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The Relationship between Radon Concentrations in the Soil and Air of Houses in Alal Region, Jordan

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Abstract: *In this research the author studied the relationship between radon concentrations in the soil and air of houses at every sector in the study area. Radon gas concentrations inside Alal houses, inside soil at a depth (50 cm) were measured. Also the author studied the risk of lung cancer due to radon gas in the study region (Alal region). The study started from 1 June 2015 to 1 September 2015. Study area was divided into four sectors (A_{East}, A_{West}, A_{North} and A_{South}). About 264 dosimeters containing highly pure CR-39 were distributed randomly among the houses of the different sectors. Two dosimeters were distributed in each house (first dosimeter in the first floor and the second dosimeter in the second floor). Also about 120 dosimeters were planted in the soil of Alal sectors at a depth 50 cm. The indoor dosimeters were collected after three months, while the soil dosimeters were collected after three weeks (from 1 June to 21 June). The collected detectors were chemically etched using 30 % KOH for 8 hours at 70 C°. An optical microscope was used to measure the nuclear alpha track density on the detectors surfaces.The author found that the average radon concentration in the study area was ranged from 35 $Bq.m^{-3}$ in the sector A_{East} to 53.4 $Bq.m^{-3}$ in the sector A_{North}. Moreover; the average radon concentration in the first floor in the study area was 56.8 $Bq.m^{-3}$ which is higher that the average radon concentration in the second floor 30 $Bq.m^{-3}$. Also the author found that the average radon concentration in soil of Alal region was 1214.5 $Bq.m^{-3}$. The author found that each 1000 $Bq.m^{-3}$ from radon gas in the soil contribute about 34 $Bq.m^{-3}$ in the sectors A_{East}, A_{West}, and A_{North}, respectively, and 40 $Bq.m^{-3}$ in A_{South}.*
The increasing in the concentration of radon increases the risk of lung cancer. The author found that the radon concentration in the study region, which equals (43.2 $Bq.m^{-3}$) leads to increased risk of lung cancer at a rate of (0.42 %).
Keywords: *radon, house radon, soil radon, lung cancer, Alal, Jordan*

I. Introduction

Radon is a radioactive noble gas such as helium; it is invisible, tasteless, odorless, and heavier than air seven and a half time [1]. Radon exists in nature as a gas, its concentration a little spread in most places on the Earth's surface, and the levels of radon concentrations in the outside air are clearly different from one location to another. Radon - 222 is one of the isotopes of radon, it is a radioactive nuclides formed within the uranium -238 series any one of its members, which is spread on the Earth's surface or in its atmosphere. Radon 220 is a second isotope of radon; it's a member of the decay of thorium-232 series (See Fig.1). These isotopes are emitting alpha particles.

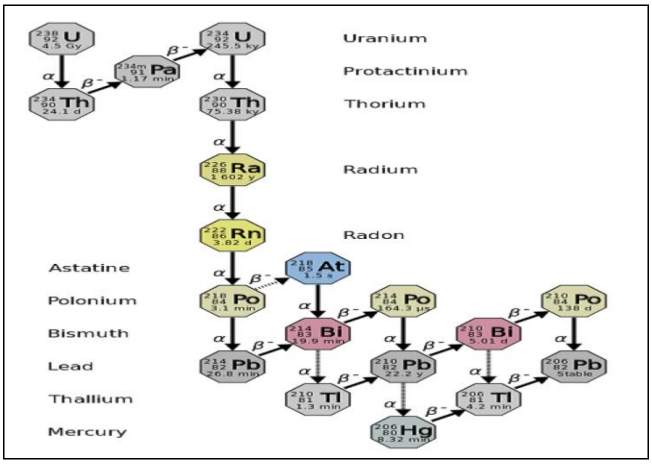

Fig. 1: shows the uranium - 238 series [2]

The United Nations scientific committee on the effects of atomic radiation estimated that radon contributes (with radioactive nuclides nascent resulting from the decay) about three-quarters of annual effective dose received by humans from natural sources, and about more than half of the total dose from all natural and industrial sources together. A large percentage of these doses are due to inhalation of these radionuclides with air in houses and buildings, in particular [3].

Radon 222 is one of the important elements in the areas of nuclear research for measuring the natural radiation of different material and the various elements of the environment. In addition to being a longer lifetime than other isotopes, enabling it to displacements long distances, and spread over large areas of the Earth's surface. The radon - 220 (Thoron) contributes to a very large part in the decay process, and his series dominant in radioactivity.

Measurement of concentration of radon - 222 in the air and building materials are very important for the prevention and human safety, and measuring its presence in the soil is extensive technical use to denote the presence of uranium 238. The simplest way to measure the concentration of radon gas is the use of solid state nuclear track detectors, and for a long time measuring to record the damage tracks caused by alpha particles emitted from the decay of radon.

Radon is emitted from the ground and enters a home through cracks in walls, basement floors, foundations and other openings. Because radon comes from rock and soil, it can be found anywhere. Exposure to limited concentrations, like those found outdoors, is impossible to avoid. However, when radon gets trapped indoors, it may build up to dangerous concentrations.

The most important source of radon gas indoors is the soil and rock surrounding the building. By sealing your home to keep radon from getting through cracks and openings, you can significantly reduce your home's radon levels. You may need to install a separate radon ventilation system in your home to remove high levels.

Radon gas and radon progeny in the air can be breathed into the lungs where they breakdown further and emit "alpha particles". Alpha particles release small bursts of energy which are absorbed by nearby lung tissue. This results in lung cell death or damage. When lung cells are damaged, they have the potential to result in cancer when they reproduce.

The only known health risk associated with exposure to high levels of radon in indoor air is an increased lifetime risk of developing lung cancer. The risk from radon exposure is long term and depends on the level of radon, how long a person is exposed and their smoking habits. If you are a smoker and are exposed to elevated levels of radon your risk of developing lung cancer increases significantly.

In Jordan, several studies conducted to measure the concentrations of radon gas in dwellings, soil and in water [4][5][6]. In the present study the author measured radon concentration in the soil and houses of study area (Alal region). The study region divided from the center in to four sectors (A_{East}, A_{West}, A_{North} and A_{South}).

II. Measuring Procetures

This study aims to evaluate the levels of radon in Alal region (houses and soil) which lies 90 km north of Jordan. Measurements carried out using (CR-39). CR-39 detector easy to use and accuracy in determining the concentration of elements emitting alpha particles, even in the case of very low concentrations [7]. Also features sensitivity and high efficiency in the registration of the effects of nuclear fission fragments and alpha particles [7] [8]. Therefore, most studies using this technique have focused on measurement of radon in soil, water, rocks and building materials.

To study the concentration of radon in the soil, we made a hole in the garden of each house at 50 cm in depth (See Table.1), and one dosimeter was planted in each hole. Dosimeters planted were left about three weeks and then collected for chemical treatment. Chemical treatment here was the same method of treatment that was used to measure the concentration of radon in the houses.

The present study started from 1 June 2015 to 1 September 2015. Study area was divided into four sectors (A_{East}, A_{West}, A_{North} and A_{South}). About 264 dosimeters containing highly pure CR-39 were distributed randomly among the houses of the different sectors. Two dosimeters were distributed in each house (first dosimeter in the first floor and the second dosimeter in the second floor) (See Table. 2). The indoor dosimeters were collected after three months. The collected dosimeters were chemically etched under the conditions (30% solution of KOH at a temperature of 70 C° for 8 h). An optical microscope was used to count track densities on the detectors surfaces.

Table.1: shows number of distributed, collected and lost dosimeters in the soil of study area.

Sector	Dosimeters distributed	Dosimeters collected	Dosimeters lost	Lost percentage
A_{East}	30	29	1	3.3%
A_{West}	30	28	2	6.7%
A_{North}	30	29	1	3.3%
A_{South}	30	27	3	10%

Table.2: shows number of distributed, collected and lost dosimeters in the houses of study area.

Sector	Number of house	Dosimeters distributed	Dosimeters collected	Dosimeters lost	Lost percentage
A_{East}	30	60	52	8	13.3%
A_{West}	30	60	50	10	16.7%
A_{North}	30	60	53	7	11.7%
A_{South}	30	60	55	5	8.3%

III. Result and Discussions

The author in this study found that the average concentration of radon in the houses of study area. In the first floor, the low average concentration was in A_{West}, while the high average concentration was A_{North}. The high concentration inside the first floor is due to near the first floor of the Earth (source of radon). Also because the lack of ventilation in the houses of the first floor for fear of inconvenience or dust as a result of its proximity to the street (See Table 3).

Table.3: shows minimum, maximum and average radon concentration in homes sectors of study area.

Sectors	First floor			Second floor		
	Minimum	Maximum	Average	Minimum	Maximum	Average
A_{East}	17.4	106.1	45.6	10.8	54.6	23.9
A_{West}	27.9	82.8	43.5	12.1	56.2	27.3
A_{North}	16.7	305.8	70.9	9.6	127.1	36
A_{South}	18.2	288.9	67.1	8.3	100.8	31

Table.3 shows that average radon concentrations in the second floor are lower than from average radon concentrations in the first floor. The reason for this is because of the ventilation rate in the second floor is greater than the first floor, and far from the ground. This means that the radon concentration be less, when the house away from Land (See Fig.2).

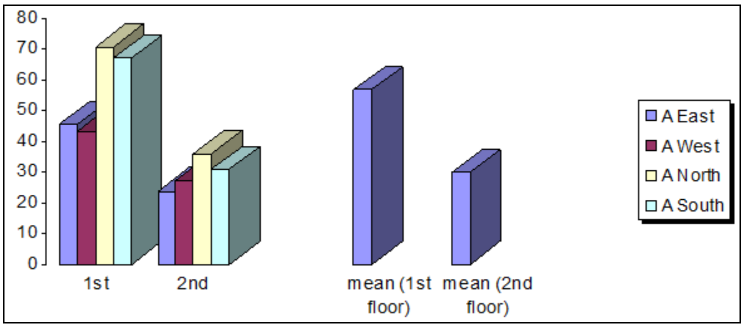

Fig.2: shows average of radon concentrations in the first and second floor of study area.

From Fig.2, we note that the average radon concentration in the second floor is less than average radon concentration in the first floor. The reason is that the age of the houses in the second floor is mostly less than the age of the houses in the first floor. In addition to the actions and behavior of the residents of the house through the ventilation of houses and care houses and continually repainted. Also Fig.2 shows the variation in the concentration of radon in the houses of the first and second floor, knowing that change in the concentration of radon in a house depends on factors such as the quality of the rocks and soil, the quality of building materials were used, the circumstances and the weather and engineering design for the home.

To calculate the ratio between the average radon concentration in the air of houses and the average concentration of radon in the soil of the study area, the author distributed 120 dosimeters in soil of study region (one dosimeter planted in soil of each house). Table.4 shows the concentrations in the soil of each sector in the study region.

Table.4: shows minimum, maximum and average radon concentration in soil sectors of study area.

Sectors	Minimum	Maximum	Average
A_{East}	60.6	5720.4	1058.4
A_{West}	101.3	2419.1	1038.1
A_{North}	190.8	4041.7	1549.8
A_{South}	179.5	3927.9	1211.6

The radon concentration in the soil at a depth of 50 cm a few thousand becquerels per cubic meter. Radon concentrations in the soil of the study area ranged from (1038.1 $Bq.m^{-3}$) in A_{West} to (1549.8 $Bq.m^{-3}$) in A_{North}. From Fig.3, we note the convergence of the concentrations of radon gas in the soil of the study sectors, the reason for this is due to the similarity nature of the soil in different sectors of study region.

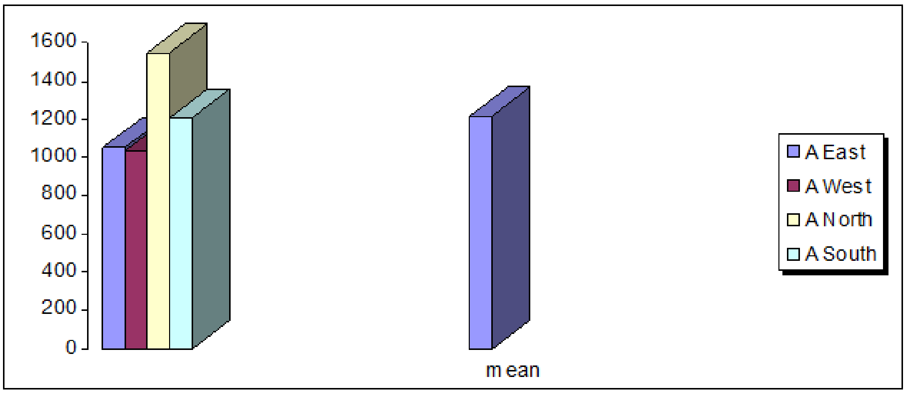

Fig.3: shows the average radon concentrations in the soil sectors of study area.

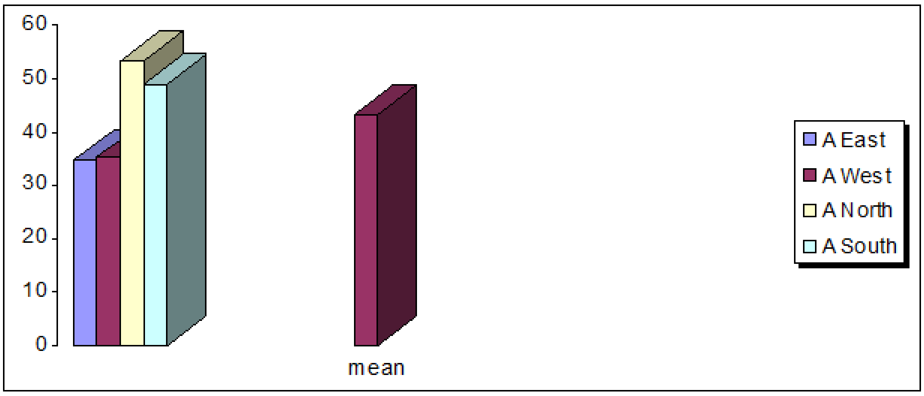

Fig.4: shows the average radon concentratin in sectors of study area.

The soil is the main source of radon, while radon gas seeping from the soil into the house through cracks, windows, vents and lanes in house, so the high average radon concentrations were in A_{North} and A_{South}. The low concentrations were in A_{East} and A_{West}, The reason for this is due to higher sectors, compared with other sectors and with field is open and excellent ventilation. The average radon concentration in the study area was 43.3 Bq.m^{-3}, which is less than the allowable concentration in the British (200 Bq.m^{-3}).

After measuring the average radon concentration in the house and soil, the author calculated the ratio between the average concentrations of radon gas in the air of houses and the average concentrations of radon gas in the soil of each sector of the study region (See Table. 5).

Table.5: shows the rates of radon gas concentration levels in the air of the house and the soil in each sector of study region.

Sectors	C_H (Bq.m^{-3})	C_S (Bq.m^{-3})	C_H/ C_S
A_{East}	35	1058.4	0.033
A_{West}	35.4	1038.1	0.034
A_{North}	53.4	1549.8	0.034
A_{South}	49	1211.6	0.040

Where,
C_H: average radon concentration in the air of house (Bq.m^{-3})
C_S: average radon concentration in the soil (Bq.m^{-3}).

From Table.5, we note each 1000 Bq.m^{-3} from radon gas in the soil contribute about 34 Bq.m^{-3} in the sectors A_{East}, A_{West}, and A_{North}, respectively, and 40 Bq.m^{-3} in A_{South}. This result is twice as calculated by researchers in other regions. The increasing in the concentration of radon increases the risk of lung cancer. If we take the coefficient of lung cancer resulting from natural radiation coefficient positioned by Cross and his colleagues [9], which is equal to (36×10^{-4}) for each (1 pCi/L), we find that the radon concentration in the study region, which equals (43.3 Bq/m^3 = 0.85 pCi/L) leads to increased risk of lung cancer at a rate of (0.42 %). This means 42 for every ten thousand people throughout the period of the middle life (See Table.6). The probability of developing lung cancer affected by several other factors, such as smoking or lack thereof, the geographical location and the body's immunity.

Table.6: shows risk of lung cancer in sectors of study area due to radon gas.

Sectors	C_H (Bq.m^{-3})	Risk of lung cancer
A_{East}	35	34 %
A_{West}	35.4	34 %
A_{North}	53.4	52 %
A_{South}	49	48 %

IV. Conclusions

The average radon concentrations in A_{East}, A_{West}, A_{North} and A_{South} areas were 35, 35.4, 53.4 and 49.4 Bq/m^3, respectively. The average radon concentration in the study area (north of Jordan) was 43.3 B/m^3; this result was higher than that found some researchers in other areas in Jordan. However, there were clear appreciable differences between radon concentrations in all sectors in the study area, where A_{North} and A_{South} have high concentrations.

The average radon concentration in the study area was below the recommended action level of ICRP [10], but higher than Jordanian national level [11]. Radon contributes in increasing the risk of lung cancer. The radon concentration in the study region, which equals (43.3 Bq/m^3 = 0.85 pCi/L) leads to increased risk of lung cancer at a rate of 0.42 % [9].

From the study of radon concentration in the soil, we note each 1000 Bq.m^{-3} from radon gas in the soil contribute about 34 Bq.m^{-3} in the sectors A_{East}, A_{West}, and A_{North}, respectively, and 40 Bq.m^{-3} in A_{South}.

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