Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

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To cite this article: Malik H Kheder *et al* 2019 *J. Phys.: Conf. Ser.* **1234** 012033

IOP Conf. Series: Journal of Physics: Conf. Series **1234** (2019) 012033 doi:10.1088/1742-6596/1234/1/012033

Radon and uranium concentration in ground water of nineveh plain region in iraq

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Abstract. The track registration technique with a CR-39 detector was used to measure radon concentrations, and uranium contents in ground water samples from the Nineveh plain region wells. Samples were selected from 20 locations for measurements. This research aimed to assess radiological risks from uranium ingestion, and measure annual effective dose AED resulting from the intake of radon in the ingested water. Radon concentrations in these water samples were found to vary from 0.362 to 1.485 BqL−1, which were below the safety recommended limits 4 to 40 BqL−1 based on the Scientific Committee of United Nations on Atomic Radiation Effects. AED was found to vary from 1.32 to 5.42 μSv/y. Uranium activity concentrations ranged from 0.356 to 1.488 BqL−1, and the corresponding uranium concentrations in water samples were found to vary from 28.76 to 120 μgL−1. Uranium concentrations were over the safety recommended limits when, compared with recommended limits of of 30 μgL−1 for drinking water based on the US environmental protection agency. The excess cancer risk varied from 0.398 to 1.666 x10-4 with a mean value of 0.9 x10-4, indicating that 9/100,000 people in these areas haves a cancer risk from the water.

1. Introduction

Since water is very important for human life, so measuring their contents of radioactivity is important and must be under control. Most of civilian's drinking water in the area under study comes from ground water, many families have their wells as the source of water.

Ground water is under the earth surface resource of water, it comes into the ground from the snow melting and the rain. In the ground, water fills the spaces between rocks and soils which contains the radioactive elements, that transfers to the water [1]. In the waters, radionuclides occurrence depends on the parent element concentration and distribution in the rock matrix, the parent element solubility, the radionuclide itself solubility, the rate of radionuclide release by leaching and mobility controlling of geochemical reactions relative recoil rate, and on the time of water residence in the well [2,3].

The presence of Uranium in soils, water, and rocks makes easy its transportation in the environment. In the particular area, rocks are the prime uranium source to the environment [4]. The deposited uranium, enters the chain of food by transferring from water to plants, and it becomes a human's health hazard source. The source of uranium in the human body is drinking water its contribution to ingested uranium is about 85% and about 15% is the contribution of food [5]. Uranium accumulation in human body inside results in its radioactive effects and chemical for two organs the kidneys and lungs. Kidneys, bones and the liver are the deposition principle sites of uranium and radium [6,7]. Chemical damage transient to the kidneys by natural uranium soluble exposure to 0.1 mg/kg of the body weight [8]. In drinking water, uranium limit of the environmental protection agency, EPA recommended as reference level of 30 μg l^{-1} [9].

Radon (Rn222) is groundwater well suited, is one of the daughters of uranium (U238), is inert radioactive gas, it dissolves in water and can readily diffuse with gases and water vapor. The sources of radon in water, from dissolved radium radioactive decay in water, and from minerals containing decay series members of thorium and uranium releases the radon [10]. Since the radon gas can escape into the air so the rivers and reservoir water contains usually very little radon, the very important radon source is its concentration in the underground water [11]. United States environmental protection EPA has recommended the maximum level (MCL) for (Rn222) in drinking water as 11Bq/L (300pCi/L) [12,13].

The technique of measurements, is by counting the tracks on the detector, that produced by the alpha particles emitted from radon gas. After chemical etching of detector to made the tracks visible. The optical microscope used to count tracks manually, then measured tracks converted to Radon concentration.

2. Materials and methods

Ground water samples, collected from 20 locations in the Nineveh plain region in Iraq (Figure 1).

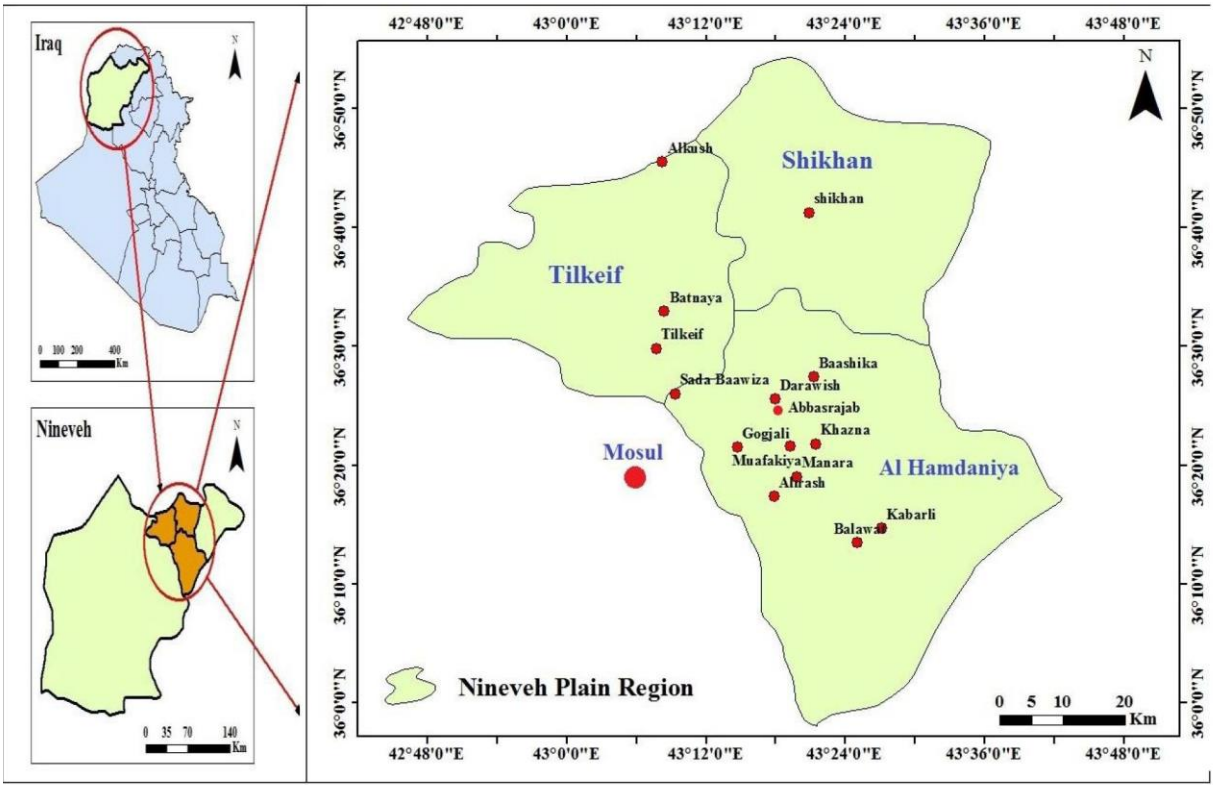

Figure 1. The study sites map of Nineveh plain region

Samples filled in a plastic can (radon dosimeter, 25 cm length, 7cm diameter) as in (Figure 2), and stored for about 65 days for further measurements. Radon concentrations measured using plastic detector CR-39 technique to register the α-particle tracks from radon in the plastic can during the 65 days exposure time, the 3cm highest, 115.4 gm equal to (115.4 ml) from each water samples were placed in the plastic can, and were placed CR-39 detectors on the bottom of radon dosimeters cover, 22 cm from the water samples surface. After completing an exposure time of 65 days, the detectors were removed from the cans and all the dosimeters were collected, etched chemically at 70◦ C in a 6.25N NaOH solution for 7 hours. Then in distilled water the detectors washed and dried. The optical microscope of 400x used to track count.

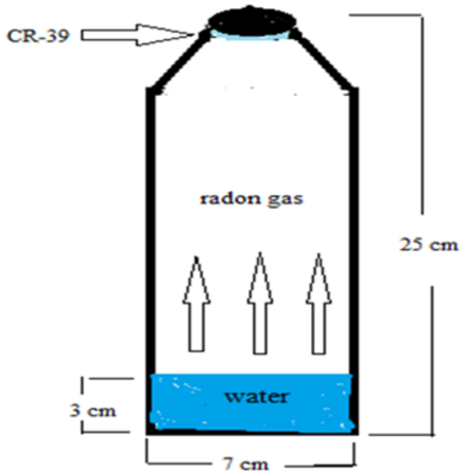

Figure 2. Plastic can (Radon dosimeter)

2.1. Radon concentration calculation

Radon concentration in the air volume inside the can, calculated from the equation [14].

$$C_S = \rho\,[KT]^{-1} \tag{1}$$

ρ; is the track density, T; is the time of exposure, K = (0.2279 Tr/cm^2.d/Bq/m^3); is the CR-39 detector calibration factor for the used radon dosimeter in this study [15].
Water samples radon concentrations, calculated by the equation [16].

$$C_{Rn} = \lambda_{Rn} C_S H T [l]^{-1} \tag{2}$$

Where C_{Rn}: is water samples Radon concentration in (Bq/m3), C_S : Radon concentration in air space (Bq/m^3), λ_{Rn}: decay constant of radon (0.1814 day^{-1}), H: is the height of air space in the plastic can (22cm), T: exposure time (65 day), l: is the thickness of the sample in the can (3cm).

2.2. Annual effective dose AED in water

The consumer AED due to radon intake from water, obtained in (µSv/y) units from the relation [17].

$$AED_W = C_{Rn}\, C_{RW}\, C_{CW} \tag{3}$$

Where C_{Rn} in (Bq/L) unit, is the radon concentration in the ingested water, C_{Rw} is (730 L/y) the water consumption rate, and D_{cw} is the factor for conversion from Becquerel to Sievert units (5 × 10^{-9} Sv /Bq).

2.3. Uranium contents calculation

The radon activity A_{Rn} in the sample can be determined from the radon concentration in the sample C_{Rn} by the relation [18]:

$$A_{Rn} = C_{Rn}\, V \tag{4}$$

Where V is the volume of sample ($V = \pi r^2 l$) = 115.39 X 10^{-6} m^3, r = 0.035m is the plastic can radius, l = 0.03 m is the sample thickness. Then

$$\lambda_{Rn}\, N_{Rn} = A_{Rn} \tag{5}$$

The number of uranium atoms N_U in the samples can be determined by using the secular equilibrium equation between uranium and its daughter radon (activity of radon equal activity of uranium) [19].

$$\lambda_U\, N_U = \lambda_{Rn}\, N_{Rn} \tag{6}$$

λ_U = (4.883 X 10^{-18} sec^{-1}) is the uranium decay constant. Then uranium weight in samples calculated using the number of uranium atoms N_U by the following equation.

$$W_U = N_U At_U [N_{avo.}]^{-1} \tag{7}$$

At_U is the uranium mass number ^{238}U, $N_{avo.}$= Avogadro number (6.02 X 1023 atom/Mol), where W_U will be in units of micrograms (µg). Uranium concentration, then calculated by

$$C_U = W_U [W_S]^{-1} \tag{8}$$

C_U: uranium concentration in part per million (ppm), when Ws = 115.4 grams is the mass of the water sample, while C_U in units of (µg/L) when Ws = 115.4 milliliter (mL).

2.4. Excess cancer risk calculation : radiological risk assessment

Radiological risk related on the activity concentration or specific activity (activity per unit of weight) of radiation, for uranium Ac is uranium activity concentration, calculated using equation (7) in the form

$$N_U = N_{avo.} [At_U]^{-1}\, W_U$$

Multiplying this equation by the decay constant of uranium λ_U and dividing on the weight of a water sample Ws in units of liters (L):

$$\lambda_U\, N_U [Ws]^{-1} = \lambda_U N_{avo.} [At_U]^{-1}\, W_U [Ws]^{-1} \tag{9}$$

Since $W_U [Ws]^{-1} = C_U$ in units of (µg/L), $\lambda_U\, N_U$ =activity of uranium then $\lambda_U\, N_U [Ws]^{-1}$ = Ac activity concentration will be in unit of (BqL^{-1}):

$$Ac = \lambda_U N_{avo.} [At_U]^{-1}\, C_U \tag{10}$$

The excess cancer risk of uranium ingestion in water, calculated by the given method of [20].

$$ECR = Ac\ R \tag{11}$$

ECR is the excess of cancer risk, and R is a risk factor (per BqL^{-1}). The risk factor R, linked with Uranium ingestion from water, calculated by the product of the risk coefficient (r) of uranium (1.19×10^{-9}) Bq^{-1} for mortality and per capita activity intake (I). Where (I) for uranium is calculated as product of life expectancy as 63.7 years, i.e. 23250 days and daily consumption of water as 4.05 L day^{-1} [21]. Then I = 4.05 L day^{-1} × 23250 day = 94162.5 L, and so the risk factor value will be

$R = r\times I = 1.19\times10^{-9}\ Bq^{-1} \times 94162.5\ L = 1.12\times10^{-4}\ L\ Bq^{-1}$.

3. Results and discussion

The obtained results from the water samples at different locations under study are listed in (Table 1), which showed the radon concentration in air space Cs (Bq/m^3), the water samples radon concentration C_{Rn} in units (Bq/L) and (PCi/L), the annual effective dose AED_W in units of (µSv/y), uranium concentrations in water samples C_U in (µg/L) uranium activity concentrations Ac (Bq/L), and the exceed cancer risk ECR. The concentration values of radon gas, in ground water (wells) samples of the Nineveh plain region, are varied from 1.485 Bq/L (40.09 pCi/L) in Abbasrajab to 0.362 Bq/L (9.77 pCi/L) in Manara. The radon in the water samples, changed from location to another due to changes in geological parameters. All measured radon concentrations in the samples of water were within the safe international recommended concentration limit, which represent that concentration in any significant risk does not result in health over the lifetime drinking of water. The agencies of health and environmental protection had a safe limit recommended of the drinking water content of radon for human beings, of 4-40 Bq/L [22] which equal to 4000 to 40000 Bq.m^{-3}.

The US Environmental Protection Agency proposed that Maximum contaminant level of radon concentration in drinking water is 11000 Bq/m3 equal to 11 Bq/L (300 pCi/L) and the alternative maximum contaminant level is 148000 Bq.m^{-3} equal to 148 Bq/L (4000 pCi/L). The obtained results of radon concentrations in water samples for drinking purposes are safe.

Table 1. The radon concentrations, and the annual effective dose, uranium activity concentrations, and the exceed cancer risk.

No	Location	C_s (Bq/m^3)	C_{Rn} (Bq/L)	C_{Rn} (PCi/L)	AED_W (µSv/y)	C_U (µg/L)	Ac (Bq/L)	ECR *x 10^{-4}
1.	Alkush	8.184	0.707	19.10	2.58	56	0.694	0.777
2.	Batnaya	6.54	0.565	15.25	2.06	45	0.558	0.624
3.	Baashika	4.91	0.424	11.45	1.54	34	0.421	0.471
4.	Balawat	10.63	0.919	24.81	3.35	74	0.917	1.027
5.	Tilkeif	12.27	1.061	28.62	3.87	85	1.054	1.180
6.	Khazna	11.45	0.990	26.73	3.61	80	0.992	1.111
7.	Darawish	5.72	0.494	13.33	1.80	37	0.458	0.512
8.	Zankel	11.45	0.990	26.73	3.61	80	0.992	1.111
9.	Sada Baawiza	6.54	0.565	15.25	2.06	45	0.558	0.624
10.	Shikhan	7.36	0.636	17.17	2.32	51	0.632	0.707
11.	Abbasrajab	17.18	1.485	40.09	5.42	120	1.488	1.666
12.	Alirash	14.73	1.273	34.37	4.64	102	1.264	1.415
13.	Omarkan	13.91	1.202	32.45	4.38	97	1.202	1.346
14.	Kabarli	6.54	0.565	15.25	2.06	45	0.558	0.624
15.	Kazkan	9.82	0.849	22.92	3.10	68	0.843	0.944
16.	Gogjali	11.45	0.990	26.73	3.61	80	0.992	1.111
17.	Majidiya	5.72	0.494	13.33	1.80	37	0.458	0.512
18.	Manara	4.19	0.362	9.77	1.32	28.76	0.356	0.398
19.	Muafakiya	4.91	0.424	11.49	1.54	34	0.421	0.471
20.	Wardak	15.5	1.344	36.28	4.90	108	1.339	1.499
	Min	4.19	0.362	9.77	1.32	28.76	0.356	0.398
	Max	17.18	1.485	40.09	5.42	120	1.488	1.666
	Mean	10.17	0.817	22.05	2.97	65.33	0.809	0.906

The annual effective dose varied from 5.42 µSv/y in Abbasrajab to 1.32 µSv/y in Manara as shown in (Figure 3). The values of uranium activity concentration of water samples, in unit (Bq/L), are the higher and lower values in the locations Abbasrajab and Manara has been found to be 1.488 Bq/L, 0.356 Bq/L as shown in (Figure 4).

The obtained results for uranium concentrations in units µg/L, the average value is 65.33 µg/L were generally over by a factor of 2 than the normal level rate of uranium concentration 30 µg/L for drinking water based on the World Health Organization's guidelines, but still not dangerous.

The excess cancer risk varied from 0.398 to 1.666 x10^{-4} with a mean value of 0.906 x10^{-4}, indicating that 9/100,000 people in these areas haves a cancer risk from the water. The availability of uranium with high rate in some regions makes it to be a source of danger on health as well as public safety, so it has no danger of human's life. Significant health effects have been seen in uranium like exposed to radon of high levels, no treatment is needed.

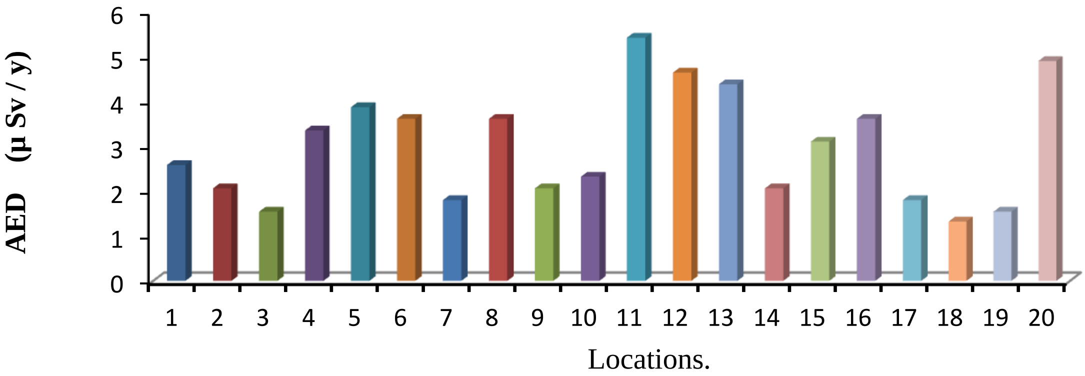

Figure 3. Annual effective dose AED variation with samples locations.

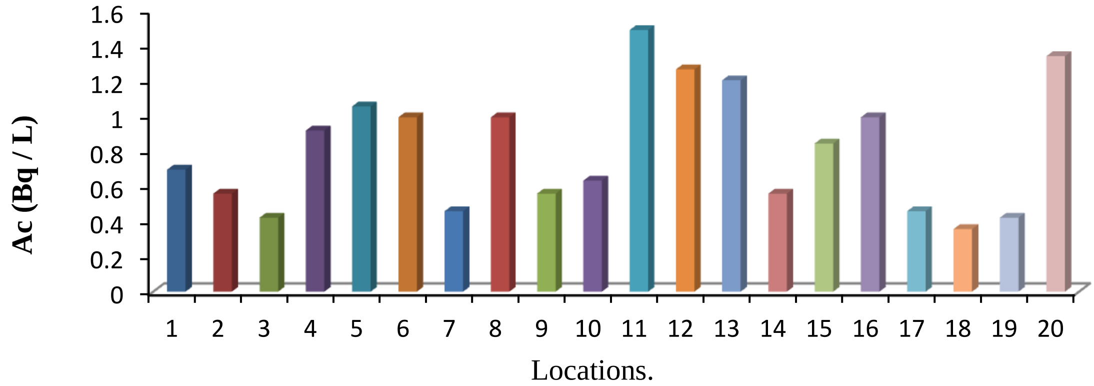

Figure 4. Uranium activity concentration Ac variation with sample locations.

The results compared with other works in (Table 2). The comparison showed that the obtained results are within the other countries measurements, for radon concentrations the obtained results less than all other countries India, Nigeria, Portugal and Malaysia, but the annual effective dose higher than Nigeria, less than India and Portugal. The comparison of the results have intermediate values among of the other measured values in Iraq for radon concentrations, the results are higher than the values of radon concentrations in Wassit, Thi-Qar, Kirkuk and Baghdad Governorates, but the results are lower than other measurements in Nineveh Province, and lower than the values of Aucashat city, Babylon and Basra Governorates. AED values and uranium concentrations results are higher than all other measurements in Iraq except of Kirkuk Governorate.

Table 2. Comparison with other authors' results.

Work location	Radon (BqL^{-1})	Uranium (μgL^{-1})	AED (μSv/y)	Reference
Present work	0.362-1.485	28.76-120	1.32-5.42	
Nineveh Province-Iraq		7.9-19.12		[23]
Nineveh - Iraq	0.1414- 0.3699			[24]
Nineveh Province-Iraq	17.4 - 36.1		64 -132	[25]
Wassit Governorate-Iraq	0.325- 0.820		0.03- 0.08	[26]
Thi-Qar Governorate-Iraq	0.108 - 0.223		0.394- 0.814	[27]
Kirkuk governorate-Iraq	0.063-0.196	119-363		[28]

Baghdad Governorate-Iraq	0.073-0.19		0.267-0.69	[29]
Aucashat city-Iraq	8.02-11.7	8.8-12.63	2.25-3.28	[30]
Babylon Governorate-iraq	1.7-5.83			[31]
Al-Najaf-Iraq		1.617-5.08		[32]
Basra Governorate-Iraq	2.050			[33]
Sungai Petani, Kedah, Malaysia	5.37- 14.7			[34]
Thirthahalli taluk, India	0.37- 87.02		1.01- 237.5	[35]
Covilha's county, Portugal	2-1690		0.018-12.34	[36]
IDAH-Nigeria	13.45		0.049	[37]
India		0.9 - 63		[38]
Abeokuta Ogun-Nigeria	3.1 - 90.8			[39]
Western Haryana-India		6.37-43.31		[40]

4. Conclusions

This study aimed to measure the radon and uranium concentrations in well water in the Nineveh plain region in Iraq, and to introduce the radiation levels of wells, for the importance of the water in human life. Water having high levels of radiation in the area of study its dangers sources for public health. So it's important to measuring the radiations concentrations in the local well. The results can be set as a background levels of radon and uranium in well water, and to understand the annual effective dose AED of radon, and exceed cancer risk ECR of uranium effects. AEDs were found to vary from 1.32 to 5.42 µSv/y, and the mean value of excess cancer risk is 0.9 x10-4, indicating that 9/100,000 people in these areas haves a cancer risk from the water.

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