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Determination of radon gas concentrations ^{222}Rn in water samples of Rivers and ground wells in Basrah Governorate, Iraq

Master A. Ali
Department of Environment, Basrah Oil Company, Ministry of Oil, Iraq
**Corresponding Author: e-mail: mastirali67@yahoo.com*

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Abstract - In this study, 52 samples were collected from natural water taken from selected areas from (Rivers, groundwater wells) in Basrah Governorate-Southern Iraq for the period from February - April 2020, to determine the concentrations of the radon gas (^{222}Rn) emitted from the selected and newborn samples of the radioactive element Radium ^{226}Ra located in the series of uranium ^{238}U and calculate the annual effective dose. Solid state Nuclear Track Detectors SSNTDs have been used, a long-term passive measurement method for the emission of (α particles) with the CR-39 detectors, LR-115typeII and a method for measuring the activity with a fast electronic device called RAD7. The results of the study showed that the lowest concentration of radon gas in samples of River water was 196 ±12 Bq.m^{-3} was in the sample No. W13 water of Garma River, and that the largest concentration was 16217 ±97 Bq.m^{-3} sample No. W9 from Al Khoura River. As for the radon gas concentration in groundwater wells, its highest concentration reached 22415 ±143 Bq.m^{-3} in sample No. W36 from Aldawajin well-2, and the lowest concentration was 682 ±46 Bq.m^{-3} in sample No. W24 in a well at Al-Barjisiah and the general average of radon gas concentration in all the study samples was 7320 Bq.m^{-3}, the annual effective dose of water was estimated and it was found that the highest value was 1.136 mSv.y^{-1} in sample No. W36 and this value falls outside the internationally approved limit By the World Health Organization WHO, 0.1 mSv.y^{-1} In general. It was found that radon concentrations in water samples of Rivers and groundwater wells selected from Basrah Governorate-Southern Iraq falls within the limits of the permissible value of 11000 Bq.m^{-3} for surface water and 20000Bq.m^{-3} for groundwater wells, according to the US Environmental Protection Agency EPA, with the exception of some samples of Rivers and underground wells, which have recorded values higher than that value, and they may pose a risk on the health of farmers in those areas.

تحديد تراكيز غاز الرادون ^{222}Rn في نماذج مياه الأنهار والآبار الجوفية في محافظة البصرة - جنوب العراق

مسطر عبد الله علي
قسم البيئة، شركة نفط البصرة، وزارة النفط، العراق

المستخلص - جمعت في هذه الدراسة 52 عينة من مياه طبيعية أخذت من مناطق منتخبة من (أنهار ، آبار جوفية) في محافظة البصرة - جنوب العراق للفترة من شباط – نيسان 2020 ، لتحديد تراكيز غاز الرادون ^{222}Rn المنبعث من العينات المنتخبة والوليد لعنصر الراديوم ^{226}Ra المشع الواقع ضمن سلسلة اليورانيوم ^{238}U وحساب الجرعة السنوية المؤثرة، لقد تم استخدام تقنية كواشف الأثر النووي الصلبة Solid state Nuclear Track Detectors SSNTDs، طريقة القياس السلبية طويلة الأمد لانبعاث جسيمات إلفا(α) من خلال الكاشفين CR-39 ، LR-115typeII وطريقة لقياس الفعالية بواسطة جهاز الكتروني سريع يدعى RAD7. أظهرت نتائج الدراسة إن اقل تركيز لغاز الرادون في عينات مياه الانهار 12 ± 196 Bq.m^{-3} كان في عينة رقم W13 مياه نهر الكرمة ضمن منطقة الدراسة، وان أعلى تركيز كان 16217 ±97 Bq.m^{-3} في عينـة رقم W9 من نهر الخورة.

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اما تركيز غاز الرادون في مياه الآبار الجوفية فقد بلغ أعلى تركيز له 22415 ±143 $Bq.m^{-3}$ في عينة رقم W36 من بئر الدواجـن رقم 2، واقل تركيز هـو 682 ±46 $Bq.m^{-3}$ في عينة رقم W24 في بئر البرجسية، وبلغ المعدل العام لتركيز غاز الرادون في جميع عينات الدراسة 7320 $Bq.m^{-3}$. قدرت الجرعة السنوية المؤثرة للمياه ووجد أن أعلى قيمـة لها 1.136 $mSv.y^{-1}$ في عينة رقم W36 وهذه القيمة تقع خارج الحد المعتمد عالميا من قبل منظمة الصحة العالمية WHO والبالغ 0.1 $mSv.y^{-1}$. وبصورة عامة وجد إن تراكيز غاز الرادون في عينات مياه الأنهار والآبار الجوفية المنتخبة من مناطق محافظة البصرة - جنوب العراق يقع ضمن حدود القيمة المسموحة والبالغة 11000 $Bq.m^{-3}$ للمياه السطحية و 20000 $Bq.m^{-3}$ لمياه الآبار الجوفية حسب وكالة حماية البيئة الأمريكية EPA باستثناء بعض من عينات الأنهار والآبار الجوفية فقد سجلت قيم أعلى من تلك القيمة، وأنها قد تشكل خطورة على صحة المزارعين في تلك المناطق.

كلمات مفتاحية: غاز الرادون، آبار جوفية، كواشف الأثر النووي الصلبة، الكاشف CR-39 و LR-115، جهاز RAD7.

Introduction

Radon ^{222}Rn is a colorless, tasteless and odorless gas. It is one of the chemically inert gases, the heaviest gases in nature. It is nine times heavier than air, emitting alpha minutes and cannot be detected by human senses. Radon gas is of natural origin resulting from the dissolution of the radioactive element radium, which returns to one of the three most important radioactive chains of natural radiation chains, which is the uranium-238 chain.

This element belongs to each of the natural radioactivity chains, the uranium-238 series, the thorium-232 and the uranium-235 series. Radon contains three isotopes, the first called ^{222}Rn, its half-life of 2.8d, generated from the dissolution of ^{226}Ra within the chain of ^{238}U, and the second is ^{220}Rn, its half-life is 55.65 S resulting from ^{228}Ra of the ^{232}Th series and the third ^{219}Rn has a half-life of 4S in the ^{235}U series. The first isotope is called Radon, and the second is Thoron.

The third is called the actinon (Hasan *et al.*, 2011; Shweikani, 2008; Porstend rfer *et al.*, 1990; WHO, 1987). Rn is naturally present almost everywhere, like radium in the Earth's crust, and the behavior of its atoms may not be differs from the behavior of the atoms of other gases, as it is similar to it, and has the property of diffusion and influence from small openings and cracks. Radon gas, with radionuclides resulting from its dissolution, contributes about 75% of the annual effective dose equivalent to that of the general population receives separately from all ground sources.

The increasing interest in studying exposure to low doses of radiation from the natural radioisotopes uranium and its decay chain products, such as gas, has emerged, which contributes 50% of the average effective radiation dose from natural radiation to almost the general population.

Since radon is an unstable inert gas, it continues with radiation, generating what is called Radon daughter, which is (^{218}po, ^{214}Bi, ^{214}pb, ^{214}po). Therefore, the effect of ^{222}Rn is indirect healthily, meaning that it does not cause lung cancer, but rather its short life span causes lung cancer. Because it is deposited in the airways and releases alpha particles, which may increase the risk of lung cancer, and this has been proven by many studies that have confirmed a close relationship between exposure to radon gas and the incidence of lung cancer cases (Subber *et al.*, 2011; Badham *et al.*, 2010; Bou-Rabee *et al.*, 2009; NRC, 1994; Hursh *et al.*, 1965).

Radon gas in water, as its solubility increases according to the decrease in its temperature, so when cold groundwater passes through the rocks of the subterranean soil or when it penetrates through the pores of the rock, it dissolves radon and pulls it from the rocks, in addition to the role of groundwater in dissolving the element radium that dissolves Radon directly from it, and when the water is heated or moved, a good amount of radon is released to the outer medium, and the radon content in the water is directly proportional to the water temperature because hot water has the ability to Beer dissolves mineral elements from rocks and soil.

Due to the increasing interest in radon gas, its methods of measurement have diversified in the environment, and Solid State Nuclear Track Detectors SSNTDs are one of the most important methods for measuring the concentration of radon gas due to their availability, accuracy of results, low cost, lack of need for complex systems as well as their sensitivity. There are two methods used in this study to measure radon gas (Nikezic and Yu, 2004; USEPA, 1999; Halbert *et al.*, 1990).

The first method is passive long term, which is the Technique of solid nuclear trace detectors SSNTDs, and the second method is effective through a fast electronic device called RAD7. This study aims to determine the concentrations of radioactive radon gas and the annual effective dose in samples from River water and groundwater wells in Basrah Governorate, Iraq.

Materials and Methods

Description of the Area:

The study area is located in the city of Basrah, in the south of the Republic of Iraq. Figure (1) between two latitude circles (31.20 ' - 29 ˚50') north and long arc (48.30° '- 46.40') to the east. With an area of 19,070 km^2, the Governorate of Basrah occupies 4.4% of total area of Iraq., is inhabited by about 3.5 million people. Its geological layers rich in oil structures distinguish Basrah Governorate, as acquires the largest oil wealth in Iraq.

The importance of the study area as a source of economic wealth for Iraq is that it is rich in water and animal resources and is considered one of the tourist areas in Iraq because of its attractive landscapes, as well as it contains the largest giant oil fields in the region.

Figure 1. Map of Iraq, showing the study area.

Sample Collection and Preparation:

Samples were collected (underground well water, River water) for the period from February - April 2020 from selected areas of Basrah Governorate - Southern Iraq. The number of samples collected were 52 samples distributed within the study area. The water samples were brought by two-liter sealed plastic bottles and at different depths from the surface and groundwater wells. The selected areas for the study were sealed and closed, the pH was measured using a PH meter type HI-8915, then each sample was placed in a centrifuge of American origin Tuttingen with a number of 3600 revolutions/minute to separate foreign materials such as impurities and suspended sediments, then they were placed in RAD7 measuring instrument vial as in Figure (2) to start the measurement process for each sample individually. SSNTDs have also used the indirect passive measurement method to measure the radon gas concentrations emitted from the samples under study as another method.

Irradiation Process:

Pieces of solid nuclear trace detectors, the two types LR-115 typeII and CR-39 with dimensions 1.5cm x 1.5cm, were prepared and placed in the irradiation chamber, which is a sealed plastic cylinders, each one of them height 10 cm and its diameter 4 cm were affixed Solid nuclear traces detectors (SSNTD) at the bottom of the cover of each cylinder from the inside so that a distance is 9 cm from the sample placed at the bottom of the cylinder at a height of 1 cm, and they are closed with seals to ensure that the samples are not contaminated from external sources, taking into account the distance between the sample surface and the sealing surface The bottom is fixed, and the samples are left for 90 days for irradiation (Fig. 2).

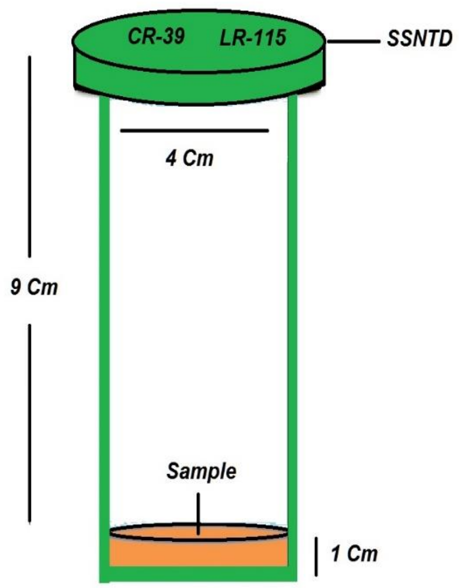

Figure 2. Dimensions of an irradiation chamber used to measure radon gas in the study models using the solid nuclear effect detectors Technique SSNTDs

Chemical etching and Microscopy:

After the expiration of the prescribed period of time for irradiation, the nuclear detectors were raised to start a new stage, which is the stage of showing the nuclear effects through the chemical skimming process of the nuclear reagents CR-39, LR-115 type II, I used the Sartorius sensor scale of German-made accuracy of ±0.01 to calculate the weight. The mass of NaOH used in the preparation of the chemical skimming solution of the aqueous NaOH solution (2.5 N at a temperature of 60 ±1 °C within 2h) of the reagent LR-115, as for the reagent CR-39 (6.25 N at 70 ±1 °C during 7 h).

The nuclear reagents were suspended to be placed inside the NaOH skimmer solution for the aforementioned period of each detector above inside a water bath of the type (memmert) which is German-made and the temperature ranges from 0-100°C and contains a thermometer to measure the temperature and a circular disk on which different temperatures are fixed. The tablet was rotated to obtain the required temperature. After the skimming time was completed, the reagents were extracted, washed with distilled water and dried with filter paper (Misdaq and Satif, 1995). To obtain the required standardization the following relationship was used (Durrani and Ilic, 1997).

$$N = \frac{M(g)}{V} \times \frac{1000}{M_W}$$

Whereas:
N: normality required
M (g): the mass of the substance measured in grams (gm).
V: The volume of distilled water used, measured in milliliters (ml).
M_W: the molecular mass of the solute equal to 40g for the substance (NaOH) used in the work, so that the relationship becomes as follows:

$$N = \frac{M(g)}{V} \times 25$$

After the completion of the chemical treatment process, the traces recorded on the LR-115 type II and CR-39 reagents are detected at this stage using an optical microscope according to an appropriate magnification power. In Figure (3) photographs of the model of alpha particles traces recorded on the detectors.

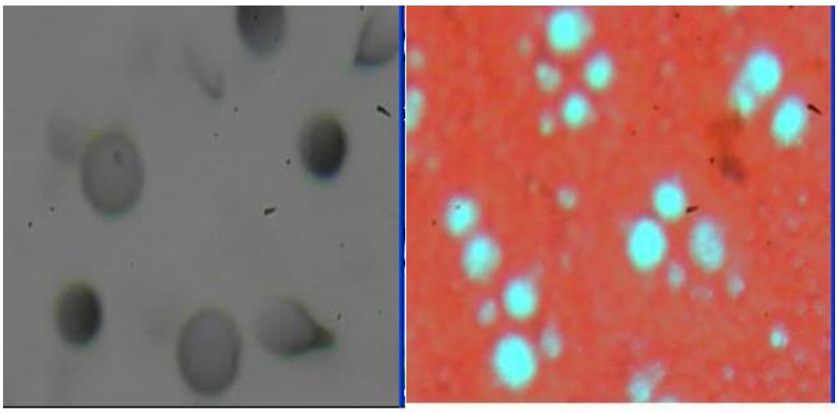

Figure 3. Shows the traces of alpha particles recorded on the LR-115 nuclear trace detectors on the left and CR-39 on the right.

Accounts:

For the purpose of measuring the concentrations of radon gas in the study samples (River water, groundwater wells) using the SSNTDs technique, the total number of effects was calculated, which depends on the calculation of the total probability of the alpha particles emitted from radon and thoron and their births that appear on the reagents LR-115typeII, CR-39, the total effects count was calculated from the relationship:

$$\rho = \frac{Number\ of\ Tracks}{irradaition\ time\ x\ Field\ area}\ (track/cm^2.s)$$

In order to determine the radon emission rate from the different study samples, the effect intensity is calculated from the following two equations (Misdaq and Eharti, 1997).

$$\rho_G^{CR} = A_c^{222}(Bq.cm^{-3})\left[\sum_{i=1}^{3} k_i\, P_i^{CR}\, R_i + \frac{A_c^{220}}{A_c^{222}} \sum_{i=1}^{4} k_i\, P_i^{CR}\, R_i\right] \quad (1)$$

$$\rho_G^{LR} = A_c^{222}(Bq.cm^{-3})\left[3P^{LR}\,\Delta R + 4P^{LR}\,\Delta R\,\frac{A_c^{220}}{A_c^{222}}\right] \quad (2)$$

Whereas:

^{220}Ac Thoron concentration.

^{222}Ac: Radon concentration detectors density.

Ri: The range of alpha particles in the detector.

ki: Branching ratio of α-particles from the emission plane.

Dividing equations 1 and 2 we get:

$$\frac{\rho_G^{CR}}{\rho_G^{LR}} = \frac{\sum_{i=1}^{3} k_i\, P_i^{CR}\, R_i + \frac{A_c^{220}}{A_c^{222}} \sum_{i=1}^{4} k_i\, P_i^{CR}\, R_i}{3P^{LR}\,\Delta R + 4P^{LR}\,\frac{A_c^{220}}{A_c^{222}}} \quad (3)$$

And when both are measured ρ_G^{CR}, ρ_G^{LR} and each P_i^{CR}, P_i^{LR} is calculated, the ratio between ^{220}Ac/^{222}Ac is found:

$$\frac{A_c^{220}}{A_c^{222}} = \frac{\sum_{i=1}^{3} k_i\, P_i^{CR}\, R_i - 3P^{LR}\Delta R\,\frac{\rho_G^{CR}}{\rho_G^{LR}}}{4P^{LR}\Delta R\,\frac{\rho_G^{CR}}{\rho_G^{LR}} - \sum_{i=1}^{4} k_i P_i^{CR} R_i} \quad (4)$$

RAD-H2O Technique:

RAD7 Technique is one of the important and advanced technologies to quickly measure the concentrations of radon and Thoron gas in the air, water and soil. Electronic circuits and turns into digital form amplify the alpha energy resulting from the decomposition of Polonium ^{214}Po and Polonium ^{218}Po into an electrical signal instantly, and the signal. Radon gas was measured for the collected samples by a rapid electronic RAD device that works according to the energy of alpha particles emitted from radon and thoron.

The measurement process for water samples is done through RAD-H2O, attached to RAD7. Figure (4), where the device measures radon gas in water with high accuracy and a wide range of concentrations to record readings for an hour after taking the sample or often the recorded readings are real, and the device is distinguished by its ability to determine the alpha particle energy electronically, this enables it to distinguish between the isotopes of radon elements polonium ^{218}Po and polonium ^{214}Po and between radon and thoron, and the purging of the RAD7 reagent must be dried with fresh air for ten minutes by connecting the drying unit in a closed loop with RAD7 so that the outside air passes through the Desiccant and returns to the inside. It is always noted that the air flow is the same way through the Desiccant, if the humidity is less than 6%, we start the test where we put the system on the Grab to extract the radon from the sample and the pump starts to work for five minutes during which the radon is drawn from the sample and delivered to the measuring room to the RAD7 and after that stops RAD7 and waits for more than 5 minutes until reaching equilibrium.

The RAD7-H2O system reaches this equilibrium state within about 5 minutes, after which no more radon can be extracted from the Water. The extraction efficiency or the percentage of radon removed from the water to the air loop is very high about 94% for a 250 ml sample. The exact value of the extraction efficiency depends to some extent on the ambient temperature, but it is always well above 90%.

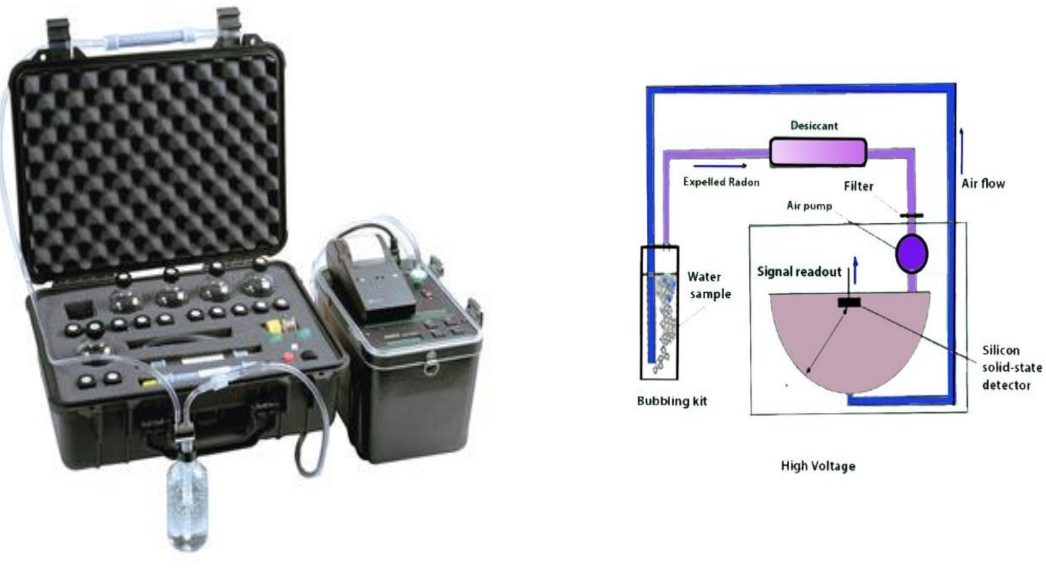

Figure 4. On the right is a picture of the RAD7 device used to measure radon gas in water models, and on the left is the RAD-H2O diagram.

The RAD7 detector converts the alpha radiation directly into an electrical signal. RAD7 has the ability to tell the difference between the new radon blocks and the old radon blocks remaining from the previous tests (Subber and Ali, 2012). This process is repeated for 4 cycles of 5 minutes each until the total test duration is 30 minutes. When each operation is completed, RAD7 prints information including average radon concentration, standard deviation, humidity and temperature reading inside the device, date and time of test, procedure in addition to operating number and number of cycles and then gives the graph of four cycles and the accumulated spectrum

The annual effective dose D_w was calculated in the case of exposure to radon gas in water from the following equation (Somashekar and Ravikumar, 2010).

$$D_w = C_w\, C_{Rw}\, D_{cw}$$

Whereas:
D_w: Annual equivalent dose ($Sv.y^{-1}$).
C_w: Radon concentration in water ($Bq.L^{-1}$).
C_{Rw}: General per capita consumption (1095 $L.y^{-1}$).
D_{cw}: Dose conversion factor for radon (5 * 10-9 Sv Bq^{-1}).

Results and Discussion

In this study, radon concentrations and the annual effective dose were determined for samples of water from Rivers and underground wells, which have a crucial relationship with the life of living organisms.

Table (1) shows sample numbers from the River water were S1-S15 and from ground wells were S16-S52. Radon concentrations, annual effective dose and carcinogenic probability by using Solid State Nuclear trace Detectors through the CR-39, LR-115typeII and the fast electronic method through the RAD7 device were listed in the Table (1). It is apparent from Table (1) that the general average of radon concentration in all the samples was 7320 $Bq.m^{-3}$, and that the lowest concentration of the gas in the River water was 196 ±12 $Bq.m^{-3}$ (sample, S13) in Al-Garma River. The highest concentration of gas is 16217 ±97 $Bq.m^{-3}$ from Al-Khora River sample No. (W9), while the highest concentration of radon gas in the groundwater well samples (W14-W52), reached 22415 ±143 $Bq.m^{-3}$ (sample, W36) in Aldawajin-2 well water, and the lowest concentration was 682 ±4625 $Bq.m^{-3}$ (sample, W24) in Al-Barjisia well-1. Figures (5 and 6) showed the relationship between the emitted radon concentration from samples of River water and ground wells measured by SSNTSs and RAD7 techniques.

A close look at the results of the first (passive) and second (active) measurement methods, indicates a difference in the results between the two techniques, so a relationship between the two methods was established (Fig. 7). This difference is due to a long-term and short-term measurements. For SSNTDs, the measurements were for a period of 90 days, while that of RAD7 were for 1 hour. A high percentage of radon was not recorded in the River except for samples W9 and W4. This is an expected result that the surface water that feeds the Rivers traverses a long distance of more than 1500 km from Turkish territory before entering the study area in Basrah. This leads to a decrease in the radon concentration during its long-distance journey or when storing. However, the increase in the radon concentrations of the two samples W4 (Rabat River) and W9 (Al-Khora River) which are due to contamination of these Rivers with wastewater. It was also found that 5 samples out of 39 samples, or 13%, belong to groundwater wells, in which radon exceeded the limits of its concentrations.

Table 1. Radon concentration ($Bq.m^{-3}$) and annual effective dose ($\mu Sv.y^{-1}$) in Samples of River water and groundwater wells in the studied stations in the areas of Basrah city - Southern Iraq.

Sample NO.	Sample Name	Rn concentration $Bq.m^{-3}$ using (RAD7) Technique	Rn concentration $Bq.m^{-3}$ using (SSNTD) Technique	Effective dose $\mu Sv\ y^{-1}$
W 1	Al-Ashaar River	191±12	246±15	0.01
W 2	Al-Shafi River	210± 26	322±23	0.01
w3	Almueaqil River	345 ±21	465±28	0.02
W 4	Alrubat River	11370±682	12152±729	0.61
W 5	Abu Alkhsieb River	329±20	435±26	0.02
W 6	Shatt Al-Basrah	410±25	496±30	0.02
W 7	Qurna River	210±13	315±19	0.01
W 8	Al-Ezz River	196±12	258±15	0.01
W 9	Al-Khora River	14201±85	16217±97	0.81
W 10	Al-Fao River	193±12	±16 273	0.01
W 11	Qurna River	182±11	±16 265	0.01
W 12	Al-Khandaq River	762±46	893±54	0.04
W 13	Al-Garma River	175±11	196±12	0. 01
W 14	North Lehais Well	2135±128	3152±189	0.15
W 15	Lehais-1	1114±67	1861±112	0.1
W 16	Lehais-2	3266±196	4741±284	0.23
W 17	Lehais-3	1879±113	2522±151	0.12
W 18	Lehais-4	7493±450	9146±549	0.46
W 19	Lehais South-1	5294±318	6128±368	0.30
W 20	Lehais South-2	8432±506	9158±550	0.46
W 21	Lehais South-3	10115±609	11342±681	0.57
W 22	Lehais South-4	9313±559	10612±637	0.53
W 23	Lehais South-5	11120±667	11730±704	0.59
W 24	Alburjsia-1	587±35	682±46	0.03
W 25	Alburjsia-2	687±41	716±43	0.04
W 26	Alshaeiba	736±44	795±48	0.04
W 27	Kasbah zubair	2316±139	2814±169	0.14
w28	Zubair-1	4518±271	4913±295	0.24
w29	Zubair-2	6251±375	6784±407	0.34
W30	Khor Al-Zubair-1	3193±192	3647±219	0.18

Sample NO.	Sample Name	Rn concentration Bq.m^{-3} using (RAD7) Technique	Rn concentration Bq.m^{-3} using (SSNTD) Technique	Effective dose μSv y^{-1}
W31	Khor Al-Zubair-2	2586±155	2978±179	0.15
W32	Umm Qasr	832±50	994±60	0.05
W 33	Safwan-1	2643±159	3729±224	0.18
W 34	Safwan-2	4728±284	5476±329	0.27
W 35	Aldawajin-1	14612±877	15213±913	0.76
W36	Aldawajin-2	20130±1028	22415±1345	1.136
W37	Aldawajin-3	17342±1040	18120±1087	0.91
W38	Aldawajin-4	12612±757	13216±793	0.66
W 39	Khoissat-1	613±37	738±50	0.03
W40	Khoissat-2	720±43	854±57	0.04
W41	Alrafidia-1	15471±928	15987±959	0.80
W 42	Alrafidia-2	13621±817	14217±853	0.71
W 43	Alnajmiu alsharqiu-1	12542±753	13211±793	0.66
W 44	Alnajmiu alsharqiu-2	9631±398	10416±625	0.52
W 45	Alnajmiu algharbiu-1	11572±694	13107±786	0.66
W 46	Rafithia-1	18913±1135	19103±1146	0.96
W 47	Rafithia-2	19120±1147	20119±1207	1.01
W 48	Rafithia-3	19641±1178	21186±1271	1.06
W 49	Rafithia-3	20103±1206	21842±1311	1.10
W 50	Alnajmi-1	17163±1030	19101±1146	0.96
W 51	Rafithia-3	20127±1208	21693±1302	1.09
W 52	Rafithia-3	18735±1124	19783±1187	0.99

The discrepancy in the results of the groundwater wells models differed due to the differences in the locations of the wells and hence the difference in the nature of the geological composition of the areas, as some of the areas may have a high radon concentration due to the nature of the rocks through which the water passes and their radium content, and that the process of radon liberation from the middle in the geological environment generally depends on the abundance of the parent isotope U-238 in the rocky ocean, meaning that the concentration of radon is directly proportional to the concentration of uranium in the rocky ocean of water, and the reason is likely to be the presence of water resources in the uranium-rich soil, and the study area is an oil lake where there are the largest gigantic oil fields in the region, and the geological composition of oil fields contains large amounts of naturally occurring radioactive materials that may have a pronounced effect on the result. The study area had previously witnessed intensive warfare operations during the Second Gulf War in 1991 and the occupation of Iraq in 2003, and the associated use of depleted uranium-coated missiles. The present results were compared with results of other studies in the world which were summarized in the source (Misconi and Navi, 2010), in Iran (Hamadan) 364 Bq.m^{-3}, Syria (Damascus) 45 Bq.m^{-3}, Jordan (north), 144 Bq.m^{-3}, Saudia Arabia (Al-Jauf) 30 Bq.m^{-3} and Yemen (Hodeidah) 42 Bq.m^{-3}, and the results of the study for radon 222Rn in River water and groundwater wells were compared with the results of studies conducted by other workers in Iraq using solid nuclear trace reagents technology (Abdul Ameer and Subber, 2013), SSNDs by Subbe, eat all and it was found that there is no difference between the results of the previous works and the present study, as close concentrations of radon were recorded with the exception of specific samples in some of the studied sites. However, when comparing these results with the permissible concentration suggested by the US Environmental Protection Agency (EPA) indicted that the highest permissible radon concentration in the water is equal to 11000 Bq.m^{-3} (EPA, 1988), was found to be within the suggested limits except for some samples which exceeded this limit. The results of the study were also compared with samples of groundwater wells and found that they also fall within the normal gas concentration ratios.

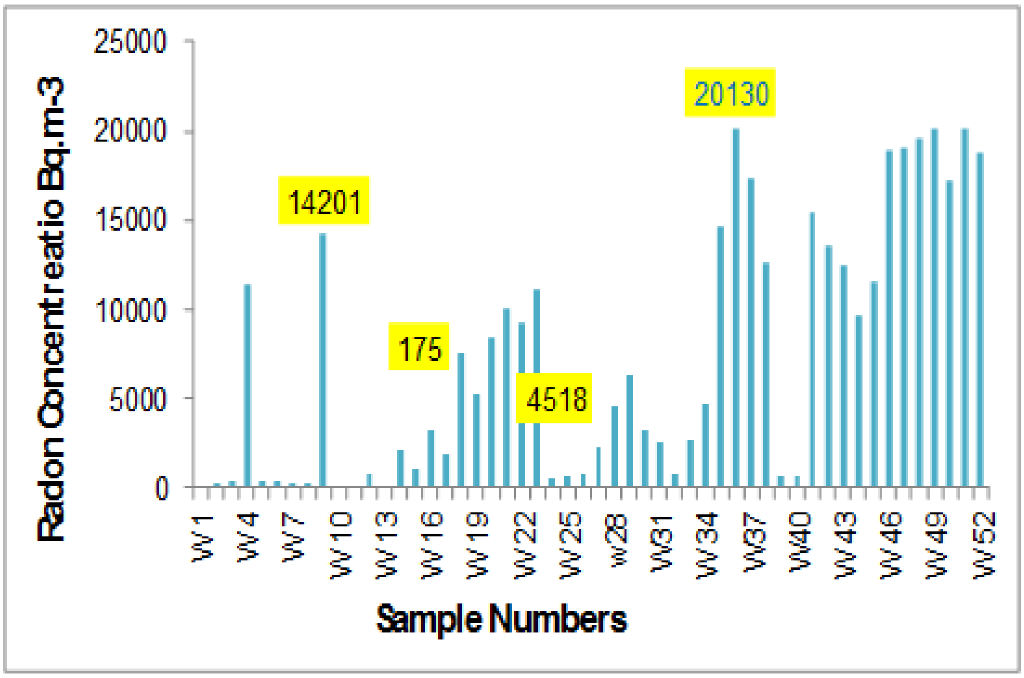

Figure 5. Radon concentration measured with RAD7 technique in water samples in the study area, in Basrah, Southern Iraq.

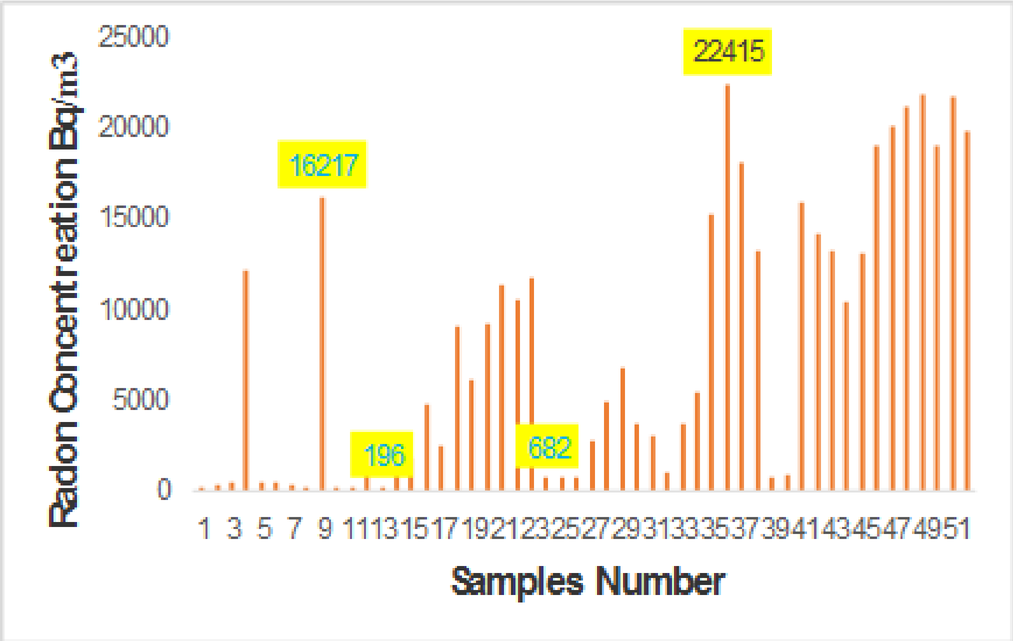

Figure 6. Radon concentration measured by SSNTDs in water samples in the study area, in Basrah, Southern Iraq.

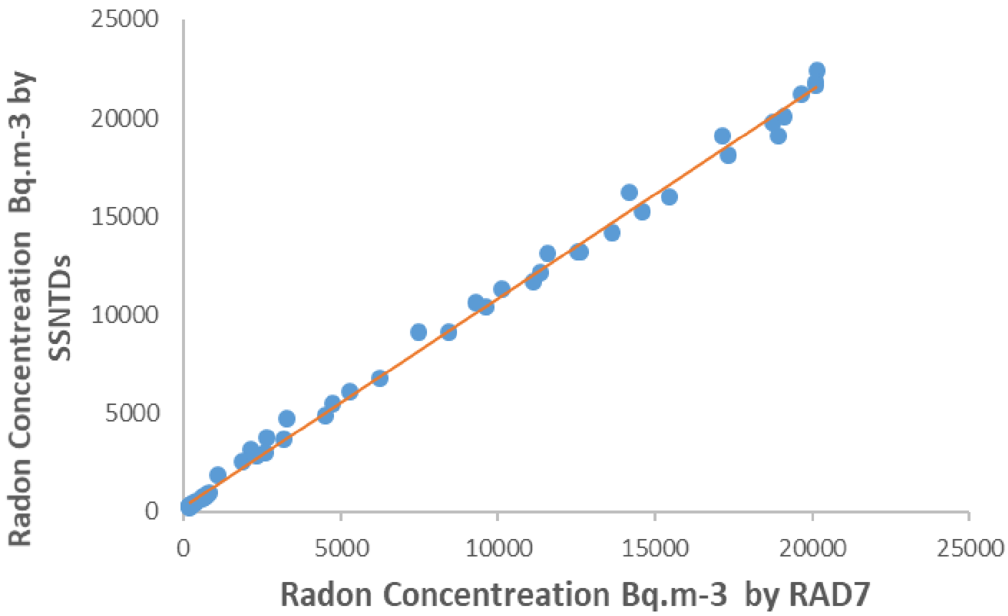

Figure 7. The linearity between (RAD7) Technique and (SSNTDs) Technique in the measurements of radioactive Radon gas annihilates from water.

Radon in groundwater, which ranges from 500-20000 Bq.m^{-3} (Ahad, 2004), with the exception of 4 samples that occurred outside those permissible limits, and the annual effective dose values for water reached its highest dose in Rivers (0.816 mSv.y-1) and was recorded in the sample that has the highest concentration of radon 16217 ±97 Bq.m^{-3}, and its highest dose in groundwater wells was 1.136 mSv.y^{-1}. These values are high compared to the internationally recommended limits (0.1 mSv.y^{-1}) (WHO, 2004).

These concentrations and doses of radon gas in some samples of River water and groundwater wells, may pose a risk to the health of those drinking it in the event that no appropriate measures are taken to educate people for not consuming this contaminated water.

Conclusion

Throughout this study, the concentrations of radon gas emitted from samples (River water, groundwater wells) in Basrah Governorate - Iraq were determined by means of solid nuclear trace detectors technology SSNTDs of the two types (CR-39, LR-115typeII) and the effective measurement method, the fast electronic method through the RAD7 device. The study conclude that the average concentration of radon gas for all models represented by the water under study is 730 Bq.m^{-3} and that the lowest concentration of River water samples is 196 ±12 Bq.m^{-3} that appeared in the sample of Al-Garma water No. W13. The largest concentration is 16217 ±97 Bq.m^{-3} in the Al-Khor water sample W9. The highest concentration of radon gas in groundwater well is 22415 ±1345 Bq.m^{-3} in a Aldawajin well-2 samples (W36), and the lowest concentration was In the sample W24 of the Burjisia-1 well. The values of the annual effective doses of water reached the highest dose in River water 0.81 mSv.y^{-1}, and it was recorded in the sample W9 and in groundwater wells, its value was 1.13 mSv.y^{-1} in sample W36, and these values are high compared with the internationally recommended limits in water 0.1mSv.y^{-1}, and they may pose a risk to the condition of people in the study area with the absence of appropriate measures taken. This study provides an important database on the concentration of radon gas and the effective doses in water samples in Basrah Governorate - Republic of Iraq.

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