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Estimating the Health Risks of Natural Radioactivity in Drinking Water in Al-Nahrawan City

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Abstract

Water samples obtained from Baghdad Governorate (Al-Nahrawan city) and examined for radon, radium, and uranium contents, as well as the radon surface exhalation rate. The measurements have been carried out using CR-39 detector. Radon and radium concentrations found in drinking water samples are below the maximum contamination levels suggested by the US Environmental Protection Agency (11.1 Bq/l) and the World Health Organization (0.555 Bq/L), respectively. Results reveal that radon consumed and inhaled through drinking and ground water poses no considerable public health concern in the studied area, except some samples in AL-meaml and center city region.In general, the values of radon, radium, uranium and radon surface exhalation rate obtained in this study(1.28-14 Bq/L ,0.10-1.50 Bq/L,0.13-1.50 ppm and 1.53-16.68 Bq/m^{2}h) respectively. The findings of this study show that radon ingestion and inhalation of drinking water provide no major public health concern.

Keywords: Drinking water, Ground water, Radium, Radon, Surface exhalation rate, Uranium.

INTRODUCTION

Natural ambient radioactivity is primarily caused by primordial radionuclides such as potassium-40, thorium-232 and uranium-238 nuclides, as well as their decay products, which are found at trace amounts in all ground formations. . Because most materials contain uranium-238, they are potential radon emitters. Because radon-222 is a daughter product of radium-226, which comes from the longer-lived uranium-238[1]. That radon-222 and its offspring are the most significant single contributors to human radiation exposure from natural or man-made radioactive sources[2]. Radon is a radioactive noble gas with three primary isotopes: radon-222, radon-220 (Thoron), and radon-219 (Actinon), each with half-lives of 3.82 days, 55.6 seconds, and 3.96 seconds[3]. Radon is a radioactive gas emitted from rocks,soils and water.

Radon is one of the leading causes of ionizing radiation exposure in the general population. We chose radon-222 because of its long half-life (3.82 days), which makes it easier for it to escape from the matrix containing its parent radium-226. Because it comes from the natural decay of uranium series deposits in soil, radon is a deadly natural radioactive gas that is exceedingly harmful to humans and the environment[4].When water is utilized for drinking in the home, the presence of radon poses a risk to one's health. Because of the amount of radon in the air that is inhaled and enters the human lungs[5]. There are two ways that radon-enriched drinking water could have produced the potential health risk: through direct intake of dissolved radon-222 in potable water and secondly transfer of radon-222 and its progenies liberated from water into indoor air and it inhalation. Given the possible health risks of waterborne radon, around 89 percent of lung cancer caused by inhalation of radon-222 escaping from water and 11 percent of stomach cancer caused by ingestion of radon-222 contaminated water have been reported. In many places of the world, radon-222 concentrations in drinkable water, air, and soil have been measured in order to determine the annual effective dose and to reduce the unfavorable health effects of radon on humans[6].

Groundwater moving through rocks and soil containing radioactive elements picks up radon. When water is pushed up from a well, it joins the water supply[7]. Radon in drinking water is a leading cause of cancers of the internal organs, particularly stomach cancer. However, this risk is lower than the risk of developing lung cancer from radon released to air from tap water[8] . The aim of this research is to determine the amount of radon, radium and uranium concentrations in water samples in Nahrawan city, as there are no previous studies in the study area. Attention to radon as it is a source of danger to people's health due to its wide spread in soil, building materials and groundwater, and the water of liquefaction networks in some areas is not free of this gas.

Location of the study:

A city located southeast of Baghdad, the capital, and the northern part of it is located near the confluence of the Diyala River with the Degla River, and it is an agricultural area originally, It is close to the city of Mada'in, which contains the of Taq Khosrau. The city is about 20 km from Baghdad. There is more than one housing complex in it, the most important of which is a housing complex for the employees of the Oil Exploration Company and some employees of the Ministry of Oil. It is also located in the largest brick-making complex in Baghdad as well as a complex for tanning leather and there are more than 300 brick factories.

Sample collection and preparation:

In this work, fortytwo water samples were collected from different locations in Nahrawan city(six samples from village 10, three samples from village8, two samples from Al-zetia area,two samples from Al-hollandia area, three samples from Al-sejad area, two samples from Al-sadeq area, four samples from Al-khansa area, four samples from Al- jazmia area, four samples from Al- meaml area, two samples from Al- nafteia area and ten samples from center city). 15 samples of pumps that depend on the ground water and 27 samples of pumps that depend on the degla river. For each sample about 150 g was placed at the bottom of a sealed can of 15 cm height and 8cm diameter Fig.1 in this study, a Solid State Nuclear Track Detector (SSNTD) was used , which is usually known as CR-39plastic detector[9]. On the top of the can's inner surface, square detector pieces of 1 cm x 1 cm were placed in such a way that the sensitive surface was always facing of water sample[10]. The detectors were left exposed for around 90 days. The sensitive side of the detector was always towards the sample during the exposed period, and it was freely exposed to emergent radon from the water sample in the can, allowing it to record alpha particles produced by radon decay in the can's remaining volume. The bombarded CR-39 detectors were recovered after the irradiation time and chemically etched in NaOH solution (6.25 M at 70 0C during 6 h) [11] After etching, the CR-39 detectors were washed in distilled water and then dipped for a few minutes in a 3 percent acetic acid solution before being washed and dried in air. The number of tracks per cm^2 in each detector was counted using an optical microscope with a magnification of 400X, and the background of CR-39 detectors was counted by optical microscope and subtracted from the count of all detectors[12].After calculating the number of traces in each detector, we can calculate the concentration of radon, radium and uranium.

Results:

Using the following relation[13], we can compute the radon concentrations in the can air above the water samples in (Bq/L):

$$C_{air} = \frac{\rho}{K.T} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

where ρ :is the density of the tracks on the exposed detectors(track.cm^{-2}). T : time of the exposure(day) . K :is calibration coefficient of the detector(track.cm^{-2}.day^{-1}/Bq.m^{-3}) and C_{air} : radon concentration in the air above a water sample (Bq.m^{-3} or Bq.L^{-1}).

To calculate radon concentration in water samples, we will use equation[14]:

$$C_{water} = C_{air} \frac{\lambda h T}{L} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where: C_{water} :radon gas concentration in water(Bq.m^{-3} or Bq.L^{-1}). λ :decay constant of radon gas(0.1814 day^{-1}). h : the distains between detector and the water surface11cm) and L :height of the water in inside the can(4cm).

Using the following relation, the radium concentration of the water samples may be estimated[15]:

$$C_{Ra} = \frac{\rho h A}{K T_e m} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where C_{Ra} : the radium concentration of the water samples(Bq.m^{-3} or Bq.L^{-1}). A : is the cross-sectional area of the can ($A = \pi r^2 = 3.14 * \left(4x10^{-2}\right)^2 = 50.24x10^{-4} m^2$). T_e :is the effective exposure time($T_e = \left[T - \frac{1}{\lambda}\left(1 - e^{-\lambda T}\right)\right]$) and m : mass of the water sample in g (150g).

To calculate the concentration of uranium, it is necessary to Calculate the number of radon atoms(N_{Rn})[16]:

$$N_{Rn} = \frac{A_{Rn}}{\lambda_{Rn}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

Where A_{Rn}:the radioactivity of radon($A_{Rn} = C_{water}V$), V : is sample volume in m^3($V = \pi r^2 L$), r : radius of the container(cm).

Using the law of radioactive equilibrium, the number of uranium atoms in the samples is found:

$$N_u = \frac{\lambda_{Rn} N_{Rn}}{\lambda_u} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$$

where: λ_{Rn} :radon decay constant($2.1x10^{-6} Sec^{-1}$), N_{Rn} , λ_u :uranium decay constant($4.9x10^{-18} Sec^{-1}$).

As for the weight of uranium in the samples(g), we find it from the relation:

$$W_u = \frac{N_u A_u}{N_{av}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

,

A_u :the mass number of uranium, N_{av} : avocadro number.

The concentration of uranium can be found by the relation:

$$C(ppm) = \frac{W_u}{W_s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 7$$

W_s :sample weight(g).

To calculate the radon surface exhalation rate we use the following equation[17]:

$$E_A = \frac{C_{Rn} V \lambda_{Rn}}{A\left[T + \frac{1}{\lambda_{Rn}}\left(e^{-\lambda_{Rn} t} - 1\right)\right]} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 8$$

E_A :is the surface exhalation rate, T :is the exposure time(h).

Table(1):explain concentrations of the(radon ,radium and uranium)and radon surface exhalation rate.

Region	**Sample No.**	**Track density**	**C_{air} Bq/L**	**C_{water}Bq/L**	**C_{Ra} Bq/L**	**C_u(ppm)**	**E_A(Bqm^{-2}h^{-1})**	**Water source**
Village 10	1	875	0.0441	1.97	0.16	0.21	2.35	Degla river
	2	789	0.0398	1.78	0.14	0.19	2.12	Degla river
	3	938	0.0473	2.12	0.17	0.22	2.52	Degla river
	4	3287	0.1660	7.43	0.61	0.80	8.86	Ground water
	5	911	0.0460	2.06	0.16	0.22	2.45	Degla river
	6	947	0.0478	2.14	0.17	0.23	2.55	Degla river
Village 8	7	846	0.0427	1.91	0.15	0.20	2.28	Degla river
	8	989	0.0499	2.23	0.18	0.24	2.66	Degla river
	9	1022	0.0516	2.31	0.18	0.24	2.75	Degla river
Al-zetia	10	2133	0.1077	4.82	0.39	0.51	5.74	Degla river

	11	2011	0.1015	4.54	0.37	0.48	5.42	Degla river
Al-hollandia	12	1675	0.0845	3.78	0.31	0.40	4.51	Degla river
	13	994	0.0502	2.24	0.18	0.24	2.67	Degla river
Al-sejad	14	1015	0.0512	2.29	0.18	0.24	2.73	Degla river
	15	2900	0.1464	6.56	0.53	0.70	7.81	Ground water
	16	2993	0.1511	6.77	0.55	0.72	8.06	Ground water
al-sadeq	17	1090	0.0550	2.46	0.20	0.26	2.93	Degla river
	18	654	0.0330	1.47	0.12	0.15	1.76	Degla river
Al-khansa	19	887	0.0447	2.00	0.16	0.21	2.39	Degla river
	20	718	0.0362	1.62	0.13	0.17	1.93	Degla river
	21	819	0.0413	1.85	0.15	0.19	2.20	Ground water
	22	1099	0.0555	2.48	0.20	0.26	2.96	Ground water
Al-jazmia	23	1987	0.1003	4.49	0.36	0.48	5.35	Degla river
	24	1654	0.0835	3.74	0.30	0.40	4.45	Degla river
	25	1548	0.0781	3.50	0.28	0.37	4.17	Ground water
	26	1122	0.0566	2.53	0.20	0.27	3.02	Ground water
Al-meaml	27	2722	0.1374	6.15	0.50	0.66	7.33	Ground water
	28	2366	0.1194	5.35	0.43	0.57	6.37	Ground water
	29	5984	0.3022	13.53	1.11	1.45	16.13	Ground water
	30	6100	0.3080	13.80	1.13	1.48	16.44	Ground water
Al-nafteia	31	569	0.0287	1.28	0.10	0.13	1.53	Degla river
	32	866	0.0437	1.95	0.16	0.21	2.33	Degla river
Center city	33	1097	0.0554	2.48	0.20	0.26	2.95	Degla river
	34	1001	0.0505	2.26	0.18	0.24	2.69	Degla river
	35	2866	0.1447	6.48	0.53	0.69	7.72	Degla river

	36	2611	0.1318	5.90	0.48	0.63	7.03	Ground water
	37	2433	0.1228	5.50	0.45	0.59	6.55	Ground water
	38	1028	0.0519	2.32	0.19	0.25	2.77	Ground water
	39	1099	0.0555	2.48	0.20	0.26	2.96	Degla river
	40	966	0.0487	2.18	0.17	0.23	2.60	Degla river
	41	745	0.0376	1.68	0.13	0.18	2.00	Degla river
	42	6188	0.3125	14.00	1.150	1.50	16.68	Ground water

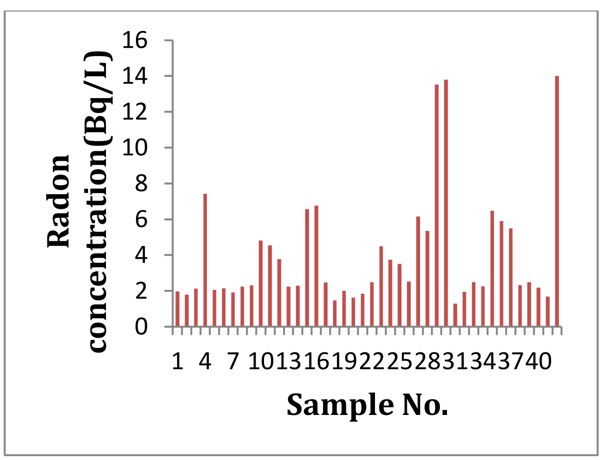
The calculated values of radon, radium, uranium and radon surface exhalation rate concentration for water samples collected from various places in Nahrawan city. are presented in table 1. The fourth and fifth columns of table, present the concentrations of radon in the can air above sample of the water and in samples water respectively, the sixth column of table 1, shows the radium concentration of the water samples, the seventh column shows the uranium concentration , while the the eighth column shows the radon surface exhalation rate concentration for water samples.

Fig.1 represents the relation between the sample number and radon concentration, Fig.2represents the relation between the sample number and radium concentration,Fig.3 represents the relation between the sample number and uranium concentration and Fig.4 represents the relation between the sample number and surface exhalation rate concentration, the highest value radon concentration in water samples in sample number 42(14 $Bq.L^{-1}$) and lowest value for radon concentration in sample number31(1.28 $Bq.L^{-1}$). And also the highest values of radium, uranium and surface exhalation rate concentrations in sample No. 42 and the lowest values in sample N0.31 because it depends on the values of radon concentrations, Fig.5 represents the relation between radon concentration and surface exhalation rate, where increases the surface exhalation rate when the radon concentration increases. In this study, clearly the present results shown that the radon and radium concentrations in most water samples were below the recommended maximum contamination levels (MCLs) as indicated by the US Environmental Protection Agency (11.1 Bq/l) and the World Health Organization (0.555 Bq/L), respectively, only in the AL-meaml area and the center city area were higher the allowed limit coined by EPA for ^{222}Rn in drinking water, Where were the radon concentrations(13.53 ,13.80 and 14)Bq/L in sample No. 29,30 and 42 respectively, and were radium concentrations(1.11,1.13 and 1.15)Bq/Lin sample No. 29,30 and 42 respectively, Therefore, it Non-potable water.

Also from Table 1, we note that the source of water for some samples is from the Tigris River and the other part is from groundwater, and we note that radon concentrations in samples that depend on the Tigris River are less than radon concentrations in samples that depend on groundwater, therefore, it is preferable to rely on the Tigris River for drinking water. The current study's radon activity levels are compared to the literature findings for drinking waters, which are shown in Table (2). The variances in radon concentration are due to differences in climate, geological and geographical elements, as well as geo-hydrological processes in the area. Another reason for the discrepancy could be related to the sample time and location, which could result in different results.

Table(2): The comparison between the obtained results and the published data for drink water in different countries.

Country	C_{water} Bq/L	References
India	**0.3-5.4**	(8)
Romania	**0.5-10**	(18)
Bangladesh	**0.1-2.7**	(19)
Iran	**1.2-9.9**	(20)
Saudi Arabia	**1.7-3.8**	(12)
Iqaqi Erbil	**1.1-13.1**	(7)
Pakistan	**1.6-18.2**	(21)
Brazil	**0.9-36**	(22)
Southern Greater Poland	**0.4-10.5**	(23)
Cyprus	**0.3-20**	(24)
West Bengal,India	**1.9-9**	(25)
Barsa,Turkey	**1.4-53**	(26)
Palestine	**0.2-1.2**	(27)
Libya	**1.02-7.2**	(28)
Iraq, AL-Najaf	**0.1-0.5**	(29)
Iraq, Baghdad	**0.2-1.2**	(30)
Iraq,Al **Nahrawan**	**1.28-14**	Present work



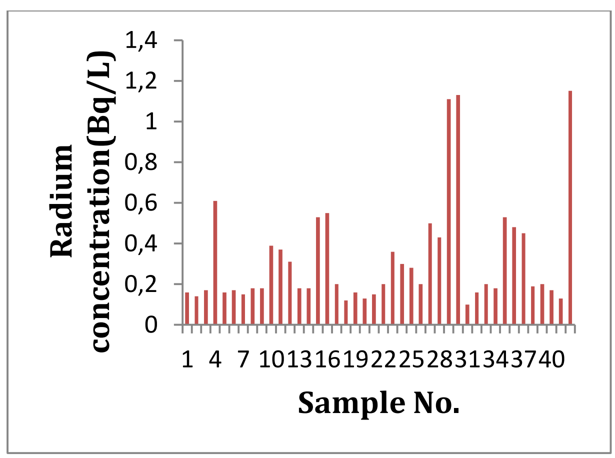
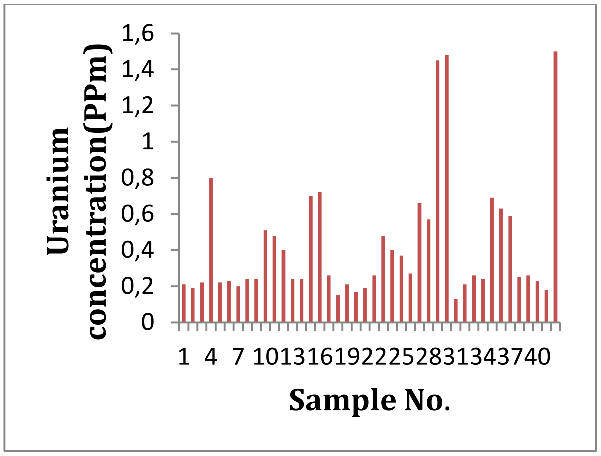


Figure 1: The relation between the sample number and radon concentration.

Figure 2: The relation between the sample number and radium concentration.



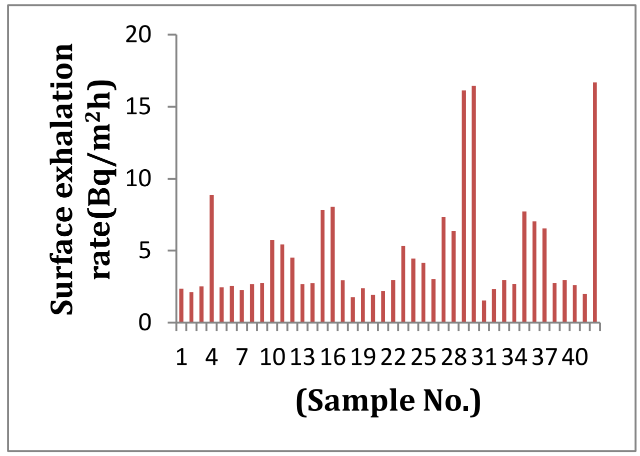


Figure 3: The relation between the sample number and Figure 4: The relation between the sample number and

uranium concentration. surface exhalation rate.

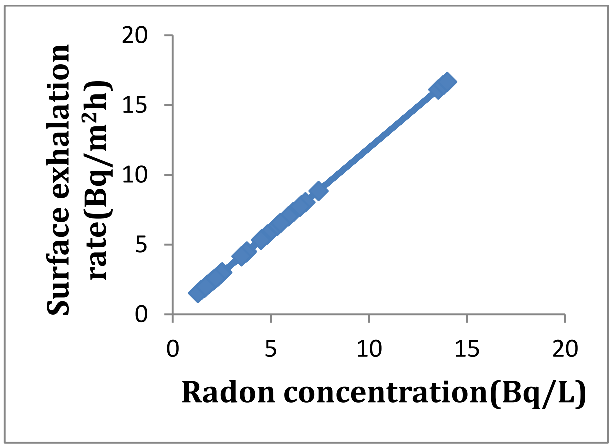


Figure 5:The correlation between radon concentration and surface exhalation rate.

Conclusion:

- The current study found that radon and radium concentrations in most drinking water samples are below proposed concentration limits, with the exception of a few locations where they are higher than the EPA's recommended level of 11.1 Bq/L and the World Health Organization's recommended level of 0.555 Bq/L, respectively.
- Elevated levels of radon concentration were observed in some areas because of the different components of the soil, such some rocks that contain higher activity of radionuclides.
- All of the radon concentrations in this study are less than 100 Bq/L, which is the World Health Organization's and EC action threshold.

In this study ,it is preferable to rely on the degla river for drinking water.

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