes through cracks and gaps in buildings and homes. Because radon comes naturally from the earth, people are always exposed to it. The U.S. Environmental Protection Agency and the Surgeon General's office estimate radon is responsible for more than 20,000 lung cancer deaths each year in the U.S. When you breathe in radon, radioactive particles from radon gas can get trapped in your lungs.(halina pienkowska,2005)

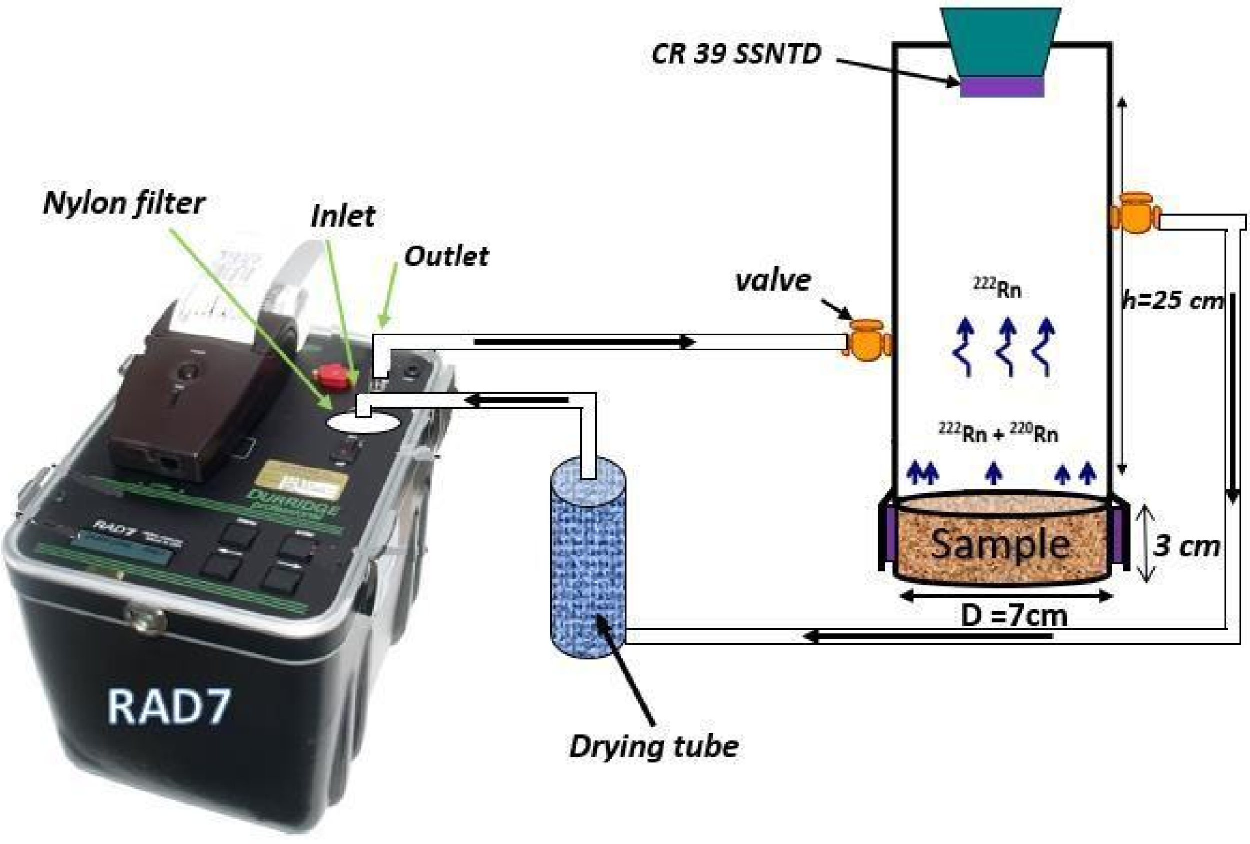
Over time, these radioactive particles increase the risk of lung cancer. It may take years before health problems appear. People who smoke and are exposed to radon are at a greater risk of developing lung cancer. EPA recommends taking action to reduce radon in homes that have a radon level at or above 4 picocuries per liter (pCi/L) of air (a “picocurie” is a common unit for measuring the amount of radioactivity).Radon and thoron Risk and Health effects Radon is a common problem encountered during uranium mining, and significant excesses in deaths from lung cancer have been identified in epidemiology studies of uranium miners and other hard rock miners employed in the 1940s and 1950s. Radon and its derivatives enter the human organism through the inhalation of air. The air includes dust measuring from around 0.01 μm to the first decimal place of mm. Short-lived radon decay products in the air are deposited on the dust. While breathing, the dust particles, along with radon decay products deposited on them, enter the lungs. The air with radon is exhaled but the dust particles with radon decay products remain in the lungs. Dust with a diameter over 1 um sets down in the nose and larynx. While dust with a diameter measuring from 0.1 to 1 μm is deposited in the bronchi. Thoron, like radon, can pose a health risk because can deliver radiation dose to lung and other tissues. However, the short halflife of thoron limits its transport from sources like soil and building materials to indoor living spaces. Thus, it was generally believed that thoron concentrations indoors would be low and have large spatial variation making thoron exposures difficult to assess. Compared with radon and its daughters, the risk of thoron and its daughters in atmosphere is usually ignored because of the shorter half-life and the relatively lower. concentrations in most circumstance(zhao guizhi,xiao deto tao and xiao yon gjun 2008)

The principal health effect attributed to inhalation of radon daughters is the lung cancer The connection between radon and lung cancer in miners has raised cancer that radon in homes might be causing lung cancer in the general population, although

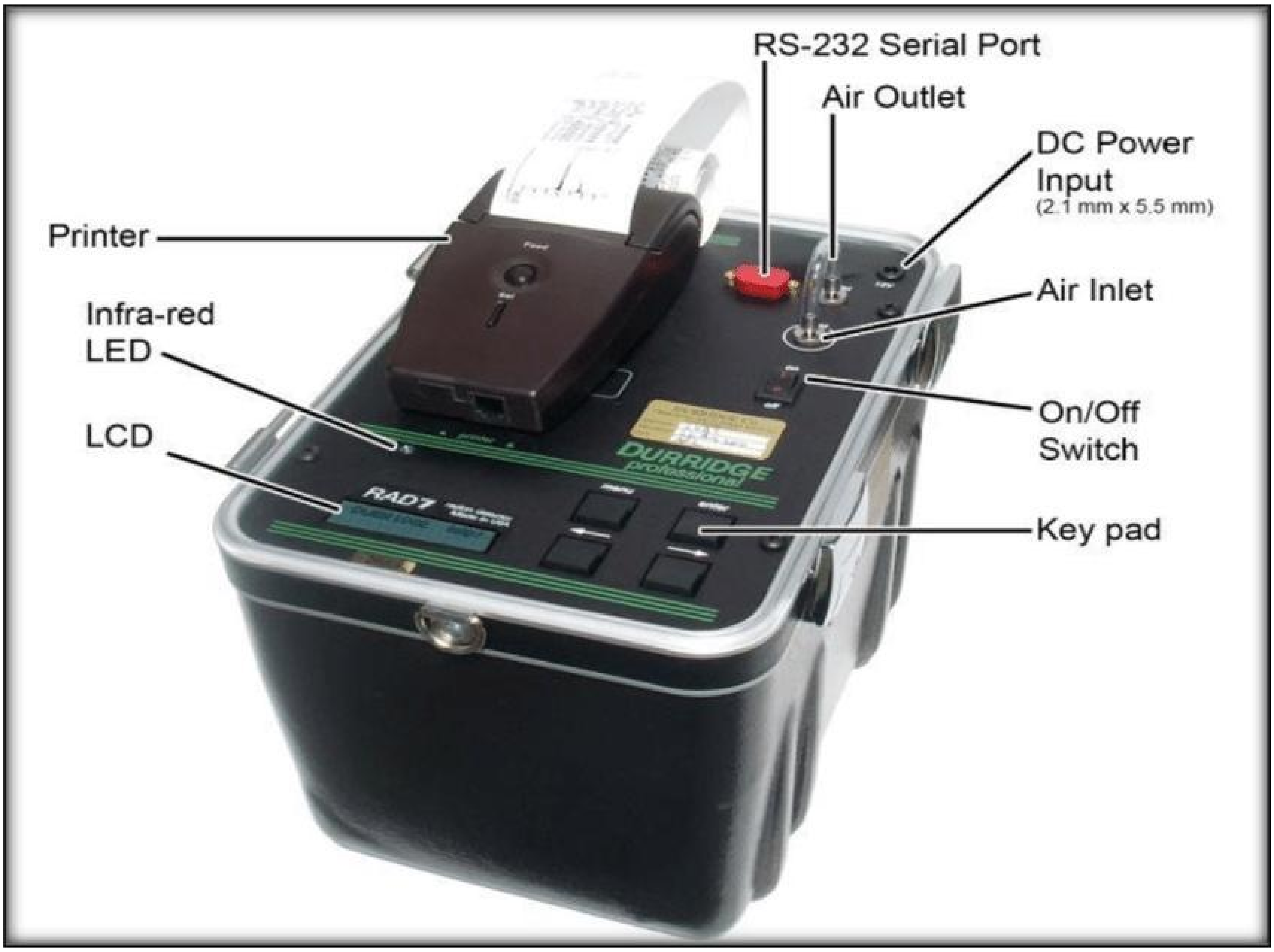
the radon levels in most Radon decays into other solid particulate radium-series radioactive nuclides. Two of these decay products, 218Po and 24Po, present a significant radio logic hazard. If the gas is inhaled, these radioactive particles are inhaled and may attach to the inner lining of the lung. The pattern of their deposition in the respiratory tract is dependent on whether they are attached to particles or not. These particles remain lodged in the lungs, and continue to decay, causing continued exposure by emitting alpha radiations. The radiation decay products can damage cells in the lung tissue, either create free radicals or cause DNA breaks, perhaps causing mutations that sometimes turn canceros (abdulahad,2004)

## 2-2 Experemental work

To determine the activity concentration of radon gas, seven types of granit (indian, indian galaxy, iran, brazilian, turkey, iran, china) were collected from area comprises of three factory in erbil The radon monitoring system consists of a long-tube technique equipped with CR-39 solid-state nuclear track detector SSNTD (as passive method) and connected to the RAD7 electronic radon monitor (as an active method) were used to determine the activity concentration of radon in granit samples. The CR-39 detector was manufactured by Track Analysis Systems Ltd., Bristol, UK (TASTRAK Co.). This detector consists of thin layers of thermal polymer 500 μm thick, which is sensitive to alpha particles. RAD7 electronic radon monitor was manufactured by DURRIDGE Company-USA. The RAD7 uses an alpha-particle solid-state semi-conductor detector in the internal hemisphere detection chamber for measurements. It can form an alpha-energy spectrum for alpha-particles emitted from the progeny of 220Rn and 222Rn in the range of (0-10 MeV) with a resolution of 0.05 MeV (Durridge Company 2015). The long-tube technique involves the CR-39 plastic track detector, which placed at 25 cm from the surface of powder samples and attached to the closed end of the rubber stopper surface to discriminate and measure radon and thoron with a high degree of resolution and accuracy (Durrani and Ilic 1997; Mansour 2000), After powdering, the rock sample was placed in the lower container of the long-tube chamber (of 3.5cm in radius, the high of the container 3cm). The detection system was set up and completely sealed to avoid any leaks, This design was left about a month at room temperature. The secular equilibrium between radium, radon and radon decay products inside the tube chamber was reached during this time. Simultaneously, the CR-39 SSNTDs were exposed to alpha-particles emitted from the decay of radon and its decay products in the air volume of the long-tube, which exhaled from the granit samples for one month.Tracks in CR-39 detectors were counted using a digital optical microscope (Motic), which is supported by the Motic imaging program. A live image from the microscope camera is displayed automatically by the Motic program. On a computer screen connected to the microscope, an image of the tracks was observed directly. A total of 25 fields of the detector was counted. The number of alpha-particle tracks per field is averaged over the number of fields counted after the background is subtracted. The average standard deviation was obtained for all the granit samples.



## 2-3 RAD7




The RAD7 possesses a periodic-fill cell. The cell is filled with air by means of a small pump that draws air into the cell once during each pre- selected time interval. In this defined cell, the radon or the Po may decay, and the decay products are counted and the cycle repeated.(willcot john speelman,2004)

## 2-4 The RAD7 has the following specifications

(D.nikezic and K.N.Yu,2000)

1. **Multi-Modes**: continuous radon gas monitor long-term/shortterm screener Sniffer, with small tube "snout", to search for radon and thoron entry points
2. **Multi-Measurements:** Measures radon in air, soil, and water (with RAD $H_2$ O ccessory).
3. **Sensitivity: Monitor:**0.4counts/min/pCi/L, Sniffer:0.2 counts/min/pCi/L
4. **Range:** 0.1 to 20,000 pCi/L.
5. **Memory:** 1,000 previous radon concentrations, and associated data. Can be read out on LCD, printed out or downloaded to PC. Also shows high, low, average and standard deviation of readings. 6. **Principle of Operation:** Electrostatic collection of alphaemitters with spectral analysis.
7. **Built-in Air Pump:** Nominal 1L/min flow rate. Inlet air filter. Inlet and outlet air connectors.
8. **Spectrum Readout:** Pulse height spectrum of alpha distribution verifies radon/thoron, and also shows the RAD7 is operating properly. Accurate determination of the alpha particle energies produces a radon signature that allows discrimination of radon and thoron's alpha particles from those of other isotopes. 9. **Fast Low-Levle Readings:** In continuous monitor mode, RAD7 measures the EPA action level of 4 pCi/L in just 1 hour, with standard deviation of 10%. Since the RAD7 has virtually no background, it is much more sensitive than other electronic detectors, easily measuring down to 0.1 pCi/L.

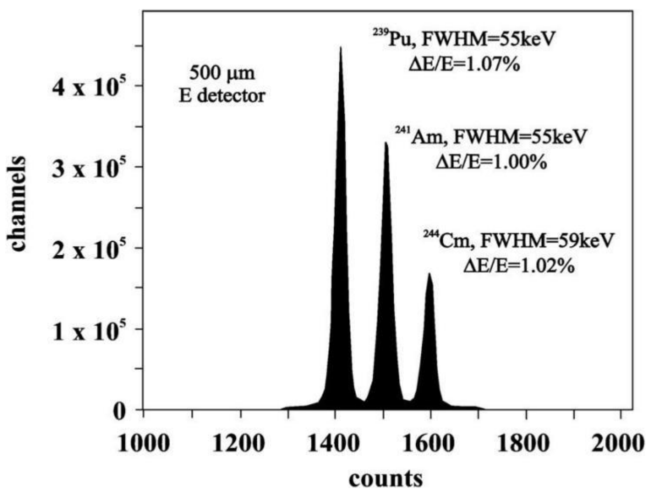
**Recovery in Minutes:** Recovers from high radon exposure with a 3.05minute half-life: to less than 10% of peak value in 12 minutes; to less than 1% of peak value in 30 minutes. Drops from 20,000 to 1 pCi/L in less than an hour

## 2-5 RAD7 Solid state detector

The RAD7 employs a solid state a-particles detection chamber for measurements and can produced a-energy spectra in the range of (0-10 MeV)with resolution of 0.05 MeV which differentiates aparticles emitted from the progeny of 222Rn . The semiconductor detector converts the alpha radiation from the decay of the radionuclide (e.g. 218Po)The RAD7's internal sample cell is a 0.7 liter hemisphere, coated on the inside with an electrical conductor, . A solid- state, Ion implanted, Planar, Silicon alpha detector is at the center of the hemisphere . The high voltage power circuit charges the inside conductor to a potential of 2000 to 2500 volts, relative to the detector, creating an electric field throughout the volume of the cell. The electric field propels positively charged particles onto the detector. A 222 Rn nucleus that decays within the cell leaves its transformed nucleus, 218Po, as a positively charged ion. The electric field within the cell drives this positively charged ion to the detector, to which it sticks. When the short- lived polonium-218 nucleus decays upon the detector's active surface, its alpha particle has a 50% probability of entering the detector and producing an electrical signal proportional in strength to the energy of the alpha particle. Subsequent decays of the same nucleus produce beta particles, which are not detected, or alpha particles of different energy. Different isotopes have different alpha energies, and produce different strength signals in the detector. Chapter Two The RAD7 amplifies, filters, and sorts the signals according to their strength. In Sniff mode, the RAD7 uses only the polonium-218 signal to determine radon concentration, and the 216Po signal to determine thoron concentration, ignoring the subsequent and longer-lived radon daughters. In this way, the RAD7 achieves fast response to changes in radon(willcot john speelman,2004)

## 2-6 RAD7 Spectrum Analysis

The electrical signal produced in the detector due to alpha radiation, is amplified and conditioned by the electronic circuitry of the detector, but also converted to digital form. The RAD7 possesses a microprocessor that receives the signal and stores it in the detector's memory. The signal that is stored is associated with the decay of a specific radionuclide and in the process of accumulating many of these signals, a spectrum can be formed. The spectrum of the RAD7 can allow for energies from 0-10 MeV. Specific interest is shown in the 6-9 MeV region, since most of the radon ad thoron decay products produce alpha particles in that range. The spectrum is divided into 200 channels that correspond to 50 keV (0.05MeV) per channel. Ideally, in the above spectrum, the 6.00 MeV alpha peak would only be a needle spike as represented but this is not the case with the RAD7, because of the electronic noise in the detector as well as in the amplifier. Another cause for the broadened peaks is the fact that some of the alpha particles enter the detector at a small angle. An increase in the temperature also causes electronic noise, and in turn affects the tail of the peaks. The analysis of the spectrum is simplified because the electronics of the RAD7 is manufactured to group the 200 channels into 8 windows. Those windows are listed as A - H in alphabetical order(willcot john speelman,2004).




An ideal high_resolution

alpha energy soectrume

## 2-7 Using the RAD7 (S.procopio,2004)

The different wase of using the RAD7.



**A:** continuous monitoring
Of radon in air.

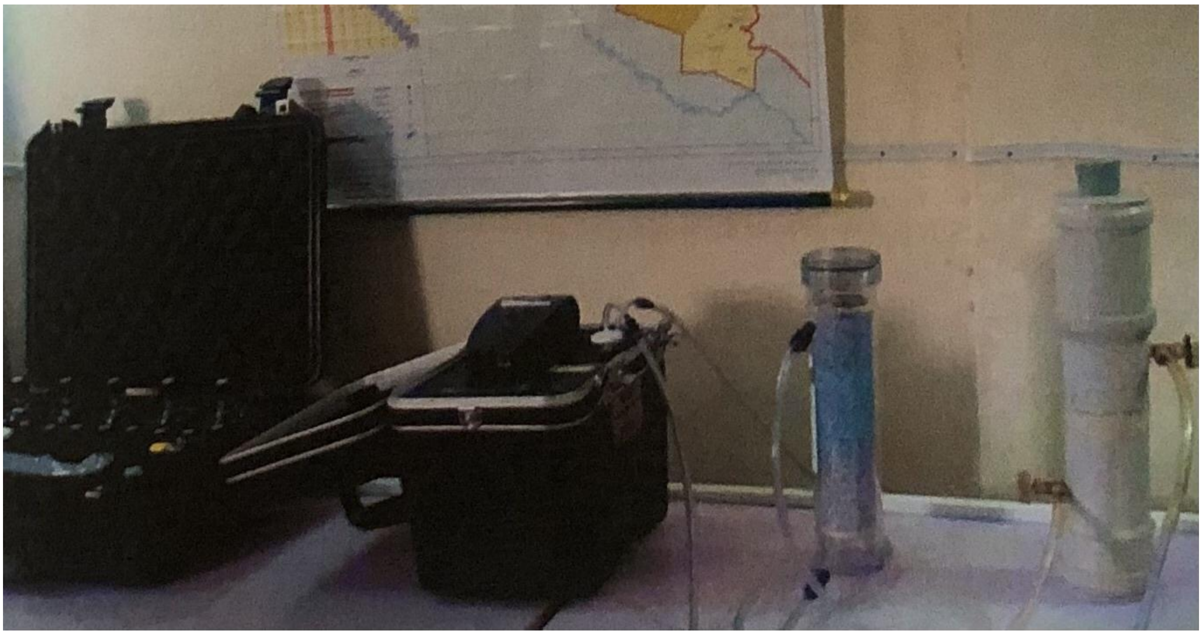
**B:** Sniffing for radon


**C:** testing air grap samples

# Chapter three

## 3-1 Determination of the calibration factor for radon activity

measurement RAD7 solid state detector which is an active instrument was used in this study to measure the activity concentration of radon. The experiment setup was shown in Fig.(3-4) which consist of long-tube technique of -Iliter size and made of poly vinyl chloride (PVC) as radon accumulation chamber. The tube is connected via vinyl tubing to a gas-drying unit filled with desiccant ($CaSO_4$) and to the radon monitor. A 226Ra was used as radon source and placed in the bottom of the tube chamber and closed from the tope by an rubber stopper and then the tube chamber was isola through valves fixed at opposite sides of the tube, as in Fig.(3-5). design has been left at room temperature about two months. During time interval the equilibrium between radium and radon and radon products have been reached inside the tube the tube chamber. A clos configuration is connected and the valves are opened. The inst draws air from the tube chamber, through the desiccant and an inl total of 24 different types of building materials that are widely used in Iraqi Kurdistan region (brick, limestone, tile, sand, gypsum, cement, metamorphic and serpentine) were sampled from different factories in (Erbil, Duhok and Suilaimaniya governorates) in Kurdistan region. The samples were cleaned from strange things, and powdered by using a special machine to obtain a homogenous grain size and then dried in an oven at 110 °C for 48 hours to evaporate all the moisture content and to maintain the actual weight (shafi ur rehman,2005) After drying, the powder of each sample



the measurement tube chamber in RAD7. The air was then returned to the enclosure from the RAD7 outlet. The filtered air decays inside the chamber, producing detectable alpha-particle emitter progeny, particularly the polonium isotopes. A high voltage of 2500V is applied to the chamber walls. The solid state detector converts the alpha radiation directly to an electrical signal using an alpha technique which is able to discriminate the electrical pulse generated by alpha-particles from 218Po and 214Po with energies 6.0 and 7.0 MeV respectively. The experiment were performed under dry condition (relative humidity under 4-9%) and room temperature from (27-29 °C). The specific activity of 222Rn is obtained from a calibration factor determined from radon chambers run by the US EPA and the DURRIDGE Co. were equal to 0.479 CPM/(pCi/l) for normal mode and 0.232 CPM/(pCi/l) for sniff mode with uncertainty (2%). In this study, up to 48 data points were collected in 48 hr (which setup RAD7 on 2 cycle mode) and stored in memory using a protocol of starting a two-days test as in appendix A. The stored value represents the average radon gas concentration measured during each interval. A convenient data output port on the unit allows attachment of the printer when a printout of the memory is desired, and the average radon concentration obtained measured by RAD7 radon monitor which equal to (361.77 ± 3.79 kBq.m). The output data and the spectrum are shown in Fig.(3-22). In

| Cod | Name | Longetude | Latetude | Mass (gm) | Density of rock (kg/m3) |
|---|---|---|---|---|---|
| 1 | indea | 36°16'50.8"N 44°29'20.3"E | 36.280787, 44.488974 | 136.4 | 1181.975737 |
| 2 | chaina | 36°17'16.1"N 44°29'28.3"E | 36.287809, 44.491206 | 153.37 | 1329.029463 |
| 3 | brazil | 36°14'11.7"N 44°36'57.0"E | 36.236586, 44.615821 | 128.8 | 1116.117851 |
| 4 | iran | 36°13'48.2"N 44°36'31.9"E | 36.230044, 44.608869 | 155.55 | 1347.920277 |
| 5 | turky | 35°57'29.1"N 44°59'49.0"E | 35.958092, 44.996954 | 130.71 | 1132.668977 |

| Activity concentration of Radon (Using RAD7) | | | | |
|---|---|---|---|---|
| 26.56666667 | 2.165833173 | 26.57 | 2.17 | 26.57 ± 2.17 |
| 23.5 | 5.312014684 | 23.5 | 5.31 | 23.5 ± 5.31 |
| 24.66666667 | 5.744635178 | 24.67 | 5.74 | 24.67 ± 5.74 |
| 31.3 | 4.030508653 | 31.3 | 4.03 | 31.3 ± 4.03 |
| 21.83333333 | 6.720181049 | 21.83 | 6.72 | 21.83 ± 6.72 |
| | | 25.57 | 3.637145859 | 25.574 ± 3.63714585904936 |

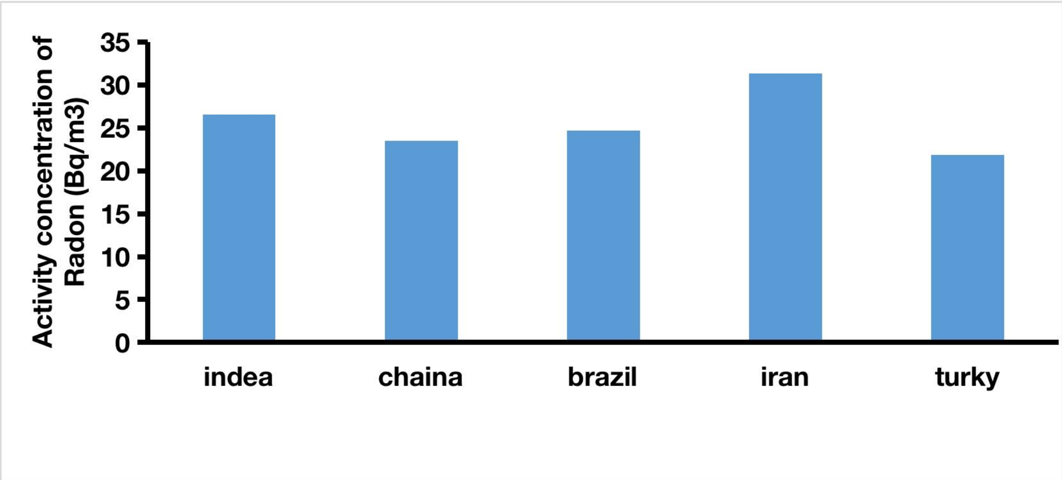
| Effective Ra-226 (Bq/Kg) | | | | |
|---|---|---|---|---|
| 0.229550691 | 0.018713996 | 0.23 | 0.02 | 0.23 ± 0.02 |
| 0.180585698 | 0.040820165 | 0.18 | 0.04 | 0.18 ± 0.04 |
| 0.225709849 | 0.052565706 | 0.23 | 0.05 | 0.23 ± 0.05 |
| 0.237153878 | 0.030538363 | 0.24 | 0.03 | 0.24 ± 0.03 |
| 0.196864378 | 0.060593783 | 0.2 | 0.06 | 0.2 ± 0.06 |
| #VALUE! | | 0.216 | 0.025099801 | 0.216 ± 0.0250998007960223 |

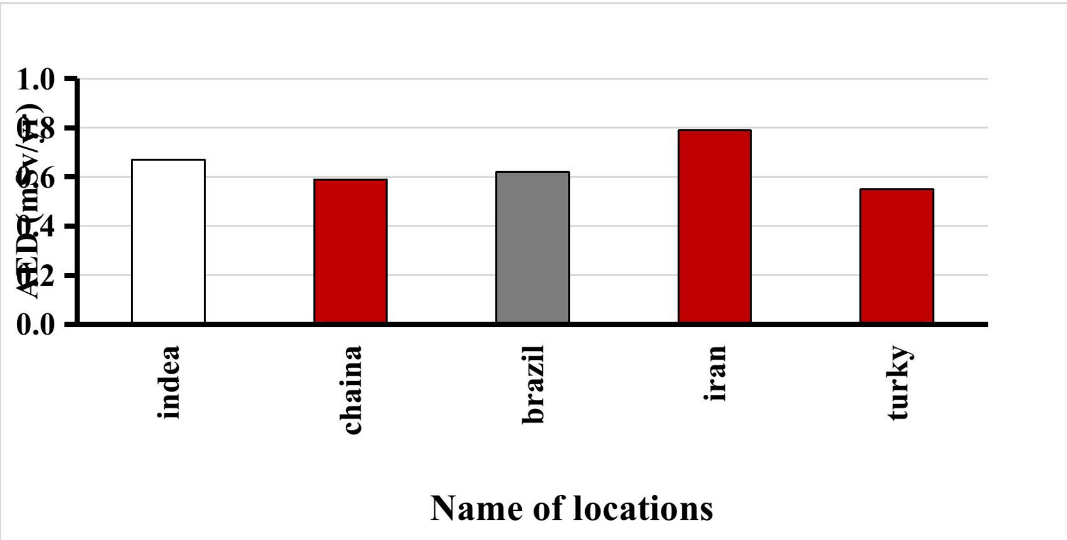
| Radon Surface Exhalation rates EA (Bq.m-2.d-1) | | | | |
|---|---|---|---|---|
| 1.469716162 | 0.119817818 | 1.47 | 0.12 | 1.47 ± 0.12 |
| 1.300062603 | 0.293870282 | 1.3 | 0.29 | 1.3 ± 0.29 |
| 1.364604718 | 0.317803632 | 1.36 | 0.32 | 1.36 ± 0.32 |
| 1.731572743 | 0.222975046 | 1.73 | 0.22 | 1.73 ± 0.22 |
| 1.207859581 | 0.371772599 | 1.21 | 0.37 | 1.21 ± 0.37 |
| | | 1.414 | 0.200324736 | 1.414 ± 0.200324736365734 |

| Radon Mass Exhalation rates EM (Bq.kg-1.d-1) | | | | |
|---|---|---|---|---|
| 0.041 | 0.000 | 0.041 | 0.000 | 0.041 ± 0 |
| 0.033 | 0.001 | 0.033 | 0.001 | 0.033 ± 0.001 |
| 0.041 | 0.001 | 0.041 | 0.001 | 0.041 ± 0.001 |
| 0.043 | 0.001 | 0.043 | 0.001 | 0.043 ± 0.001 |
| 0.036 | 0.001 | 0.036 | 0.001 | 0.036 ± 0.001 |
| | | 0.039 | 0.004 | 0.0388 ± 0.00414728827066554 |

| Annual Effective Dose from the Inhalation of Radon AEDL (222Rn)(mSv/y) | | | | |
|---|---|---|---|---|
| 0.67 | 0.05 | 0.67 | 0.05 | 0.67 ± 0.05 |
| 0.59 | 0.13 | 0.59 | 0.13 | 0.59 ± 0.13 |
| 0.62 | 0.14 | 0.62 | 0.14 | 0.62 ± 0.14 |
| 0.79 | 0.10 | 0.79 | 0.10 | 0.79 ± 0.1 |
| 0.55 | 0.17 | 0.55 | 0.17 | 0.55 ± 0.17 |
| | | 0.64 | 0.09 | 0.644 ± 0.0926282894152761 |

| | PAEE(mWL) | WLM/Yr. | He(mSv/Yr) |
|---|---|---|---|
| | 0.005405405 | 6.18124E-05 | 0.000309062 |
| | 0.014054054 | 0.000160712 | 0.000803561 |
| | 0.015135135 | 0.000173075 | 0.000865374 |
| | 0.010810811 | 0.000123625 | 0.000618124 |
| | 0.018378378 | 0.000210162 | 0.001050811 |



# Chapter four

## 4-1 results and discussion

he radon monitoring system which consists of the long-tube technique was used to determine the activity concentration of radon gas, effective radium content, surface and mass exhalation rate of radon gas in granit samples were collected from area comprise of factory in Erbil and  Governorate in Iraqi Kurdistan Region. The obtained results of these parameters were arranged in Tables  The activity concentration of Rn gas in the granit samples was measured  The results reveal that the highest value of Rn activity concentration was found in iran(31.3±4.03) In Contrast, the lowest value of Rn activity concentration was found in granit in turky (21.83±6.72) The variation in values of 222Rn activity concentration in rock samples is due to the differences in the content of Ra in rock samples and the geological and geographical conditions in the studied area.
The results obtained for the analyzed mineral-induced granit are presented in Table  which shows the average radon concentrations of each granit, their corresponding average exhalation rates, and other radiological indices. For the average radon concentration, the value obtained the highest exhalation rate while pegmatite has the least. Granite is a coarse intrusive igneous rock that is rich in quartz and feldspat it is the most common plutonic rock of the Earth's crust, forming by the cooling of magma at a particular depth. The high radon concentration recorded in the granite rock can be attributed to the relatively high uranium content in its natural formation,"
The results showed that the radon concentration is directly proportional with the radon exposure, when the equilibrium factor and exposure time are constant. This suggests t that any

individual who decided to use only one of all these granit in the interior decoration of a building will only be exposed based on the radon concentration of the selected granit. This relationship between the indoor radon exposure and the concentrations emanating from the granit samples may not be totally correlated, but it does describe an existing pattern for the mineral-induced granit. However, it will be advisable that any individual who wishes to beautify and decorate the interior of its building should go for the rock type with the least radon concentration to avoid and mitigate exposure to 222Rn

## 4-2 conclusions

The close can technique (modified) connected to the RAD7 detector have been employed to assess radon exhalation rate in different granit samples to assess the contribution of mineral induced granit to indoor radon exposure and its implication on human health. The results obtained from the study showed that the radon exhalation rates from iran granite have relatively high values when compared to other granit samples and fall within the action level limit. Thus, it can be concluded that iran granite samples are not safe for use as building materials; however, adequate cross ventilation must be ensured to diffuse the radon gas appropriately if other granit types are to be used for building decoration. The procedure employed in this study can be used as reference information in assessing the radon exhalation rate. The results obtained can be used as baseline data for future investigation of radon exhalation rates in granit in any locality.

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