ISSN: 0975 -8542

Journal of Global Pharma Technology

Available Online at: www.jgpt.co.in

RESEARCH ARTICLE

Radon Concentration Measurements and Physiochemical Parameters of Sawa Lake Water-Samawa City, South of Iraq

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Abstract

Radon concentration measurements were carried out for 85 water samples collected from Sawa Lake in Samawa city, Southern part of Iraq, in order to obtain the levels of radon concentration in this area and for enhancing the national radon survey. For the measurements, a continuous radon monitoring detector (RAD7) was used. The period of assessment was two months (from December, 1st 2018 to February, 1st 2019) during the winter season. Radon activity concentrations were ranged from (0.111 Bq/l) to (0.965 Bq/l), while the average value was (0.396 Bq/l), the annual effective dose (AED) of inhalation was estimated from the measured radon concentrations and is found to be ranged from (0.080784 μSvy^{-1}) to (0.917136 μSvy^{-1}) with a mean value of (0.325764 μSv/y). Physiochemical parameters such as pH, EC, TDS, resistivity, and turbidity were determined samples and the correlation between these parameters and radon concentrations was conducted. The results have revealed that the radon concentration and the associated annual effective dose does not pose any kind of health hazard to the population and tourists, and were found to be well within the reference levels as reported in the ICRP 2000.

Keywords: *Radon, Sawa Lake, Samawa City, Physiochemical Parameters, RAD7Detector.*

Introduction

According to the origin of radioactivity, there are two major sources of radiation, natural and man-made sources. The natural sources classify into cosmic sources (originated outside the earth) and terrestrial sources (produced by NORM within the earth). All of these sources cause external and internal exposure to the environment [1]. The natural background radiation exposure to human beings comes from air, water, soil, rocks, and consuming of plants and animals. The main contribution to the total background radiation comes from radon (^{222}Rn) gas (about 54%) [2]. Radon is radioactive gas, with a half-life of (3.82) days. It is naturally occurring, an odorless, tasteless, colorless, and a chemically inert noble gas.

^{222}Rn produced continuously from the natural decay of the uranium-238 radionuclides, which present in most soils, rocks, and water all over the earth. It is disintegrated by emitting alpha particle into a series of short-lived progenies produced out of which polonium-218 (^{218}Po) and polonium-214 (^{214}Po) that emit high-energy alpha particles which are highly effective in damaging tissues [3].

In recent decades, high interesting has been paid to radon, especially to the issues associated with intaking radon and its products by human being either by inhalation or ingestion. The greatest health hazard comes from the inhalation of radon progenies (solid aerosols) that are formed during the radon decay. Because of these radionuclides (^{218}Po and ^{214}Po) are alpha emitters, the serious health risk of these products is due to its disintegration within the human body releasing high energy alpha particles, which can damage the living cells of inner tissues such as lung tissue and lead eventually to lung cancer over the lifetime [4,5].

However, radon is released naturally in surface and underground water as a result of decay process of the naturally occurring radionuclides (^{238}U and ^{232}Th) which exist at variable concentrations in the surrounding geological formations (soils, rocks) [6,7]. Airborne radon that dissolved into water may also be regarded as a source of radon in water [8]. Radon can be dissolved and accumulate in the underground water mostly from underground sources, such as wells, and springs. When water containing radon is used or exposed to the air, radon gas escapes from the water into the atmosphere. It dissolves in water, depending on the temperature of the water. According to the U.S. Environmental Protection Agency, 1000 pCi/l of radon gas concentration in water increases its concentration in the air by 1 pCi/l [9]. It is released from the water and mixes with atmospheric air. Thus, radon from water contributes to the total inhalation risk associated with radon in indoor and outdoor air.

In view of this, the present work was made to measure the concentration of radon in the water samples of Sawa Lake collected from different positions. Because of the high salinity of the lake water which it is not suitable for human use, the annual effective dose due to inhalation which received by individuals who live around the lake and tourists has been estimated. Physiochemical parameters such as PH, TDS, electrical conductivity, turbidity, and resistivity of the samples were measured in order to asses the quality of the lake water, and correlation analysis between radon concentration and all of these parameters were done.

Study Area

Sawa Lake is a natural water body created almost 10,000 years ago in the desert environment northwest of Samawa City, the capital of Al-Muthanna Province - Southern part of Iraq, Fig. (1). It is located approximately between longitudes (44° 59′ 13″) - (45° 11′ 68″) east and the constituencies of latitudes (31° 17′ 24″) – (31° 20′ 17″) north and covers an area about (5,048) km^2, with an elevation of about 16 m above the sea level. It is a strange lake in the south of Iraq and characterized by the highest salinity value among the Iraqi inland waters.

It is supplied with water mainly from the groundwater that flows out through three geological cracks in the bottom of the lake, and secondary from the seasonal rains in the area. It is believed that of marine origin water due to the mixing of Dammam formation water (meteoric and rich with CaSO4) with Euphrates formation water (marine origin) [10]. Furthermore, the water of the lake is colorless and has an unlikable taste because of the presence of dissolved sulfur compounds, hydrocarbons materials and over saturated with calcite, dolomite, aragonite, gypsum, anhydrite minerals with a high concentration of salts. The climate of the study area is dry, hot summer and a cool winter with medium humidity.

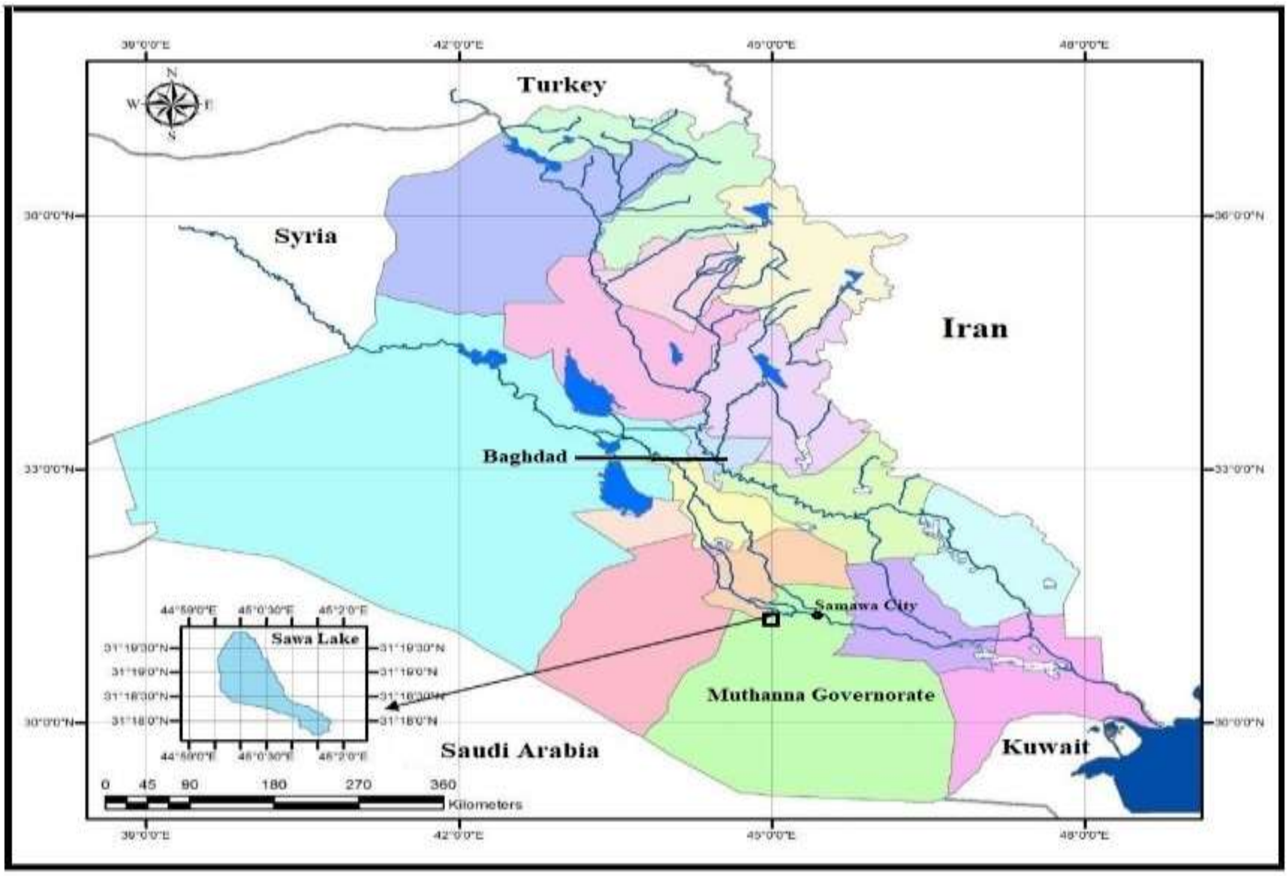


Figure 1: Map of Iraq Showing the location of Sawa Lake in Al-Muthanna Province

Materials and Methods

Water Samples Collection and Preparation

A total of (85) water samples were collected from the Sawa Lake during the winter season from December, 1st 2018 to February, 1st 2019. Plastic bottles with a capacity of 1.5 L were used for samples collection with a label on each one shows the number of sample and date of collection, the samples were taken at a depth between (20-30) cm below the water surface, the bottles filled completely and sealed under water. The position of each sample is determined and documented by using GPS portable device (The Global Positioning System). The geographical coordinates that obtained previously with helping of the GPS are used later to draw a map shows the location of each sample within the lake body. Fig. (2) illustrates the positions of samples in the lake.

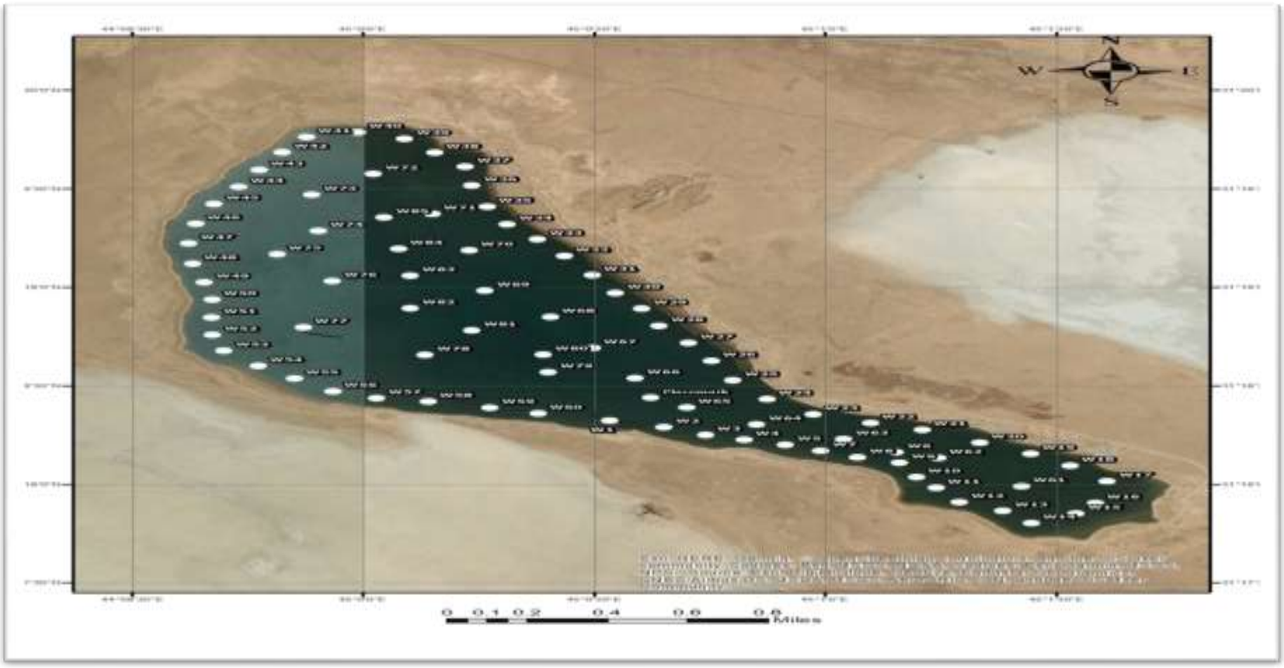


Figure 2: The Positions of the Water Samples at the lake

Measurements of Radon Activity

The measurements of radon concentration in Sawa Lake water were carried out by using RAD7 an electric radon detector (Durridge company Inc., USA). RAD H2O accessory is used to measure radon concentration in water, it is capable of obtaining the radon level within an hour of taking the sample over a wide range of concentrations (Fig. 3) [11]. The water samples were analyzed on the same day of collection to avoid the using of the time correction factors.

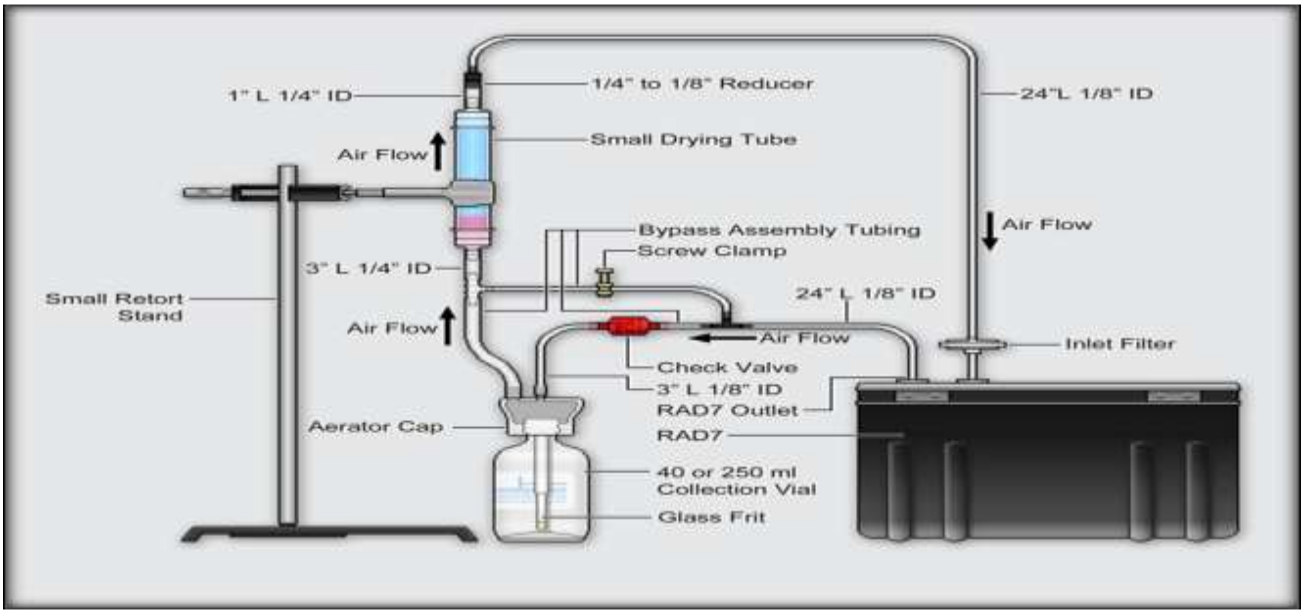


Figure 3: Schematic Diagram of the RAD7 Experimental System [11]

The effective dose due to radon concentration can be classified into two types, the dose from inhalation and the dose from ingestion. Because the salinity of the lake water exceeds high levels (about 27 ppt), so Sawa Lake water is not suitable for human consumption. Hence, in the present study, the annual effective dose received by a human being is estimated due to inhalation only (D_{inh}). The annual inhalation effective dose was calculated according to UNSCEAR publication (2000) [12]:

$$D_{inh}(mSv\ year^{-1}) = A_{RnW} \times C_{aW} \times F \times I \times DCF \quad (1)$$

Where A_{RnW} the concentration of radon in the water (Bq/l), C_{aW} is the ratio of radon concentration in the air to radon concentration in the water ($=10^{-4}$), F is the equilibrium factor between radon and its products (= 0.6), I is the mean outdoor occupancy time per individual (= 1760 h/y), and DCF is the dose conversion factor for radon exposure [9 ($nSv\ h^{-1}$) / ($Bq\ m^{-3}$)].

After collecting out the sufficient quantity of water from the lake, about 0.5 liter of water from each sample was used for the determination of physiochemical parameters. The pH values of all collected samples were measured by using digital pH meter (HI 98127 Waterproof pH Tester, Germany), total dissolved solids (TDS), electric conductivity (EC), and resistivity in the collected samples have been measured by using digital meters (HI 2300 EC/TDS Bench Meter, Germany). The turbidity of the samples was measured by using the digital meter (LP 2000 Microprocessor-based Bench Turbidity Meter, Germany).

Results and Discussion

The concentrations of radon in 85 water samples collected from Sawa Lake-Samawa City, south of Iraq, were determined by using RAD7 radon monitor, and the values are summarized in Table (1). The radon concentration in the study area varies between (0.111 ± 0.11 Bq/l) and (0.965 ± 0.38 Bq/l), with an average value of (0.396 ± 0.191 Bq/l).

The higher concentration of radon in water samples were observed in the samples W27, W28, W29, W30, W31, W32, and W33, collected at locations (N 31° 18.717' , E 45° 00.703'), (N 31° 18.804' , E 45° 00.639'), (N 31° 18.892' , E 45° 00.601'), (N 31° 18.970' , E 45° 00.544'), (N 31° 19.061' , E 45° 00.493'), (N 31° 19.159' , E 45° 00.433'), and (N 31° 19.244' , E 45° 00.375'), respectively. Which are on the east side of the lake. The reason for this is, these locations lie in the vicinity of the main cracks that provide the lake with water, and hence the radon activity is higher when compared to other locations of water samples. The other possible reason is maybe these locations lie in the direction of the wind that blowing in the north-west direction most of the year which contribute to drift water continuously toward these locations.

It can be seen from Table (1) that the minimum values of radon concentration have been observed in the samples W76, W77, and W78 located at (N 31° 19.032' , E 44° 59.932'), (N 31° 18.796' , E 44° 59.869'), and (N 31° 18.657' , E 45° 00.132'), which may be due to these locations are far from the main springs, as well as, they have shallow water depths which means that radon escapes easily from water. However, the observed wide variations in the radon concentrations in the present study may be attributed to the local geology, radionuclides such as uranium and radium dissolved in water and hydrogeological conditions at the aquifer [13].

From the present study, it is observed that all the collected samples have radon concentration very much less than the maximum contamination limit of (11.1 Bq/l) proposed by US Environmental Protection Agency (EPA) [14], or (20 Bq/l) proposed by WHO [15]. The annual inhalation effective dose due to the radon concentrations in the lake water are also summarized in Table (1).

The inhalation dose varies from (0.081 μSv/yr) to (0.917 μSv/yr) with an average value of (0.326 μSv/yr). From the results, it has been observed that the (D_{inh}) received by the public due to inhalation of radon is very much less than the (1 mSv/yr) recommended by WHO [15], and far below the (20 mSv/yr) recommended by ICRP [16]. Fig. (4) represents the variation of radon with different samples.

Table 1: Mean concentration of Radon and Annual Effective Dose from Different Water Samples Collected from Different Position

No.	Sample	Location		Low (Bq/l)	High (Bq/l)	Mean (Bq/l)	S.D.	Effective Dose
		Latitude	Longitude					(μSv/y)
1	W1	N 31° 18.321'	E 45° 00.531'	0.154±0.74	0.155±0.75	0.154	0.14	0.1463616
2	W2	N 31° 18.289'	E 45° 00.649'	0.00±0.55	0.464±0.93	0.124	0.12	0.1178496
3	W3	N 31° 18.250'	E 45° 00.739'	0.00±0.55	0.777±1.1	0.311	0.21	0.2955744
4	W4	N 31° 18.226'	E 45° 00.822'	0.00±0.55	0.311±0.84	0.124	0.12	0.1178496
5	W5	N 31° 18.200'	E 45° 00.911'	0.00±0.55	0.311±0.84	0.154	0.14	0.1463616
6	W6	N 31° 18.163'	E 45° 01.150'	0.154±0.74	0.464±0.93	0.363	0.25	0.3449952
7	W7	N 31° 18.170'	E 45° 00.988'	0.154±0.74	0.619±1.0	0.356	0.23	0.3383424
8	W8	N 31° 18.137'	E 45° 01.068'	0.00±0.55	0.311±0.84	0.216	0.16	0.2052864
9	W9	N 31° 18.108'	E 45° 01.159'	0.00±0.55	0.461±0.92	0.154	0.14	0.1463616
10	W10	N 31° 18.036'	E 45° 01.195'	0.00±0.55	0.464±0.93	0.351	0.24	0.3335904
11	W11	N 31° 17.981'	E 45° 01.238'	0.00±0.55	0.615±0.95	0.384	0.19	0.3649536
12	W12	N 31° 17.909'	E 45° 01.288'	0.308±0.84	0.769±1.06	0.532	0.29	0.5056128
13	W13	N 31° 17.865'	E 45° 01.382'	0.00±0.6	0.619±0.11	0.278	0.19	0.2642112
14	W14	N 31° 17.803'	E 45° 01.444'	0.151±0.72	0.523±0.82	0.319	0.17	0.3031776
15	W15	N 31° 17.850'	E 45° 01.541'	0.311±0.82	0.755±1.03	0.529	0.28	0.5027616
16	W16	N 31° 17.903'	E 45° 01.582'	0.181±0.82	1.07±1.11	0.576	0.28	0.5474304
17	W17	N 31° 18.015'	E 45° 01.608'	0.00±0.62	0.308±0.84	0.181	0.15	0.1720224
18	W18	N 31° 18.094'	E 45° 01.527'	0.00±0.63	0.562±0.91	0.301	0.22	0.2860704
19	W19	N 31° 18.155'	E 45° 01.442'	0.00±0.62	0.544±0.93	0.181	0.15	0.1720224
20	W20	N 31° 18.211'	E 45° 01.332'	0.00±0.61	0.186±0.72	0.111	0.11	0.1054944
21	W21	N 31° 18.276'	E 45° 01.208'	0.182±0.73	0.552±0.93	0.368	0.22	0.3497472
22	W22	N 31° 18.311'	E 45° 01.096'	0.187±0.74	0.378±0.82	0.264	0.19	0.2509056
23	W23	N 31° 18.354'	E 45° 00.972'	0.00±0.61	0.545±0.92	0.255	0.18	0.242352
24	W24	N 31° 18.432'	E 45° 00.872'	0.00±0.63	0.731±1.00	0.336	0.19	0.3193344
25	W25	N 31° 18.527'	E 45° 00.798'	0.00±0.62	0.357±0.82	0.432	0.18	0.4105728
26	W26	N 31° 18.627'	E 45° 00.751'	0.00±0.62	0.328±0.81	0.231	0.17	0.2195424
27	W27	N 31° 18.717'	E 45° 00.703'	0.370±0.82	1.65±1.24	0.924	0.36	0.8781696
28	W28	N 31° 18.804'	E 45° 00.639'	0.365±0.84	0.923±1.3	0.552	0.21	0.5246208
29	W29	N 31° 18.892'	E 45° 00.601'	0.328±0.82	0.912±1.31	0.602	0.23	0.5721408
30	W30	N 31° 18.970'	E 45° 00.544'	0.524±0.92	1.21±1.19	0.823	0.32	0.7821792
31	W31	N 31° 19.061'	E 45° 00.493'	0.437±0.86	1.51±1.33	0.891	0.33	0.8468064
32	W32	N 31° 19.159'	E 45° 00.433'	0.283±0.75	0.835±1.03	0.523	0.27	0.4970592
33	W33	N 31° 19.244'	E 45° 00.375'	0.427±0.86	1.23±1.24	0.711	0.28	0.6757344
34	W34	N 31° 19.320'	E 45° 00.310'	0.00±0.62	0.903±1.10	0.432	0.24	0.4105728
35	W35	N 31° 19.409'	E 45° 00.266'	0.00±0.62	0.189±0.82	0.113	0.11	0.1073952
36	W36	N 31° 19.517'	E 45° 00.233'	0.00±0.61	0.359±0.84	0.181	0.15	0.1720224
37	W37	N 31° 19.612'	E 45° 00.219'	0.00±0.62	1.14±1.14	0.341	0.22	0.3240864
38	W38	N 31° 19.684'	E 45° 00.153'	0.184±0.74	0.912±1.13	0.511	0.26	0.4856544
39	W39	N 31° 19.753'	E 45° 00.088'	0.185±0.74	0.370±0.82	0.223	0.17	0.2119392
40	W40	N 31° 19.786'	E 44° 59.986'	0.00±0.62	0.328±0.81	0.231	0.17	0.2195424
41	W41	N 31° 19.763'	E 44° 59.876'	0.154±0.73	1.24±1.62	0.637	0.23	0.6054048

42	W42	N 31° 19.684'	E 44° 59.824'	0.181±0.75	0.363±0.84	0.288	0.22	0.2737152
43	W43	N 31° 19.595'	E 44° 59.773'	0.00±0.62	0.599±0.93	0.363	0.23	0.3449952
44	W44	N 31° 19.509'	E 44° 59.729'	0.294±0.74	0.812±1.12	0.511	0.26	0.4856544
45	W45	N 31° 19.423'	E 44° 59.676'	0.255±0.72	0.714±1.01	0.431	0.24	0.4096224
46	W46	N 31° 19.323'	E 44° 59.636'	0.324±0.81	1.92±1.46	0.965	0.38	0.917136
47	W47	N 31° 19.222'	E 44° 59.621'	0.472±0.86	1.24±1.25	0.819	0.32	0.7783776
48	W48	N 31° 19.120'	E 44° 59.629'	0.238±0.74	1.07±1.19	0.632	0.24	0.6006528
49	W49	N 31° 19.026'	E 44° 59.655'	0.274±0.74	0.592±0.92	0.381	0.21	0.3621024
50	W50	N 31° 18.938'	E 44° 59.671'	0.00±0.62	0.236±0.74	0.154	0.14	0.1463616
51	W51	N 31° 18.847'	E 44° 59.670'	0.00±0.62	0.248±0.74	0.164	0.15	0.1558656
52	W52	N 31° 18.759'	E 44° 59.672'	0.00±0.62	0.258±0.75	0.164	0.15	0.1558656
53	W53	N 31° 18.678'	E 44° 59.697'	0.00±0.62	0.156±0.71	0.092	0.11	0.0875318
54	W54	N 31° 18.601'	E 44° 59.771'	0.00±0.61	0.163±0.72	0.123	0.12	0.1168992
55	W55	N 31° 18.536'	E 44° 59.849'	0.115±0.72	0.215±0.74	0.152	0.14	0.1444608
56	W56	N 31° 18.472'	E 44° 59.933'	0.00±0.62	0.124±0.72	0.095	0.11	0.0903830
57	W57	N 31° 18.437'	E 45° 00.027'	0.00±0.62	0.236±0.75	0.123	0.12	0.1168992
58	W58	N 31° 18.420'	E 45° 00.139'	0.00±0.62	0.167±0.72	0.121	0.12	0.1149984
59	W59	N 31° 18.387'	E 45° 00.273'	0.123±0.71	0.346±0.82	0.249	0.18	0.2366496
60	W60	N 31° 18.359'	E 45° 00.377'	0.00±0.62	0.218±0.74	0.128	0.12	0.1216512
61	W61	N 31° 17.990'	E 45° 01.422'	0.00±0.62	0.355±0.84	0.177	0.14	0.1682208
62	W62	N 31° 18.134'	E 45° 01.241'	0.00±0.62	0.358±0.84	0.184	0.15	0.1748736
63	W63	N 31° 18.228'	E 45° 01.038'	0.00±0.62	0.385±0.84	0.195	0.15	0.185328
64	W64	N 31° 18.303'	E 45° 00.850'	0.00±0.61	0.548±0.91	0.259	0.18	0.2461536
65	W65	N 31° 18.390'	E 45° 00.698'	0.00±0.62	0.184±0.74	0.143	0.13	0.1359072
66	W66	N 31° 18.538'	E 45° 00.587'	0.182±0.75	0.549±0.93	0.329	0.21	0.3126816
67	W67	N 31° 18.691'	E 45° 00.494'	0.00±0.62	0.733±1.00	0.292	0.19	0.2775168
68	W68	N 45° 00.494'	E 45° 00.403'	0.167±0.72	0.512±0.91	0.259	0.18	0.2461536
69	W69	N 31° 18.983'	E 45° 00.262'	0.222±0.74	0.555±0.91	0.369	0.22	0.3506976
70	W70	N 31° 19.187'	E 45° 00.228'	0.354±0.82	0.745±1.00	0.56	0.26	0.532224
71	W71	N 31° 19.372'	E 45° 00.147'	0.123±0.72	0.456±0.84	0.335	0.23	0.318384
72	W72	N 31° 19.575'	E 45° 00.021'	0.00±0.62	0.228±0.74	0.161	0.14	0.1530144
73	W73	N 31° 19.469'	E 44° 59.888'	0.00±0.62	0.311±0.82	0.288	0.19	0.2737152
74	W74	N 31° 19.286'	E 44° 59.902'	0.00±0.62	0.173±0.72	0.129	0.12	0.1226016
75	W75	N 31° 19.168'	E 44° 59.812'	0.366±0.81	0.548±0.91	0.403	0.23	0.3830112
76	W76	N 31° 19.032'	E 44° 59.932'	0.181±0.72	0.554±0.91	0.258	0.18	0.2452032
77	W77	N 31° 18.796'	E 44° 59.869'	0.00±0.62	0.174±0.74	0.085	0.11	0.080784
78	W78	N 31° 18.657'	E 45° 00.132'	0.00±0.62	0.239±0.74	0.141	0.13	0.1340064
79	W79	N 31° 18.568'	E 45° 00.398'	0.00±0.62	0.366±0.82	0.147	0.13	0.1397088
80	W80	N 31° 18.658'	E 45° 00.388'	0.00±0.62	0.311±0.82	0.153	0.14	0.1454112
81	W81	N 31° 18.780'	E 45° 00.233'	0.137±0.72	0.539±0.91	0.336	0.18	0.3193344
82	W82	N 31° 18.893'	E 45° 00.101'	0.00±0.62	0.492±0.84	0.262	0.17	0.2490048
83	W83	N 31° 19.058'	E 45° 00.100'	0.00±0.62	0.527±0.91	0.231	0.16	0.2195424
84	W84	N 31° 19.196'	E 45° 00.075'	0.00±0.62	0.431±0.84	0.188	0.15	0.1786752
85	W85	N 31° 19.355'	E 45° 00.043'	0.00±0.62	0.647±0.92	0.331	0.18	0.3145824
Mean value						0.34276471	0.19	0.325763576

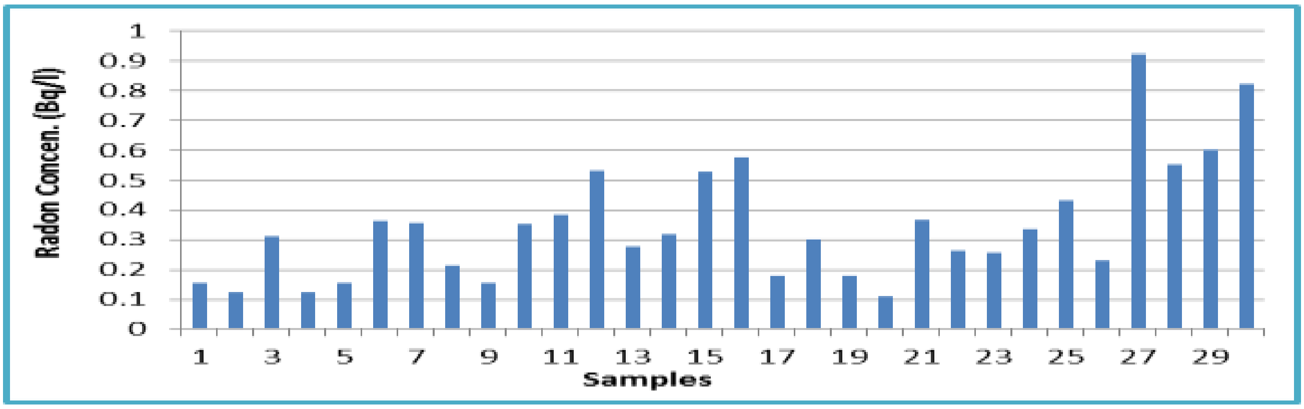
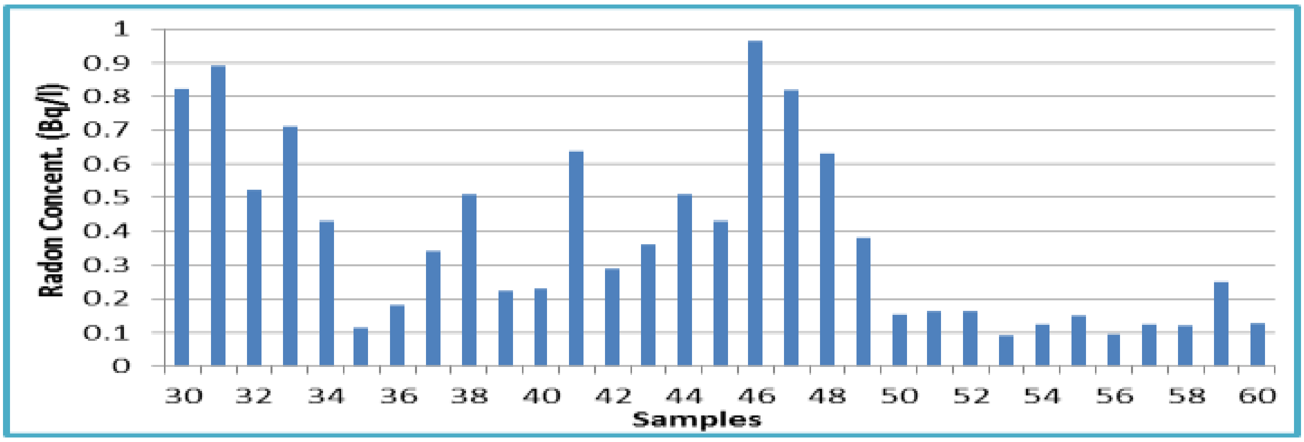


Figure 4: Bar Diagram Showing Variation in Radon Concentration of the Water Samples



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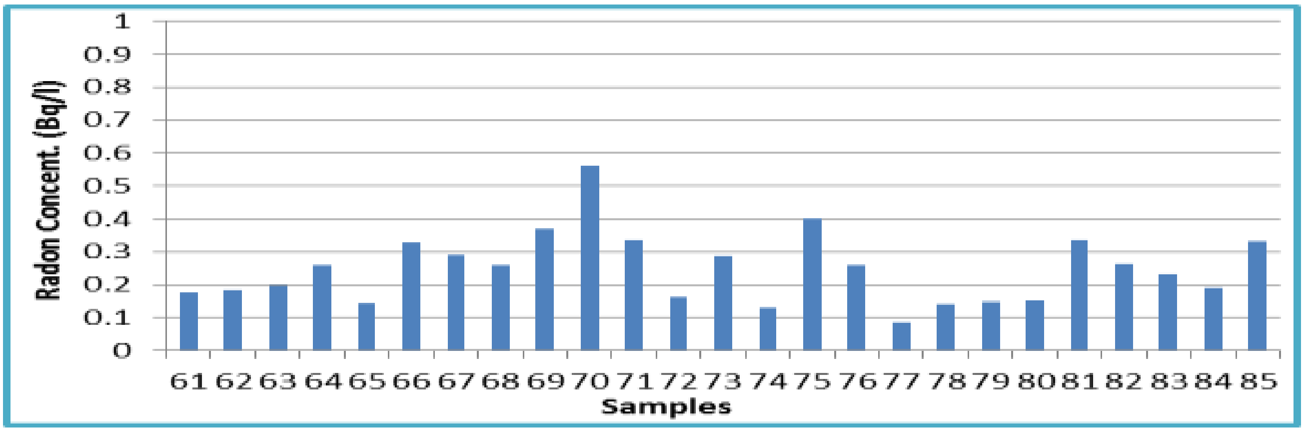

Figure 4: Continued

However, in the scope of the above results, the mean value of radon concentration in Sawa Lake water obtained from the present study was compared with the values reported by the other studies in different parts of the world are summarized in Table (2). The table shows that radon concentration values obtained from water samples in the present study generally lay under the range reported by others and approximately similar to the values reported in Egypt by A. S. Hussein, which it could be due to the similarity at the geological structure between Tanoum Gulf, Dobaa and Sawa Lake.

Table 2: Comparison of radon concentration in lake water with those reported by the others in different parts of the world

Site	Source of water	Mean radon Concent. (Bq/l)	References
Iraq, Darbendakhan Lake	Underground Water	1.85	[17]
Jordan, Eastern Rift	Underground Water	6.2	[18]
Sudan, Khartoum State	Well Water	59.20	[19]
Turkey, Yalova basin	Underground Water	2.4	[20]
Egypt, Tanoum Gulf	Sea Water	0.37	[21]
India, Karnataka State	Well Water	16.42	[22]
Iraq, Basra	Underground Water	1.45	[23]
Saudi Arabia, Qassim Area	Underground Water	2.8	[24]
Iraq, Aucashat City	Underground Water	9.35	[25]
Sawa lake – Samawa - Iraq	Underground Water	0.396	Present Study

Physiochemical parameters of lake water such as PH, total dissolved solids (TDS), electric conductivity (EC), resistivity, and turbidity have been measured to evaluate the impact of these parameters on radon concentration. The values obtained for different samples from different locations are summarized in Table(3), which revealed diverse relationships between these parameters and radon concentrations. The electric conductivity (EC) of the collected water samples were found to be from (20460 μs/cm) to (31900 μs/cm) with an average value of (26744.59 μs/cm). The high value of EC in the lake water is due to the presence of a high amount of dissolved salts.

Fig. (5) represents the variation of radon concentration with (EC). It shows a weak positive correlation with radon concentration (R^2= 0.0872). Total dissolved solids (TDS) values vary between (13708.2 mg/l) and (21373 mg/l) with an average value of (17918.87 mg/l). All water samples have the values very much higher than the WHO maximum permissible value of (500 mg/l). Fig. (6) shows a weak positive correlation between radon concentration and TDS. The resistivity of water is a measure of water's property to oppose the flow of electric current. Its value varies in the collected water samples from (3.13×10^{-5} Ω.m) to (4.88×10^{-5} Ω.m) with an average value of (3.7679×10^{-5} Ω.m). Fig. (7) represents the variation of radon concentration with resistivity, which indicates a negatively weak correlation (R^2= - 0.866). Turbidity is an optical property of water wherein suspended and some dissolved materials such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms cause light to be scattered and absorbed rather than transmitted in straight lines [26]. The turbidity value of collected water samples are carried out and it is found to be in the range of (1.42 – 8.86 NTU) with an average value of (4.701 NTU). Fig. (8) shows no correlation (R^2 = 0.0007) between radon concentration and turbidity. The measurements of pH are important in water treatment and many other applications.

It is a measure of the hydrogen ion concentration in water and indicates whether the water is acidic, alkaline or neutral. The pH values of the collected water samples varied between (8.18) and (8.42) with an average value of (8.26), which are well within the range (6.5 – 8.5) recommended by WHO for drinking water [27], and slightly higher than the range (7-8) of the ocean or sea water. The pH values of all samples indicate a weak negative correlation with radon concentration (R^2 = - 0.0195) (Fig. 9) and this is mainly due to the fact that radon is an inert gas [22]. The variation of the pH value of the water samples may be due to the contact with the carbonate rocks such as dolomite and limestone [28].

Table 3: Physiochemical Parameters of Different Water Samples Collected from Different Locations of the Study Area

No.	Sample	Conductivity (μS/cm)	TDS (mg/l)	Resistivity (Ω.m)	Turbidity (NTU)	pH
1	W1	25780	17272.6	3.87898E-05	5.23	8.22
2	W2	26390	17681.3	3.78931E-05	6.83	8.22
3	W3	26530	17775.1	3.76932E-05	5.19	8.23
4	W4	26480	17741.6	3.77644E-05	7.74	8.21
5	W5	26780	17942.6	3.73413E-05	7.13	8.22
6	W6	25890	17346.3	3.8625E-05	3.18	8.24
7	W7	25120	16830.4	3.98089E-05	5.92	8.19
8	W8	26360	17661.2	3.79363E-05	7.36	8.19
9	W9	27240	18250.8	3.67107E-05	8.17	8.2
10	W10	28980	19416.6	3.45066E-05	8.28	8.19
11	W11	28310	18967.7	3.53232E-05	7.69	8.2
12	W12	27980	18746.6	3.57398E-05	6.71	8.21
13	W13	27530	18445.1	3.6324E-05	4.37	8.21
14	W14	27520	18438.4	3.63372E-05	6.16	8.22
15	W15	26900	18023	3.71747E-05	7.73	8.19
16	W16	25560	17125.2	3.91236E-05	8.86	8.23
17	W17	26240	17580.8	3.81098E-05	8.3	8.23
18	W18	24920	16696.4	4.01284E-05	3.9	8.25
19	W19	28820	19309.4	3.46981E-05	7.15	8.24
20	W20	28780	19282.6	3.47464E-05	4.8	8.25
21	W21	31900	21373	3.1348E-05	4.79	8.25
22	W22	28700	19229	3.48432E-05	1.53	8.18
23	W23	27510	18431.7	3.63504E-05	4.95	8.2
24	W24	29480	19751.6	3.39213E-05	5.7	8.23

25	W25	30800	20636	3.24675E-05	8.09	8.25
26	W26	28710	19235.7	3.48311E-05	7.95	8.26
27	W27	26410	17694.7	3.78644E-05	3.93	8.31
28	W28	29250	19597.5	3.4188E-05	4.8	8.26
29	W29	29320	19644.4	3.41064E-05	7.13	8.28
30	W30	26830	17976.1	3.72717E-05	7.28	8028
31	W31	28500	19095	3.50877E-05	8.16	8.27
32	W32	25880	17339.6	3.86399E-05	3.1	8.27
33	W33	28750	19262.5	3.47826E-05	3.45	8.29
34	W34	28510	19101.7	3.50754E-05	3.43	8.24
35	W35	28640	19188.8	3.49162E-05	4.4	8.25
36	W36	28950	19396.5	3.45423E-05	2.98	8.24
37	W37	28470	19074.9	3.51247E-05	2.31	8.26
38	W38	28490	19088.3	3.51E-05	2.37	8.27
39	W39	27890	18686.3	3.58551E-05	2.56	8.27
40	W40	28230	18914.1	3.54233E-05	2.73	8.26
41	W41	28640	19188.8	3.49162E-05	2.41	8.25
42	W42	27980	18746.6	3.57398E-05	3.11	8.25
43	W43	28870	19342.9	3.4638E-05	3.78	8.21
44	W44	29120	19510.4	3.43407E-05	3.57	8.21
45	W45	29140	19523.8	3.43171E-05	4.17	8.2
46	W46	29690	19892.3	3.36814E-05	2.13	8.23
47	W47	29300	19631	3.41297E-05	5.78	8.21
48	W48	28900	19363	3.46021E-05	4.91	8.26
49	W49	28460	19068.2	3.5137E-05	6.41	8.3
50	W50	28510	19101.7	3.50754E-05	5.28	8.27
51	W51	29100	19497	3.43643E-05	5.12	8.28
52	W52	30120	20180.4	3.32005E-05	4.63	8.23
53	W53	28910	19369.7	3.45901E-05	2.98	8.25
54	W54	28190	18887.3	3.54736E-05	3.81	8.19
55	W55	27860	18666.2	3.58938E-05	3.46	8.19
56	W56	27310	18297.7	3.66166E-05	4.71	8.21
57	W57	27900	18693	3.58423E-05	5.73	8.26
58	W58	28450	19061.5	3.51494E-05	5.24	8.27
59	W59	27100	18157	3.69004E-05	4.87	8.25
60	W60	27120	18170.4	3.68732E-05	4.16	8.28
61	W61	24240	16240.8	4.12541E-05	1.42	8.38
62	W62	24180	16200.6	4.13565E-05	5.16	8.41
63	W63	24180	16200.6	4.13565E-05	1.66	8.35
64	W64	23290	15604.3	4.29369E-05	1.53	8.39
65	W65	24390	16341.3	4.10004E-05	2.45	8.42
66	W66	24420	16361.4	4.095E-05	2.25	8.33
67	W67	23750	15912.5	4.21053E-05	3.61	8.31
68	W68	23240	15570.8	4.30293E-05	2.71	8.32
69	W69	24440	16374.8	4.09165E-05	6.14	8.38
70	W70	23380	15664.6	4.27716E-05	4.32	8.35
71	W71	24040	16106.8	4.15973E-05	3.05	8.31
72	W72	23350	15644.5	4.28266E-05	2.11	8.29
73	W73	24140	16173.8	4.1425E-05	2.23	8.31
74	W74	23840	15972.8	4.19463E-05	3.95	8.3
75	W75	22910	15349.7	4.36491E-05	3.99	8.32
76	W76	24170	16193.9	4.13736E-05	1.68	8.39
77	W77	23530	15765.1	4.24989E-05	2.12	8.29
78	W78	20460	13708.2	4.88759E-05	8.72	8.36
79	W79	24230	16234.1	4.12712E-05	4.48	8.36
80	W80	23560	15785.2	4.24448E-05	6.42	8.35
81	W81	24250	16247.5	4.12371E-05	1.69	8.29
82	W82	23710	15885.7	4.21763E-05	2.75	8.31
83	W83	23930	16033.1	4.17885E-05	5.41	8.31
84	W84	23520	15758.4	4.2517E-05	5.92	8.3
85	W85	24140	16173.8	4.1425E-05	5.93	8.29

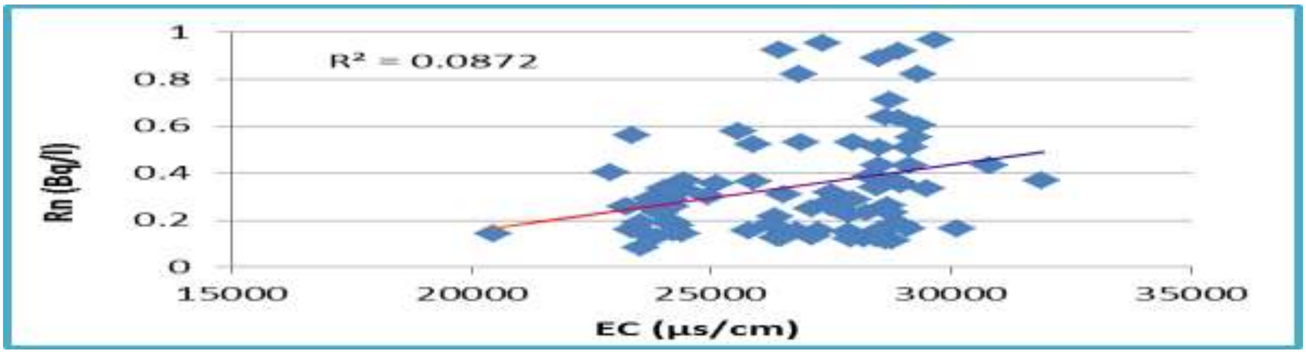

Figure 5: The Correlation Between Radon Concentration and EC

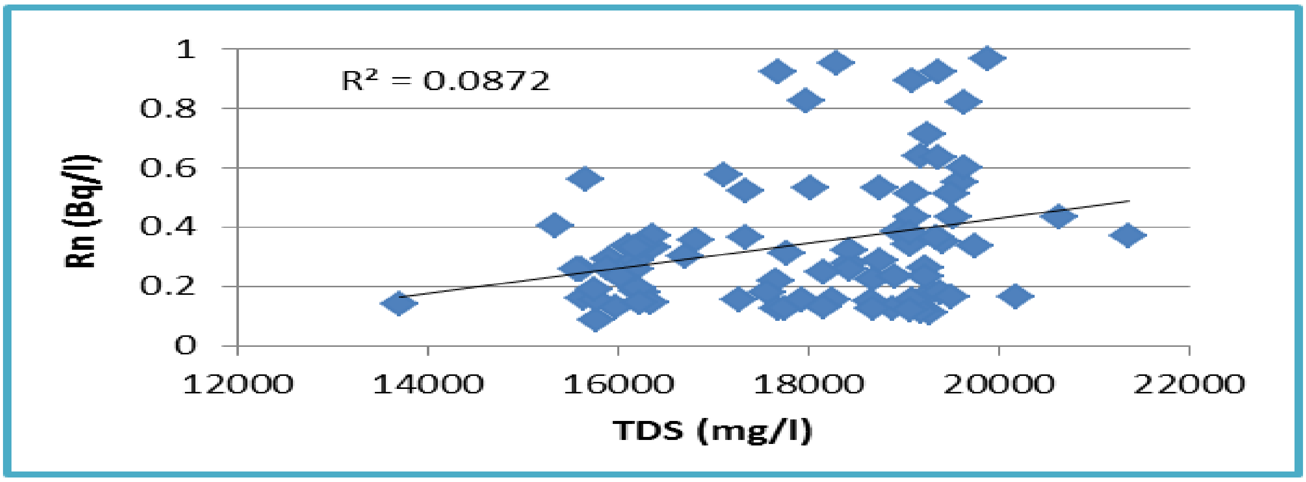

Figure 6: The correlation between Radon Concentration and TDS

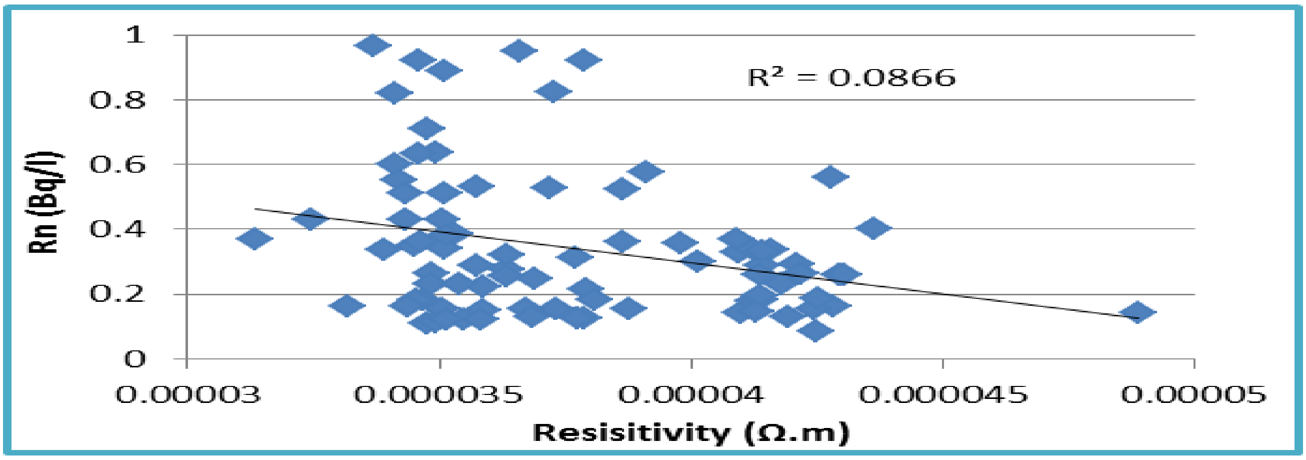

Figure 7: The Correlation Between Radon Concentration and Resistivity

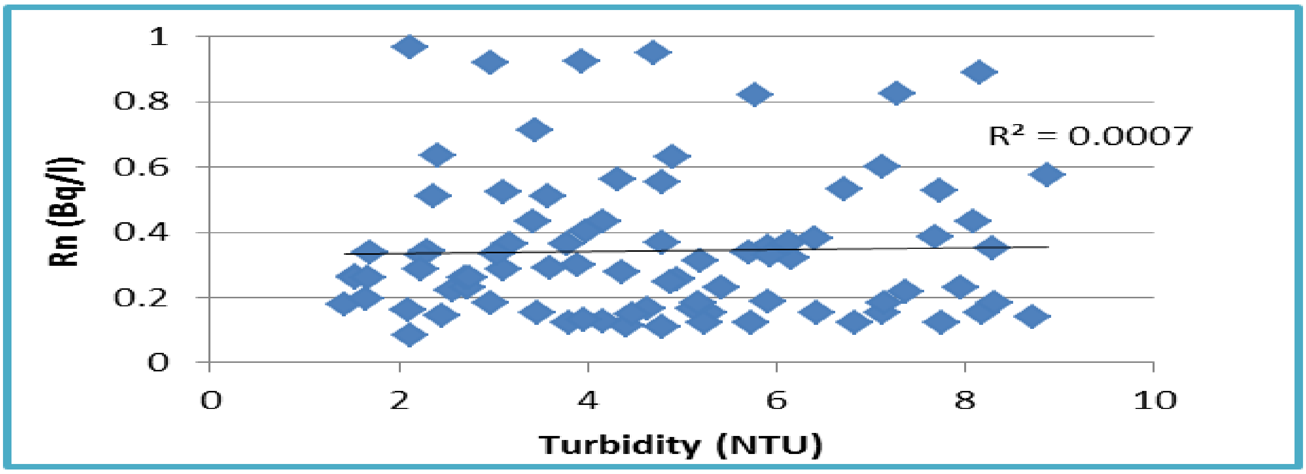

Figure 8: The Correlation Between Radon Concentration and Turbidity

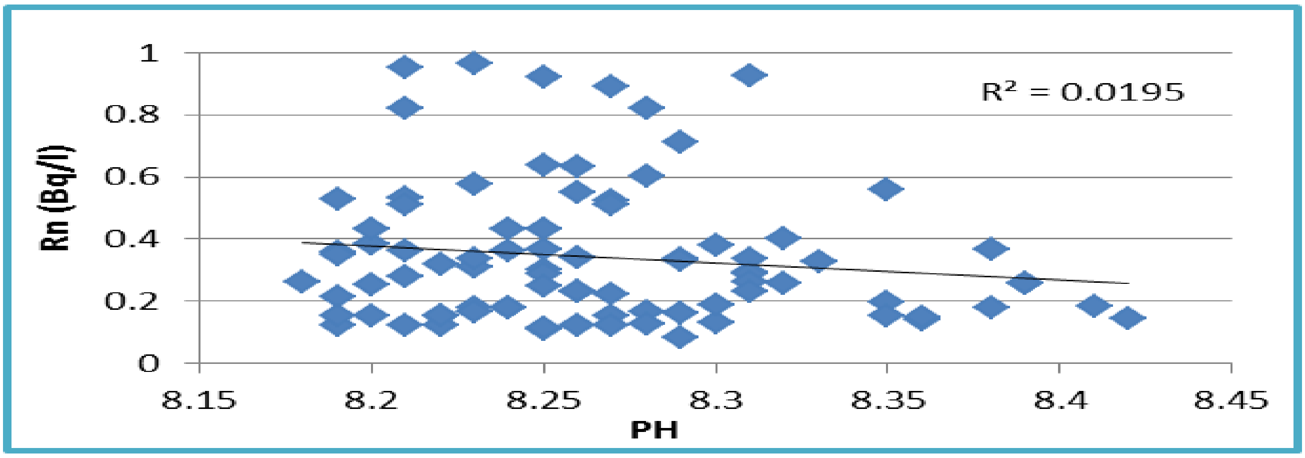

Figure 9: The correlation between Radon Concentration and pH

Conclusion

The present study reveals that the radon concentration in the Sawa Lake water are well below the recommended safe level, where the average value of radon concentration was (0.396 Bq/l) which is far less than the maximum contamination level (MCL) for radon content in water (11.1 Bq/L) as reported by the EPA [14].

The measurements of the water samples have shown variations of radon levels with different locations. Radon concentration in the lake water seems to mainly depend on local geology, depth of the bore wells, stream intensity of water in the sample locations, as well as the activity of uranium and radium dissolved in water. Radon concentration has been observed higher in the northeastern regions and lesser at southwestern regions of the lake. The mean value of the annual effective dose is well below from the value proposed by UNSCEAR of (1 mSv/yr) [12], which means that the water of Sawa lake in particular or the study area in general, does not pose any kind of health risk to the lake visitors and the people lived around it. The study also revealed that there is no strong correlation between the physiochemical parameters and the radon concentration for the analyzed water samples.

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