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RESEARCH ARTICLE

RADON CONCENTRATION MEASUREMENTS IN SOIL GAS OF SAWA LAKE, SAMAWA CITY – SOUTH OF IRAQ.

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Abstract

Radon concentration measurements in the soil gas and in the atmospheric air was carried out around Sawa lake, Samawa City, Southern part of Iraq. Thirtieth chosen locations as sampling points of soil around the lake have been studied. The radon in soil gas were measured using a continuous radon monitoring device RAD7. Radon concentrations was found in the range of (86.9 $Bq.m^{-3}$) to (6448 $Bq.m^{-3}$) with an average value of (1963 $Bq.m^{-3}$). Annual effective dose (AED) due to inhalation was estimated from the measured radon concentration near to the soil surface and is found to be ranged from (0.000826) to (0.061282 $mSv.y^{-1}$) with an average value of (0.01866 $mSv.y^{-1}$). The AED due to inhalation were found to be within the safe limit recommended by WHO of 0.1$mSv.y^{-1}$ and or far below from the reference levels proposed by ICRP of 1$mSv.y^{-1}$, which revealed that the radon concentration and the associated annual effective dose does not pose any kind of health hazard to the population and tourists in the study area.

Introduction:-

Radon is a noble gas, occurs naturally as a product of uranium-238 decay series, it has no odor or taste, with no color, radioactive gas decays by emitting alpha particles with characteristic amounts of energies to give a set of short-lived radionuclide (such as polonium-218 and polonium-214). Radon has a half-life of (3.82 days) which is long relative to some of its progenies and sufficiently enough for detecting and measuring. The major source of radon gas in the atmosphere is the soil surface, although secondary contributions come from ground and surface water, natural and volcanic gases, and others [1]. A distribution of radon in soils has been related to geological controls in terms of its production and migration; uranium content in bedrocks and soil influence production. The soil moisture and permeability, control the transportation of radon [2]. The radium and uranium contents of the soil, generally, reflect that of the bedrock from which the soil materials have originated due to weathering processes [3]. Radon gas escapes easily from the surface soils and rocks into the air through the process called exhalation. The factors which influence the exhalation of radon from the soil into the air are: The concentrations of uranium, thorium and radium in the bedrock and soil materials, The emanation capacity of the ground, The porosity of the soil or rock, Barometric pressure gradient between the interfaces, soil moisture and water saturation grade of the medium and other variables such as micro-cracks of bedrocks, rainfall, air temperature, and surface winds [4–6]. Due to its low mobility and its short half-life, radon obviously diffuses from a short distance below the measuring device [7]. This distance is approximately (2m) under the soil surface in areas where slow diffusive flow presences [8]. Hence, the

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higher radon concentration is often to be due to convective movement in addition to the diffusive processes. Generally, there is a direct proportion between radon activities and flows, and hence because of the increase of gas velocity, the gas decay occurs faster with more extraction [9]. The estimation of radon in the soil-gas and in the atmosphere has been suggested as a tool for many investigations such as exploration for uranium, earthquake prediction, groundwater transport and geothermal resource assessments [10,11]. However, radon and its progeny are responsible for about 45% of the exposure of the world population to ionizing radiation from natural sources [12–14]. Breathing of radon does not affect human beings directly, whereas its decay products adhere to the liner of the lungs. Since it is an alpha emitter, it damages the inner soft tissues and may cause health hazard [15]. Hence, it is very much essential to monitor the radon activity in the soil gas and its exhalation rate. In the present work, the soil surrounding Sawa lake has been studied in order to estimate radon activity and its contribution to the annual effective dose that the public receives due to inhalation in the mentioned area.

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 Muthanna governorate - Southern part of Iraq, as shown in 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 , the elevation of the lake is about 16 m above the sea level. The main source of the lake is groundwater that flow up through three main springs. The soil surrounding the lake consists mainly of salt deposits, includes gybsum, calcite, and dolomite, drifted by the influencing of water stream and weathering processes to form a thin layer of salt deposition (less than 1 m), below this layer, several types of rocks (sand stone, limestone, and marel) are prevailing, which are classified within the (Euphrates Formation) that back to (Miocene age). The lake is located in the southwestern part of the west dessert, so the dessert climate is dominant.

3. Materials And Methods :-

3.1 Radon Activity Measurement in Soil Gas

Radon concentration measurements of (30) different locations of soil surrounding Sawa lake are carried out for a period of one month (January 2019) (i.e. during the winter season). The measured locations covered the whole area surrounding the lake. The soil samples were in situ analyzed using RAD7 radon monitor provided with soil gas probe accessory (Durridge Company, USA) which allows the determination of radon soil gas levels directly Fig. (2). The RAD7 setup that used is shown in Fig. (3). Because the high humidity decreases the measuring efficiency [16], RAD7 needs to be purged for almost 10 minutes to get the humidity within the instrument down to less than 8% before each measurement to avoid the contamination due to the previous run. Soil gas probe was hammered in the soil at depth of (30 cm), proper care necessary to make sure that no contact with outside air as much as possible. Because of the rocky nature of the soil, a soil gas probe was not able to reach a depth more than (30 cm) for all locations. The other end of the probe was connected to RAD7 inlet port through a desiccant and dust filter while the outlet port of the device is left free. The using of the desiccant is necessary to avoid the increasing of the humidity inside the internal chamber of RAD7 during the measuring process.

At the beginning of each measurement, the RAD7 fills its sampling cell with air by sniffing it from the sampling point through the probe for five minutes and waits for other five minutes to reach the equilibrium between radon and its products [17]. After that, it starts the measuring of radon concentration in five cycles, on an average of five minutes for each cycle and five minutes waiting between the cycle and another. Geographical coordinates of all locations were documented using GPS portable device. These coordinates were used later to draw a map shows the location of each sampling point around the lake using GIS (Geographic Information System), as shown in Fig. (4).

The annual effective dose (AED, mSv/y) that received by the public due to inhalation has been calculated using the relation proposed by the UNSCEAR 2000 [18], which is:

$$\boldsymbol{D_{inh} = C_{Rn} \times F \times I \times (DCF)} \text{ -----------(1)}$$

Where $\boldsymbol{D_{inh}}$ is the annual effective dose received by the public, $\boldsymbol{C_{Rn}}$ is the radon concentration in the air near the soil surface which is calculated using the relation [19]:

$$\boldsymbol{C_{Rn} = C_{SG}\sqrt{\frac{d}{D}}} \text{ ------ (2)}$$

Where $\boldsymbol{C_{SG}}$ is the radon activity in the soil gas, $\boldsymbol{d}$ is the exhalation diffusion constant (= 0.05 cm^2/s) and $\boldsymbol{D}$ is the eddy diffusion coefficient (=5×10^4 cm^2/s), $\boldsymbol{F}$ is the equilibrium factor between radon and its products (= 0.6), $\boldsymbol{I}$ is the mean outdoor occupancy time per individual (= 1760 h/y), and DCF is the dose conversion factor for radon exposure [9 nSv (Bq h $m^{-3})^{-1}$].

Results And Discussion:-

The concentration of radon for (30) locations of the soil surrounding Sawa lake, have been carried out using RAD7 radon detector are summarized in Table (1) and shown in Fig. (5). The samples showed a high variation between location and another as shown in Fig. (5), where the radon concentration values ranged between (86.9 Bq/m^3) and (6448 Bq/m^3) with an average value of (1963 Bq/m^3). The samples S3, S4, and S5 that located at (N 31° 19.027', E 45° 00.631'), (N 31° 19.228', E 45° 00.521'), and (N 31° 19.432', E 45° 00.395'), respectively, recorded the highest values of radon concentration during the measurements, which required to take more samples between and close to these sampling points in order to confirm the validity of the measurements results. So, the radon concentration measurements of the samples S26, S27, S28, S29, and S30 that located at (N 31° 19.087', E 45° 00.606'), (N 31° 19.155', E 45° 00.569'), (N 31° 19.288', E 45° 00.461'), (N 31° 19.355', E 45° 00.426), and (N 31° 19.503', E 45° 00.377'), respectively, were conducted and the results came to confirm the high radon concentration in this zone relative to other parts of the study area, which is located at the northeastern side of the lake. The reason for this high concentration is, this area lies in the vicinity of the springs that provide the lake with water, and hence the radon activity is higher when compared to other locations of soil samples. The other possible reason it may be because of these locations lie in the direction of the wind that is blowing in the north-west direction most of the year which contribute to drift water continuously toward these locations. The lower radon concentrations were observed in the samples S1, S2, S11, S12, and S25 that located at (N 31° 18.576', E 45° 00.855'), (N 31° 18.804', E 45° 00.750'), (N 31° 18.857', E 44° 59.589'), (N 31° 18.573', E 44° 59.678'), and (N 31° 18.403', E 45° 00.982'), respectively. The reason behind that may be these sampling points are located far from the springs, or it may back to the lack of uranium and radium content beneath it. However, the observed variation in radon concentration in radon soil gas may be due to the difference in the underlying bedrocks, or in the other words due to the geological condition of locations and geochemical process in soils. The porosity of sandstone which is normally found mainly under the Togo formation and high outgassing rate at faulted zones where the gas permeability is relatively high. Also, it may be attributed to Rn^{222} gas coming from the earth's deep interior not from surrounding rocks only because the rocks found at both studied areas do not fall under major rocks containing naturally occurring radioactive materials (NORMS) [20]. From the present results, it can be observed that the most sampling points have radon concentrations below the action levels of (0.4 – 4 kBq/m3) proposed by UNSCEAR (2000) [18]. On the other hand, several locations have radon concentrations exceed the allowed levels (locations S3, S4, S5, S26, S27, S28, S29, and S30). The big difference may be due to holes falling exactly on covered fault lines in the earth crust, since Radon gas concentration in soil is taken as proportional to fracture opening, or it may be due to the parent radionuclide Ra^{226} which is more readily leached from soil during the winter rainy season.

The annual effective dose due to radon inhalation has been determined to all studied locations and it was found to be in the range of (0.000826 – 0.061282) mSv.y^{-1} with a mean value of (0.01866 mSv.y^{-1}), which were found to be well within the safe limit of 0.1 mS.y^{-1} as recommended by World Health Organization (WHO, 2004) and European Council (EU, 1998) [21], and far below from the reference levels proposed by ICRP of 1 mSv.y^{-1} [22].

The values of radon concentrations obtained in soil gas compared to those reported by the other investigators in different parts of the world are summarized in Table (2). From the table, it is evident that radon concentration value obtained from soil samples in the present investigation generally lay above the range reported by others, except the radon concentration values reported in Iraq, Al-Najaf city, Al-Kufa city, Karbala city, Basra sport city, Hilla city, Dikili area, Southwestern Sinai, as given in table (2).

Table 1:-Radon concentration in soil samples and corresponding effective dose.

No.	Sample	Location		C_{SG} (Bq.m^{-3})	S.D.	C_{Rn} (Bq.m^{-3})	Effective Dose (mSv/y)
		latitude	longitude				
1	S1	N 31° 18.576'	E 45° 00.855'	102	60	0.102	0.000969408
2	S2	N 31° 18.804'	E 45° 00.750'	167	70	0.167	0.001587168
3	S3	N 31° 19.027'	E 45° 00.631'	6000	460	6	0.057024
4	S4	N 31° 19.228'	E 45° 00.521'	5960	460	5.96	0.05664384
5	S5	N 31° 19.432'	E 45° 00.395'	6448	480	6.448	0.061281792

6	S6	N 31° 19.681'	E 45° 00.307'	511	130	0.511	0.004856544
7	S7	N 31° 19.849'	E 44° 59.997'	1310	200	1.31	0.01245024
8	S8	N 31° 19.692'	E 44° 59.753'	1280	160	1.28	0.01216512
9	S9	N 31° 19.458'	E 44° 59.607'	1350	200	1.35	0.0128304
10	S10	N 31° 19.143'	E 44° 59.557'	403	110	0.403	0.003830112
11	S11	N 31° 18.857'	E 44° 59.589'	94	52	0.094	0.000893376
12	S12	N 31° 18.573'	E 44° 59.678'	124	60	0.124	0.001178496
13	S13	N 31° 18.395'	E 44° 59.901'	801	160	0.801	0.007612704
14	S14	N 31° 18.335'	E 45° 00.190'	677	150	0.677	0.006434208
15	S15	N 31° 18.267'	E 45° 00.459'	88.8	50	0.0888	0.000843955
16	S16	N 31° 18.165'	E 45° 00.746'	419	110	0.419	0.003982176
17	S17	N 31° 18.075'	E 45° 01.024'	431	110	0.431	0.004096224
18	S18	N 31° 17.863'	E 45° 01.170'	86.9	54.7	0.0869	0.000825898
19	S19	N 31° 17.736'	E 45° 01.378'	370	101	0.37	0.00351648
20	S20	N 31° 17.769'	E 45° 01.623'	617	116	0.617	0.005863968
21	S21	N 31° 17.958'	E 45° 01.745'	1292	160	1.292	0.012279168
22	S22	N 31° 18.121'	E 45° 01.587'	1270	155	1.27	0.01207008
23	S23	N 31° 18.243'	E 45° 01.383'	1130	257	1.13	0.01073952
24	S24	N 31° 18.334'	E 45° 01.196'	437	110	0.437	0.004153248
25	S25	N 31° 18.403'	E 45° 00.982'	138	69	0.138	0.001311552
26	S26	N 31° 19.087'	E 45° 00.606'	5544	420	5.544	0.052690176
27	S27	N 31° 19.155'	E 45° 00.569'	5376	400	5.376	0.051093504
28	S28	N 31° 19.288'	E 45° 00.461'	6347	480	6.347	0.060321888
29	S29	N 31° 19.355'	E 45° 00.426	5976	460	5.976	0.056795904
30	S30	N 31° 19.503'	E 45° 00.377'	4154	335	4.154	0.039479616
Mean value				1963.4	204.6	1.9634	0.018660692

Table 2:-Values of radon concentration in the soil for some studies compared to the present work.

No.	Country	Region	Radon (Bq/m^3)		References
			Low	High	
1	Iraq	Al Najaf City	9	9290	[23]
2	Iraq	Karbala City	50	7800	[24]
3	Iraq	Basra Province	61.18	2237.77	[25]
4	Iraq	Amara City	53.18	2047.51	[26]
5	Iraq	Al Kufa City	41.45	12775	[20]
6	Iraq	Al Najaf Province	38.5	100	[27]
7	Iraq	Salahaddin Province	45.25	100.75	[28]
8	Iraq	Basra Sport City	1439	38765	[29]
9	Iraq	Hilla City	25	12700	[2]
10	Saudi Arabia	Al Qassim Area	26	340	[5]
11	Saudi Arabia	Jazan Region	896.81	302.91	[30]
12	Jordan	Irbid Province	697	6335	[31]
13	Turkey	Dikili Geothermal Area	98	8594	[32]
14	palastine	Gaza	23.48	584.15	[33]
15	Egypt	Southwestern Sinai	648	21361	[34]
16	Iraq	Sawa Lake – Samawa City	40	6448	Present study

Conclusion:-

The radon concentration in soil gas of the soil surrounding Sawa lake, Samawa City, south of Iraq, were measured using the continuous radon monitoring device RAD7. The measured radon concentration in soil varied from location to another. This may be due to the geological changes in the locations. The high radon concentration in few locations may be due to the presence of parent materials and soil type in that area, or it could be because these sites are located in the face of running water from the main cracks that feeding the lake with groundwater. The maximum value of radon activity was (6448 Bq/m^3), for the sampling point (S5), and the minimum value was (86.9 Bq/m^3), for the sampling point (S18). The average value of radon activity was (1963 Bq/m^3) which is well within the world average of $4kBq/m^3$ as reported in the UNSCEAR. It is found that the radon concentrations of the most soil samples are less than the recommended levels reported by UNSCEAR (2000). The AED has been calculated depending on the radon concentration in air near the soil surface was found to be within the range of (0.000826 – 0.061282) $mSv.y^{-1}$, with a mean value of (0.01866 $mSv.y^{-1}$), which shows that the dose received by the public is lower than that of the suggested value of (1 $mSv.y^{-1}$). Hence, the present study has revealed that radon soil gas concentration and associated annual effective dose is within referenced levels and the study area does not pose any kind of health hazard that tourist and population possibly received.

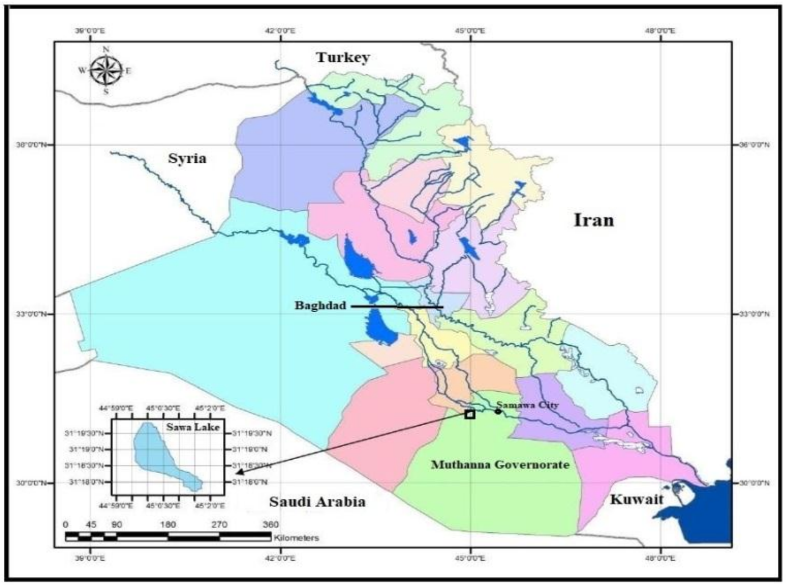

Figure 1:-Map of Iraq Showing the location of Sawa Lake in Al-Muthanna Province.

Figure 2:-Radon soil gas measurements.

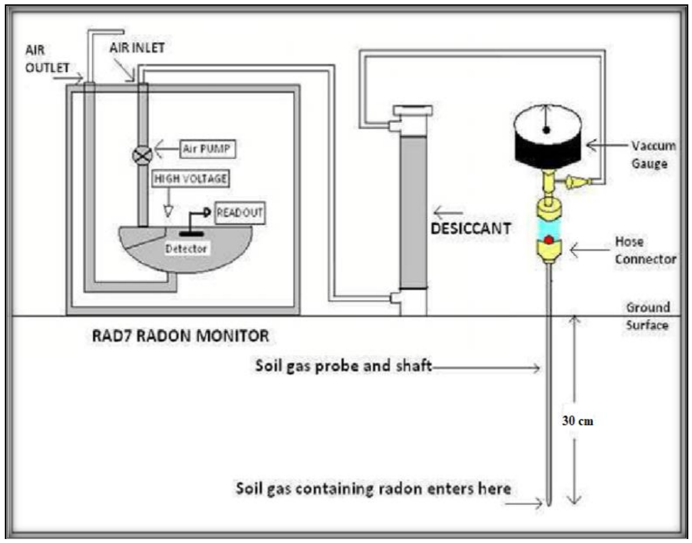

Figure 3:-Diagram of the RAD7 setup [7].

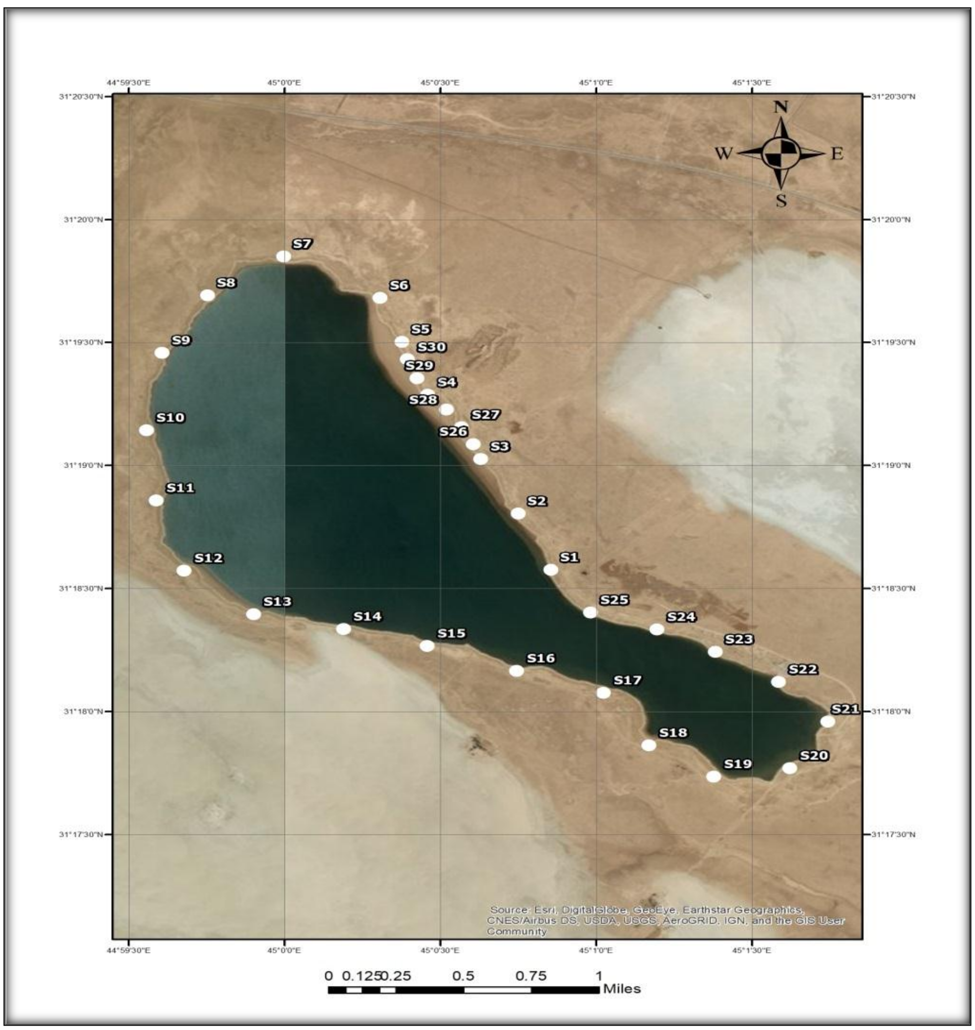

Figure 4:-The locations of sampling points around the lake.

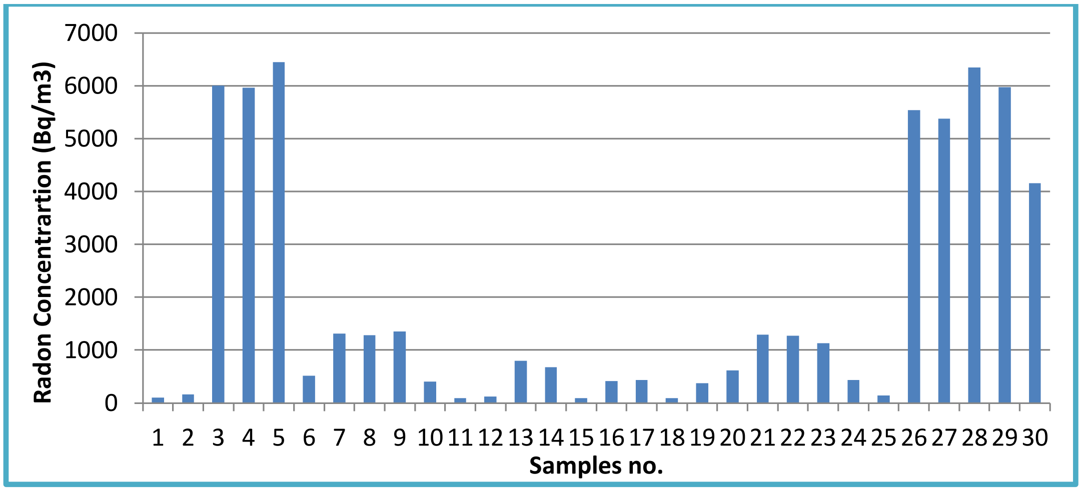

Figure 5:-Radon concentration in soil gas of each Sampling Points.

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