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Measurement of radon concentration, and uranium concentration in drinking water in Kirkuk governorate

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Abstract: Radon and its daughters are the second most important cause of lung cancer after smoking in many countries. It is estimated to range from 3% to 14% of all lung cancers; depending on the average radon level in the area.The radon from water contributes to the total inhalation risk and associated in some areas of Iraq. The aim of this research is to measure the radon (^{222}Rn) concentration and thoron (^{220}Rn) in drinking water in Kirkuk governorate (Iraq) and describes the results on radon (^{222}Rn) and thoron (^{220}Rn) which were performed by analyzing the water samples Results**:** The values of radon concentration, in Kirkuk's district are varied from 196.39 Bq m^{-3} in Qadseay Yeak to 63.96 Bq m^{-3} in Hay Qharnata, and the values of thoron concentration, in Kirkuk's district are varied from 993.870 Bq m^{-3} in Qadseay Dwo to 278.806 Bq m^{-3} in Eskan. The values of uranium and thorium activity concentration from drinking water samples under the study. The higher and lower values of uranium in the locations (Eskan) and (Hay Qharnata) have been found to be (0.363) ppm, (0.119) ppm, and the higher and lower values of thorium in the locations (Qadseay Dwo) and (Eskan) have been found to be (1.864) ppm, (0.523) ppm. The results obtained were generally lower than the normal levels because the results of the average radon of concentration in drinking water in Kirkuk city were smaller than the accordable limit as reported in WHO [1]. The allowed maximum concentrations level for ^{222}Rn in water is 500 Bq.m^{-3}. There were no indications of survival of radon problems in the water sources in this survey. Therefore the drinking water in Kirkuk city is harmless as far as radon concentration is concerned.

Key words: Radon and thoron concentration; SSNTDs; Uranuim and thorium concentration; CR-39; Alpha particle radiation

1. Introduction

Radon is a chemically inert gas; it's a colourless, odourless, tasteless gas that occurs naturally in most soils, rocks, materials building and water**.** Radon and its daughters are the second most important cause of lung cancer after smoking in many countries. It is estimated to range from 3% to 14% of all lung cancers, depending on the average radon level in the area (WHO, 2009). Radon and its short-lived decay products are the most important contributors to human exposure to alpha particles from natural sources; this contribution represents 50 % of the average annual dose from natural background (Hammood and Al-Khalifa, 2011). Radon is soluble in water, and it comes from the radium in the water, surrounding soil and bedrock (Khan et al., 2010). When we use water such as washing clothes, showering and flushing toilets, and radon is released from the water and mixes with the indoor air. Thus radon from water contributes to the total inhalation risk associated with radon in indoor air. In recent years, radon monitoring has become a global phenomenon due to its health risks inside dwellings. The purpose of this study is to investigate the radon levels of sources water being used for drinking as potable water in some areas and to determine the health hazards (Hammood and Al-Khalifa, 2011).

Alpha particle radiation is one of the major types of natural radiation in our environment. It is derived from radioactive decay of radon (^{222}Rn) and it is leaded to cause cancer in the most world (WHO, 2009). Radon (^{222}Rn) is produced in the subsurface by the continuous decay of naturally occurring (Radium-226) (Semprini and Istok, 2006). It is produced in the soil where it can diffuse and reach the surface before decaying (Buchillier and Valley, 1999). One of alpha particle detector which is used to measure Radon is Solid state alpha detectors (SSNTDs). The science of solid state nuclear track detectors was born in 1958 when D. A. Young discovered first tracks in a crystal of LiF (Nikezic and Yu, 2004)

2. Radon in drinking water

There is no federal or state standard for radon in drinking water. N.H. Department of Environmental Services (NHDES) uses 2,000 pCi/L as a recommended action level for radon in drinking

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water, meaning that at or above that level, NHDES recommends testing radon levels in air and taking action to reduce exposure (John, 2014) Radon concentrations can be measured either in terms of a volume of air ($Bq.m^{-3}$) or a volume of water (Bq/L). As well as the amount of radon in air or water commonly isreported in terms of activity with units of (pCi/L) of air or water. An activity of (1 pCi/L) is about equal to the decay of two atoms of radon per minute in each liter of air or water (Husain et al. 2009).

Soil is the most important sources of radon to the environment, and water role depends on the nature of the rock layers in contact with groundwater (Kurosaki et al., 2008). Radon dissolves with water, depending on the temperature of the water. According to the U.S. Environmental Protection Agency, 10000 pCi /L of radon gas concentration in water increases its concentration in the air by 1 pCi /L in the case of normal use of drinking water at homes (Jonsson, 1991). Ninety-five percents (95%) of exposure to radon is from indoor air; about one percent (1%) is from drinking water sources. Most of this 1% drinking water exposure is from inhalation of radon gas released from running water activities, such as bathing, showering, and cleaning. Although the effects of ingested radon are not fully understood, calculations suggest that the great majority of the radiation dose from such exposure is in the stomach (Gillmore and Jabarivasal, 2010). In many countries, some homes obtain drinking water from groundwater sources (springs, wells, adits, and boreholes). Because of its volatility, radon contamination occurs primarily in ground, not surface, water sources of drinking water. Underground, this water often moves through rock containing natural uranium that releases radon to the water. That is why; water from wells normally has much higher concentrations of radon than surface water such as rivers, lakes, and streams (Kurosaki et al., 2008).

3. CR-39 detector

CR-39 is a clear, colorless, rigid plastic, with a density of 1.30 g/ cm^3, and chemical formula $C_{12}H_{18}O_7$ (Enge, 1981) made out of the polyallyl diglycol carbonate (PADC) resin (Fuchs et al., 2007). The rectangular piece of the NTD is 15×15×0.5 mm^3 in size and 1.31 g cm^{-3} in density. The sensibility of CR-39 is such that it is physically able to register low energy alphas. Its high degree of reproducibility from batch to batch ensures the correct determination of the “background signal”, giving an accurate estimate of the actual radon concentration (Tzortzis and Tsertos, 2004).

4. Tube – technique (PVC)

PVC tube is a plastic cylinder, made from PVC (Poly Vinyl Chloride), in the form of cylinder of (2 mm) thickness, a diameter of (4 cm) and (13 cm) long, used in this work to determine the radon concentration in water.

5. Experimental procedure

Drinking water samples (each of two liters) were collected from fifteen sites in Kirkuk governorate of north region in Iraq, whereas. Each sample separated in a plastic can and stored for about eight weeks prior for farther measurements.

The measurements of radon and thoron concentrations were carried out by using a long-tube technique with the plastic detector CR-39 to register the track of α-particle from radon during the time of exposure in the long-tube, The 40 gm (40 ml) from each water samples were placed in one end of the long-tube (bottom), and two CR-39 detectors were placed inside radon dosimeters, one with distance 6 cm and the other at 12 cm at the bottom (water samples) of the tube (12 cm from the surface of the water samples) to register the track of α-particle from both radon and thoron during the time of exposure in the long-tube. The samples were stored for 60 days in cylindrical container and placed without any moving under 4 °C degrees.

After completed an exposure time of 60 days, the detectors were removed from the cans and all the dosimeters were collected at the end of the exposure (2 months), etched chemically in a 6.25N NaOH solution at 70 ± 0.5 ◦C for 8h. Chemical etching is the simplest and most widely used technique for revealing the latent damage trails of ionizing particles in solids when alpha particles deposed in to the body to measuring the radon concentration (Tzortzis and Tsertos, 2004) and then the detectors were washed in distilled water. The tracks were counted for both detectors by using an optical microscope. The number of tracks per area is used to calculate the radon concentration level of the samples tested using the equation in Ref. (Tome et al., 1999).

The concentration of radon and thoron were measured as presented in Tables 1 and 2 by relation;

$$C_w\ (Bq\ m^{-3}) = (\rho/ K\ T) \text{ ----------------(1)}$$

ρ ; is the track density , T ; is the time of exposure. K is the calibration factor for the radon and thoron. Then the concentration of the ^{238}U and ^{232}Th were found in Tables 1and 2 by using the relations (Ukla, 2004).

$$W_{(U, Th)} = N_{(U, Th)} A_{(U, Th)} / N_{avo.} \text{ -------- (2)}$$

$$C_{(U, Th)} = (W_{(U, Th)} / W_w)\ (ppm) \text{ ---------(3)}$$

Where $A_{(U,Th)}$; The mass number for uranium (238) and thorium (232).

N_{avo} ; The number of Avogadro (6.023 × 10^{23} mol^{-1}).

λ_{Rn} ; Decay constant of radon (2.1× 10^{-6} s^{-1}) and of thoron (1.3 × 10^{-2} s^{-1}).

N_{Rn} ; The number of radon and thoron atoms.

$\lambda_{(U,Th)}$; Decay constant of uranium (4.8833× 10^{-18} s^{-1}), thorium (1.56× 10^{-18} s^{-1}).

$w_{(U, Th)}$; The mass of uranium and thorium .

$C_{(U,Th)}$; The concentration of ^{238}U and ^{232}Th.

W_w ; The mass of water.

6. Results and discussion

In this study the tracks registered by two detectors, one at 6 cm and the other are at 12 cm away from the sample. The detector at 12 cm (upper) records the radon gas only, while other detector at 6 cm (lower) from the sample records (radon + thoron). Then the signals was separated by ($\rho_{Thoron} = \rho_{lower} - \rho_{upper}$). However, it has been disusseded before in Ref. (Fleischer and Campero, 1978).

The calibration for radon (K_{Radon} =0.025 (track/cm^2)/(Bq.m^{-3}). h) and for thoron (K_{Thoron} = 0.0030 (track/cm^2)/(Bq.m^{-3}).h).These values are fairly in agreement with those reported by other investigators in Ref.(EL – Ghossain and Abu Saleh, 2007).

Tables 1 and 2 showed the results of the track density of radon and thoron with emanation rate values for the water samples at different locations under study in Iraqi region.

Table 1: Estimation of radon concentrations and uranium concentrations in drinking water in kirkuk governorate

No.	Location	Con. of ^{222}Rn Bq.m^{-3}	Con. of ^{222}Rn pCi/L	Con. of ^{238}U ppm
1	Shorja	165.89	4.484	0.308
2	Horya	131.31	3.549	0.244
3	Ahmad aqha	157.92	4.268	0.294
4	Azady	118.14	3.193	0.220
5	Tapa	166.78	4.508	0.310
6	Arafa	104.37	2.821	0.194
7	Rahym awa	160.36	4.334	0.298
8	Eskan	195.19	5.275	0.363
9	Eman -Qasm	141.45	3.823	0.263
10	Qadseay Yeak	196.39	3.308	0.225
11	Qadseay Dwo	184.28	4.979	0.343
12	Hay Wasty	84.99	2.296	0.158
13	Hay Qharnata	63.96	1.728	0.119
14	Hay Askari	191.84	5.185	0.355
15	Musalah	152.70	4.127	0.284

Table 2: Estimation of thoron concentrations and thorium concentrations in drinking water in kirkuk governorate

No.	Location	Con. of ^{220}Rn Bq.m^{-3}	Con. of ^{220}Rn pCi/L	Con. of ^{232}Th ppm
1	Shorja	675.055	18.245	1.266
2	Horya	413.195	11.167	0.775
3	Ahmad aqha	967.130	26.138	1.814
4	Azady	846.113	22.868	1.587
5	Tapa	581.682	15.721	1.091
6	Arafa	450.970	12.188	0.846
7	Rahym awa	919.325	24.846	1.724
8	Eskan	278.806	7.535	0.523
9	Eman -Qasm	869.180	23.491	1.630
10	Qadseay Yeak	795.630	21.503	1.492
11	Qadseay Dwo	993.870	26.861	1.864
12	Hay Wasty	338.312	9.143	0.636
13	Hay Qharnata	458.659	12.396	0.860
14	Hay Askari	776.579	20.988	1.456
15	Musalah	694.007	18.757	1.301

The results of concentration values for radon gas in all samples have been found to be greater than the concentration values for thoron in the same samples. This can be attributed to the difference in the production rate for both gases in the same period of time since the production rates depends on λ^{-1}, where λ is the decay constant, as shown in Fig.1.

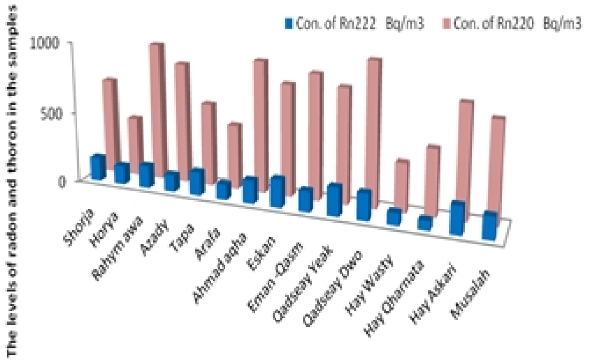

Fig. 1: The compared between the concentrations of radon at thoron in water samples

The values of radon concentration, in Kirkuk's district are varied from 196.39 Bq m^{-3} in Qadseay Yeak to 63.96 Bq/m3 in Hay Qharnata), as shown in Fig. 2. And the values of thoron concentration, in Kirkuk's district are varied from 993.870 Bq m^{-3} in Qadseay Dwo to 278.806 Bq m^{-3} in Eskan, as shown in Fig. 3.

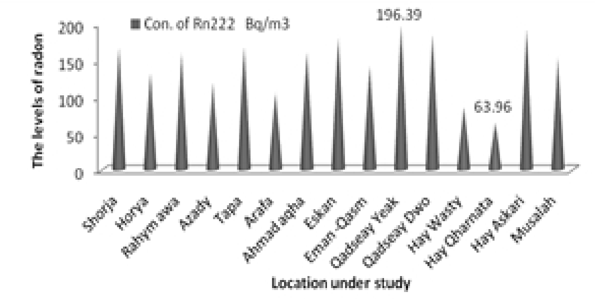

Fig. 2: The relation between the concentrations of radon and the location under study

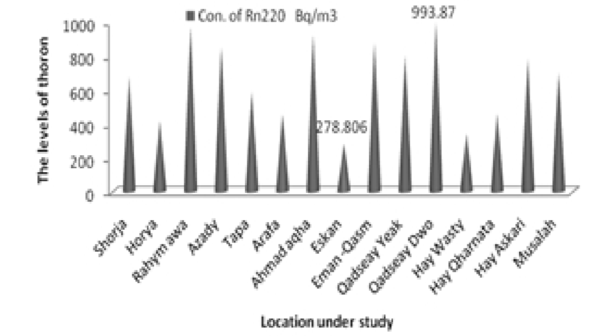

Fig. 3: The relation between the concentrations of thoron and the location under study

It can be seen that the radon in the water samples changed from location to other. This variation in radon content in each water sample may be due to different degrees of agitation and change in meteorological parameters. The health and environmental protection agencies had recommended safe limit of radon in drinking water for human beings. The recorded radon concentrations in all the water samples from various areas related to Kirkuk governorate were within the international recommended safe limit of 4000 to 40000 Bq.m^{-3} (UNSCEAR, 1993) and hence safe for drinking purposes. The US Environmental Protection Agency (EPA) proposed that Maximum contaminant level of radon concentration in drinking water is 11000 Bq/m3 and alternative maximum contaminant level is 148000 Bq.m^{-3} (Hammood and Al-Khalifa, 2011). These levels were set to represent a concentration that does not result in any significant risk to health over the lifetime drinking of water.

The values of uranium and thorium activity concentration from drinking water samples under the study, in unit (ppm) are given in Tables 1 and 2. The higher and lower values of uranium in the locations (Eskan) and (Hay Qharnata) have been found to be (0.363) ppm, (0.119) ppm, and the higher and lower values of thorium in the locations (Qadseay Dwo) and (Eskan) have been found to be (1.864) ppm, (0.523) ppm, respectively.

The results obtained were generally lower than the normal levels (which is lower than the normal rate of uranium concentration in nature that reaches (2-2.8) ppm (Mohammed, 2013) also reaches (6-10) (Escobar, Tome et al. 1999) ppm in thorium. One considers this as a secure situation for the benefit of the society and human environmental safety in the region, where the availability of uranium with high rate in some regions makes it to be a source of danger on health as well as on public safety, so it has no danger on human is life.

Significant health effects have been seen in uranium like exposed to high levels of radon. However, Radon is much more likely to cause lung cancer in people who smoke. The aim of this study was determined the important radioactive element radon in healthy drinking water, because several factors such as increases used it and availability in markets different types. The aim of the present work is to measure the concentration of radon in drinking water in Kirkuk city. Others have reported that the geological structure of an area is a predominant factor for high radon concentration and climate is also an important factor (Abojassim, 2013). The allowed maximum concentrations level for ^{222}Rn in water is 500 Bq.m^{-3}. The reason for vibration in radon concentration could be a function of geological structure of the area, depth of the water source and also differences in the climate.

7. Conclusions

This study is the first radon concentration measurement in water sources that is performed in the area of Kirkuk Governorate (Iraq). The results can be helpful in finding background levels of radon in drinking water and river water, as well as to understand the effects of it. This paper aims to introduce radon gas as the most important natural radiation sources in the environment, and to raise awareness of its dangers to public health and to emphasize the importance of measuring its concentration in the local environment. Has been chosen this subject of the current study of the importance of water in human life and living, and the lack of previous studies in the study area. The results could be utilised to make distinctive supplementary contributions when contamination event occurs and to implement water quality standards by concerned authorities to maintain.

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