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## ARTICLE

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### Measurement of Radon -222 Concentration Levels in Spring Water in Iraq

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**Abstract:** This work describes the results of measurements on the concentrations of radon (<sup>222</sup>Rn) found in seven mineral water samples collected from some natural mineral springs at seven sites in Nenevah governorate of north region in Iraq. Heat drying method was used to concentrate the radioactive nuclides in measured samples. Test tubes technique employed to measure (<sup>222</sup>Rn) using (CR – 39) plastic nuclear track detectors. The activity density of (<sup>222</sup>Rn) ranges from (3.82 PCi / L) to (9.999 PCi / L); while the average value was (5.8054 PCi / L). All results were below the maximum contaminant level (MCL) for (<sup>222</sup>Rn) in drinking water as reported by Environmental Protection Agency (EPA).

**Keywords:** CR-39 plastic nuclear track detectors; Radon -222 concentration levels; MCL.

## Introduction

Radiation is a natural part of the environment in which we live. All people receive exposure from naturally occurring radioactivity in soil, water, air and food. The largest fraction of the natural radiation exposure we receive comes from a radioactive gas, radon. Radon (<sup>222</sup>Rn) is emitted from uranium, a naturally occurring mineral in rocks and soil; thus, radon is present virtually everywhere in the air over the earth, but particularly over land, relative to that over water surface. Thus, low levels of radon are present in all the air we breathe [1].

Radon concentrations can be measured either in terms of a volume of air (Bq/m<sup>3</sup>) or a volume of water (Bq/L). As well as the amount of radon in air or water commonly is reported 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 [2].

Underground water often moves through rock containing natural uranium that releases radon to the water. Water from wells normally has much higher concentrations of radon than surface water such as lakes and streams.

Radon has also been identified as a public-health concern when present in drinking water. The World Health Organization (WHO) suggest that radon causes up to 15% of lung cancers worldwide [3].

In 1991, Environmental protection Agency (EPA) proposed a Maximum Contaminant Level (MCL) for radon of 11 Bq/L (about 300 PCi/L) for radon in drinking water. In 2000, the law of IAEA is required to set a new MCL based in part on this report. The law also directed EPA to set an alternative MCL (AMCL); an AMCL is the concentration of radon in water that would cause an increase of radon in indoor air that is no greater than the level of radon naturally present in outdoor air. Limiting public risk

from radon by treating the water alone is not feasible because radon is also naturally present in the air. Thus, the AMCL is the tool that allows (EPA) to limit exposure to radon in water to a practical level, that is, allowing no more risk from the radon in water than is posed by the level of radon naturally present in outdoor air [1].

Since radon is acknowledged as a cancer-causing substance, the law directs (EPA) to set a maximum contaminant level (MCL) for

radon to restrict the exposure of the public to the extent that is possible, that is, as close to zero as is feasible.

## Experimental Procedure

Water samples (each of two liters) were collected from seven sites in Nenevah governorate of north region in Iraq, as shown in Fig. 1.

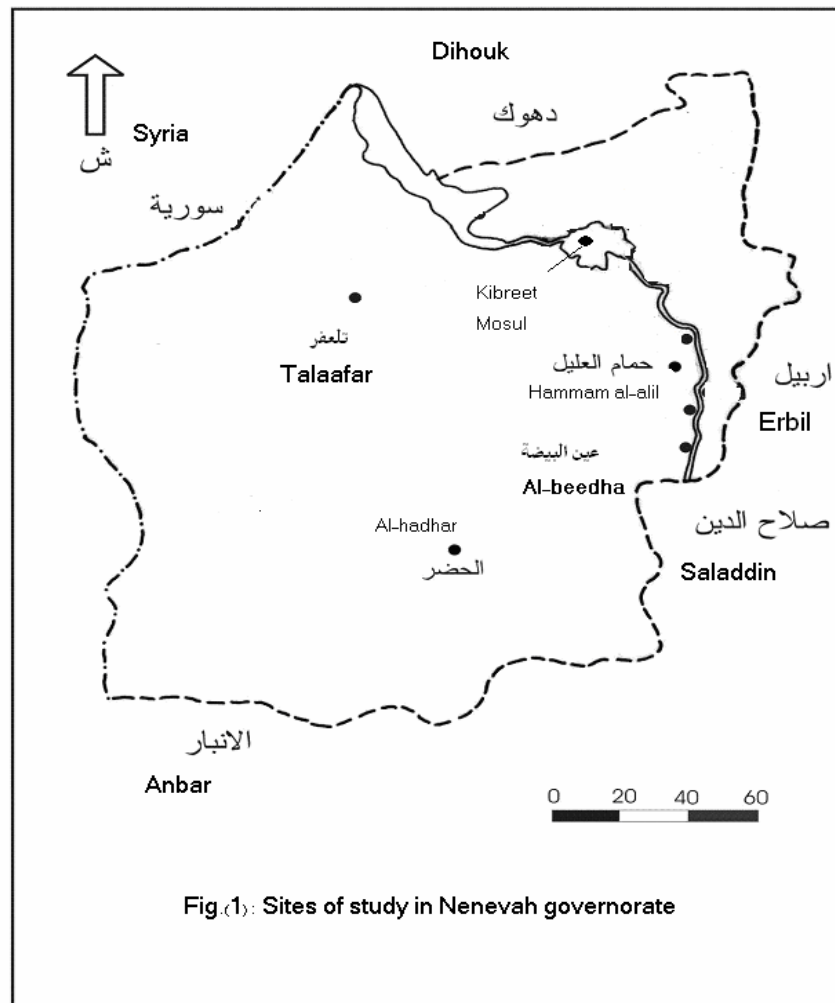


FIG. 1. Sites of study in Nenevah governorate

Test tube technique used to determine ( $^{222}\text{Rn}$ ) levels in water samples, the calibration of such technique was discussed by Barillon *et al* [4].

Heat drying method employed to concentrate the radioactive nuclides in water samples. The powder (residual precipitate)

after drying each water sample was transferred to a test tube of diameter (2.1 cm), in order to measure ( $^{222}\text{Rn}$ ) content using (CR-39) plastic solid state nuclear track detectors. The area of each detector was one  $\text{cm}^2$ , see Fig. 2.

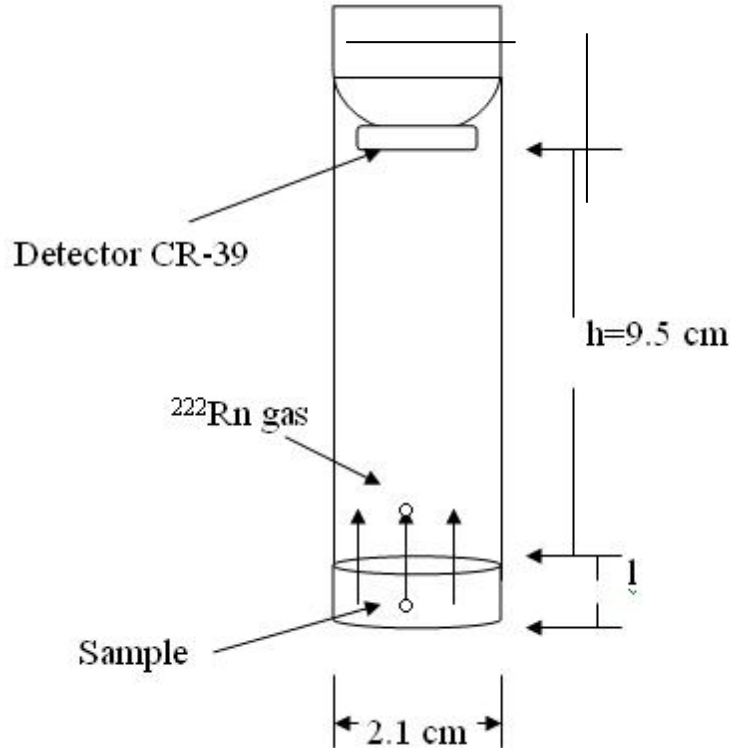


FIG. 2. Test tube technique used in the study.

After an exposure time of 60 days, the detectors were removed and chemically etched using a NaOH solution of normality (6.25 N) at temperature of 70°C with etching time of 5.5 hr. The alpha tracks per cm<sup>2</sup> in each detector were determined using an optical microscope.

### Results and Discussion

In order to measure (<sup>222</sup>Rn) concentration levels in natural mineral spring water, the surface density of tracks on the employed detectors ( $\rho$ ) measured in (Tr/cm<sup>2</sup>) unit used in the following equation [5]:

$$\rho = K . C . T \quad (1)$$

where,

$C$  = <sup>222</sup>Rn concentration within the test tube air, above the sample measured in (Bq/m<sup>3</sup>).

$T$  = exposure time.

$K$  = <sup>222</sup>Rn gas diffusion constant [4]. Such that:

$$K = \frac{1}{4} r \left[ 2 \cos \theta_c - \frac{r}{R} \right]$$

$$= 1.31 \times 10^{-3} \left( \frac{Tr / \text{cm}^2 . \text{hr}}{\text{Bq} / \text{m}^3} \right)$$

where,

$r$  = test tube radius = 0.0105 m.

$\theta_c$  = critical angle for CR-39 = 35 degree.

$R$  = range of <sup>222</sup>Rn alpha particle in air = 0.0415 m.

The <sup>222</sup>Rn activity density ( $C_{Rn}$ ) in the powder due to water sample in the test tube was determined according to the following relation [6]:

$$C_{Rn} = \frac{C . \lambda . h T}{l} \quad (2)$$

where,

$\lambda$  = decay constant for (<sup>222</sup>Rn) = 7.554x10<sup>-3</sup> (hr<sup>-1</sup>).

$h$  = distance from the powder surface to the detector = 0.095 m.

$T$  = exposure time = 60 day = 1440 hr

$l$  = depth of the powder. (m)

The activity of ( $^{222}\text{Rn}$ ) in the water samples will be calculated in (Bq/L) unit from the following relation:

$$A_{Rn} = Q \cdot C_{Rn} \cdot V \quad (3)$$

where,

$Q$  = Correction factor due to original volume of water sample (two liter) = 0.5.

$V$  = Volume of the sample in the test tube  
 $= \pi r^2 l (m^3)$ .

Table 1 shows the results of radon levels in mineral water samples obtained in this work. The  $\rho$  refers to the net value of surface density for tracks on the detector (CR-39), which is equal to the difference between the surface density of tracks due to sample and the surface density of tracks due to background (131 Tr/cm<sup>2</sup>).

TABLE 1. Results of ( $^{222}\text{Rn}$ ) activity in mineral spring water.

Spring name	$l (m)$	$\rho (Tr/cm^2)$	$A_{Rn} (Bq / L)$	$A_{Rn} (PCi / L)$
Kibreet(Mosul)	0.018	3900	0.3699	9.9992
Talaafar	0.008	2110	0.2002	5.4098
Al-shoura	0.015	1710	0.1622	4.3843
Al-beedha	0.018	1490	0.1414	3.8202
Al-gorn	0.016	3010	0.2855	7.7173
Hammam al-alil	0.018	1840	0.1746	4.7176
Al-hadhar	0.042	1790	0.1698	4.5894
Mean value			0.2148	5.8054

Because of the relatively small volume of water used in homes, the large volume of air into which the radon is emitted, and the exchange of indoor air with the ambient atmosphere, radon in water typically adds only a small increment to the indoor air concentration. Specifically, radon at a given concentration in water adds only about 1/10,000 as much to the air concentration; that is, typical use of water containing radon at 10,000 Bq/m<sup>3</sup> will on average increase the air radon concentration by only 1Bq/m<sup>3</sup>. There is always radon in indoor air from the penetration of soil gas into homes, so only very high concentrations of radon in water will make an important contribution to the airborne concentration.

It has been difficult to set a standard for radon, in the same manner as for to other radionuclides in drinking water, because of the absence of authoritative dosimetric information for radon dissolved in water. Furthermore, radon presents a unique

regulatory problem in that its efficient transfer from water into indoor air produces a risk from the inhalation of its decay products. Thus, it is regulated as a radionuclide in water, but a major portion of the associated risk occurs because of its contribution to the airborne radon concentration [1].

The (EPA) has not established a (MCL) for radon in drinking water; however, the proposed (MCL) is (300 PCi/L) [3].

It is clear from Table 1 that all results were below the maximum contaminant level (MCL) for radon ( $^{222}\text{Rn}$ ) gas in drinking water. As well as, the mean value of ( $^{222}\text{Rn}$ ) activity in water samples is about ten times lower than the value of (MCL).

A comparison of the results obtained in this work is done with reported values for ( $^{222}\text{Rn}$ ) levels in water spring samples of other workers as shown in Table 2.

TABLE 2. Comparison of ( $^{222}\text{Rn}$ ) levels in spring water with results from other workers.

Sample type	Country (site)	Range (PCi/L)	Mean (PCi/L)	References
Cold spring	Jordan (Al-Karak)	3.568 – 14.43	7.32	[7]
Cold spring	Jordan (Irbid)	89.19 - 289.2	145.9	[6]
Cold spring	Mexico (Mexico)	3.16 – 63.84	25.3	[8]
	Iraq (Nenevah)	3.820 – 9.999	5.805	This work

Radon is a naturally-occurring radioactive gas that may cause cancer, and may be found in drinking water and indoor air. Some people who are exposed to radon in drinking water may have increased risk of getting cancer over the course of their lifetime, especially lung cancer. Radon in soil under homes is the biggest source of radon in indoor air, and presents a greater risk of lung cancer than radon in drinking water. As required by the Safe Drinking Water Act, EPA has developed a proposed regulation to reduce radon in drinking water that has a multimedia mitigation option to reduce radon in indoor [3].

Because radon is easily released by agitation in water, many uses of water release

radon into the indoor air, which contributes to the total indoor airborne radon concentration.

Since (10,000 PCi/L) in water translates to about (1 PCi/L) in air, relatively there is no need to worry about the health risks due to water- borne radon [1].

## Conclusion

All results of this work shows that the water from the examined sources generally make only a small contribution to the indoor airborne radon concentration, so that the risk posed by radon released from water, is estimated to be lower than the risks posed by the other drinking water contaminants that have been subjected to regulation.

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