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## RESEARCH ARTICLE

### A STUDY OF RADON CONCENTRATIONS AND THE RADIATION DOSE LEVELS IN SALT SAMPLES EXTRACTED FROM SAMAWA SALTERN - IRAQ.

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#### Abstract

The radon concentrations in the environment and food concern all people involved in radiation protection. Because the salt is used in food and industry, radon ( $R_n^{222}$ ) activity measurements in the salt samples extracted from Samawa Saltern- south of Iraq, were carried out from radiation protection point of view of the occupational workers and general public. For the measurements, Radon Alpha Detector (RAD-7) were used. Results of various measurements of the radon activity, exposure to radon daughters, the annual inhalation dose received by the workers, and the excess lifetime cancer risk (ELCR) have been reported. The radon activity concentrations were found to vary from ( $7.2 \text{ Bq/m}^3$ ) to ( $52.3 \text{ Bq/m}^3$ ) with a mean value of ( $24.99 \text{ Bq/m}^3$ ). It was found that the As-salt workers is exposed annually to (0.058) Working Level Month (WLM) from radon gas and its short – lived daughters. The annual inhalation dose in the environment of Samawa Saltern was found to vary from ( $0.127 \text{ mSv/yr}$ ) to ( $0.898 \text{ mSv/yr}$ ) with an average of ( $0.429 \text{ mSv/yr}$ ). The excessive lifetime cancer risk due to radon in the Samawa Saltern was found to vary from ( 0.06% ) to ( 0.43% ) with an average of (0.21% ). The results have revealed that the radon concentration and the associated inhalation radon dose does not pose any kind of health hazard to the occupational workers, consumer of salt and or when it used in the industrial purpose.

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#### Introduction:-

Natural radioactivity present in human environment is the main sources of both external and internal radiation dose being received by population [1]. It is wide spread in the earth's environment and it exist in various geological formations in soil, rocks, salt , water , air,..... [2]. There are three types of radiations to which human beings are exposed. first, is the alpha radiation from the decay of radon gas, 2nd, is the alpha and gamma radiation from the intake of radioactive materials present in foodstuff like vegetables, meat, table salt, ...., and 3rd , is the gamma radiation from the decay of  $U^{238}$ ,  $Th^{232}$ , and  $K^{40}$ . Naturally occurring radionuclides enters the human body mainly by inhalation of radon and Thoron gases and their decay products [3], and also by ingestion of primordial radionuclides and their progeny [4].

Radon, is naturally occurring radioactive gas, has many isotopes, but the three main isotopes  $Rn^{222}$  (Radon),  $Rn^{220}$  (Thoron), and  $Rn^{219}$  (Actinon), produced from the decay of  $U^{238}$ ,  $Th^{232}$ , and  $U^{235}$  respectively, were our concern because of their presence in our human environment and the possibility of their health effects on the public. As far

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as radon exposure is concerned,  $Rn^{222}$  is the most significant isotopes due to its longer half- life (3.82d) which is long enough for it to enter into indoor and cause an increase in the indoor concentration, but it is relatively too long to enter into the respiratory tracts and to irradiate the cells. The decay series which indicates the origins of  $Rn^{222}$  is illustrated in Figure 1.

Because the salt is an important constituent of the foodstuff, and a large quantity of it is prepared for human consumption, whereas a lot of quantities go to different industries, it is therefore necessary to measure the radon concentrations in the environment of saltern area due to its health hazards and environmental pollution and is of concern with the control and minimization of such radiation exposure, as well as, such information can be used as the associated parameter values for radiological assessment [5].

However, a through literature search reveal that no studies on the radon concentration measurements in salt samples extracted in Iraq. Such lake was the main motive to conduct the current study in addition to meet the annual inhalation dose received by the salt extraction workers in the environment of surrounding saltern area.

Thus, the purpose of the present work is to measure the radon concentrations in salt samples extracted from Samawa saltern - south of Iraq using the active (RAD-7) technique which were not reported previously, and hence knowing about the intake exposure of salt extraction workers to alpha particles from radon and its decay product, and radioactive inhalation dose levels, with a view to establishing their radiological risk.

### Samawa Saltern area:-

The Samawa saltern was located in Al-Muthanna Province 280 km south of Baghdad the capital of Iraq. it is situated at 20km to the southwest of Samawa city (The modern capital of the Al-Muthanna Governorate). It is the oldest in Iraq which is discovered in 1986 and the salt production started in 1989. The latitude and longitude of the steady area is  $31^{\circ} 19' N$  and  $45^{\circ} 17' E$ , respectively, and at an altitude of (9m) above the sea level. The location map of Samawa saltern in the Al-Muthanna province is shown in Figure 2, and in the map of Iraq is shown in Figure 3. The Samawa saltern have been estimated to contain a total of 43 million tons of salt deposits and are the Iraq's first largest reservoirs of rock salt. The current annual production from the saltern is 200.000 tons. The Samawa saltern have 4 stories below the ground level. The total length of the middle canal is more than 6000m and the width of about 10m and depth of 5 to 7m in the center of the canal, covering an area of about  $60,000m^2$ . The salt of Samawa saltern is transparent, white, and rock salt is 98.74% pure NaCl.

### Materials and Methods:-

#### Sample Collection and Processing:-

A total of thirty seven salt samples were collected from different locations of the Samawa saltern to represent the overall salt body. The samples were first drying in an electric oven (memmert type UNB200, Germany) at  $110^{\circ} C$  for 12 hours to ensure complete removed of moisture and cooled to room temperature. After that they were grounded into affine powder, and sieved by using 100 micron mesh to obtain homogenized particle size (uniform emanation of radon). About (70gm) from each sample were enclosed in a 250ml glass cylindrical can which was used as the radon accumulation chamber, and sealed for a period of 30days in order to get secular equilibrium between radium and radon.

A radon gas detector (RAD-7) was used to measure radon emanation from the salt samples. In this system, the above accumulation chamber is connected to the RAD-7 detector by vinyl tubing (Figure 3), with a gas drying unit filled with a desiccant  $CaSO_4$  with 3%  $COCl_2$  as an indicator between them, to maintain the relative humidity at less than 10% within the measurement system. The system is a closed loop in which the gas circulates continuously. The experiment was performed at a relative humidity of 10%,  $18-25^{\circ}C$ , and normal room atmospheric pressure.

#### Radiological hazard:-

The radiological hazard in the Samawa saltern environment can be estimated as due to the exposure to radon daughters and the annual inhalation dose. The exposure to radon daughters in the Samawa saltern was calculated on the basis of the measured radon concentration using the following equation [6,7]:

$$E_R = R_c \times (2.7 \times 10^{-4}) \times F \times n \times \frac{8766}{170} \dots \dots \dots (1)$$

Where  $E_R$ , is exposure to radon daughters in  $WLMy^{-1}$ ,  $R_c$  is the radon concentration in  $Bq/m^3$ ,  $(2.7 \times 10^{-4})$  is the factor for the conversion of radon concentration to the WL per  $Bq/m^3$ ,  $F$  is the indoor equilibrium factor ( $= 0.4$ ),  $n$  is the occupancy factor ( $= 0.42$ ). The annual inhalation dose from radon was calculated according to ICRP publication (1993) [8]:

$$D = (R_c \times K \times H) / (3700 Bq/m^3 \times 170 hr) \dots \dots \dots (2)$$

Where  $D$  is the annual inhalation dose ( $mSv^{-1}$ ),  $R_c$  is the radon concentration,  $K$  is the ICRP dose conversion factor ( $5mSv/WLM$  for occupational workers), and  $H$ , is the annual occupancy at the location ( $2160$  hr for workers). The excess lifetime cancer risk (ELCR) due to radon exposure in the Samawa saltern was determined using the following equation [6]:

$$ELCR = E_R \times T \times F_R \dots \dots \dots (3)$$

Where  $E_R$ , is the exposure to radon in  $WLMy^{-1}$ ,  $T$  is the average lifetime expectancy, which is ( $70.4$ ) years in Iraq as per WHO [9], and  $F_R$  is the risk coefficient factor for exposure to radon in equilibrium with its daughters. Based on the recommendations of ICRP [10], the  $F_R$  is taken as  $5 \times 10^{-4}$  per WLM.

### Results and Discussions:-

The concentrations of  $R_n^{222}$  measured with the RAD-7 varied from ( $7.2 Bq/m^3$ ) to ( $52.3 Bq/m^3$ ), with an average value of ( $24.99 Bq/m^3$ ), which indicates low emission of radon by the salt samples. However, this average value of radon concentration is quite lower than that values measured in most of the buildings (houses, schools, hospitals, offices, universities.....etc) in Iraq [11,12,13]. Also, this indicates that there is no or very little radon or radon sources in the area of Samawa saltern. From the result (Table 1), it is noted that only one region (sample 16) located at the middle of main tunnel have high radon concentration ( $52.3 Bq/m^3$ ) as shown in Figure 2. Figure 4 shows the histogram that represents the observed values. The high radon region it may be is composed of rocks contain uranium minerals in traces which yield radon or, this radon seems to have been brought in by the incoming water to the center of the middle tunnel as it the lowest region in it.

The low radon concentration region (samples 27, 29, 32, 33, 34, and 35) located at different positions in the saltern as indicated in table 1. The main reason for this low concentration is the non-existence of naturally occurring radioactive decay series in the salt samples. In general, the present measurement of radon indicate that radon level in the Samawa saltern were below the action level of ( $500-1500 Bq/m^3$ ) recommended by the International Commission on Radiological Protection (ICRP 1993) [14], and in the range of a reference level ( $100 Bq/m^3$ ) proposed by the World Health Organization (WHO) [15] to minimize health hazards due to indoor radon exposure.

The exposure to radon daughters ( $E_R$ ) was calculated by applying Eqn. (1). It is calculated from radon concentrations in different salt samples extracted from different region in Samawa saltern, and the results are given in Table (1). The ( $E_R$ ) varied from ( $0.017$ ) to ( $0.122$ )  $WLMy^{-1}$  with an average value of ( $0.058$ )  $WLMy^{-1}$ . The average value of exposure rate to radon daughters ( $0.058 WLMy^{-1}$ ) is much lower than the values reported from other salt mines in the world [7], and according to USA law, an mine workers should not be exposed to a radiation exceeding ( $4WLMy^{-1}$ ) [7].

The annual inhalation dose due to  $R_n^{222}$  in salt samples was calculated using Eqn. (2) and it was found to varies from ( $0.124 mSv^{-1}$ ) to ( $0.898 mSv^{-1}$ ) with an average value of ( $0.429 mSv^{-1}$ ). The results are presented in Table (1) and Figures 5. The average of annual inhalation dose observed in this study was less than the average of the world wide inhalation dose. According to UNSCEAR report (2000), the permissible worldwide average of annual inhalation exposure of radon in salt mines is ( $1.15 mSv^{-1}$ ). Also, it is lower than the typical range of annual inhalation exposure of radon in the world salt mines of ( $0.20 - 10.00 mSv^{-1}$ ) [7], and the world range in other mines (excluding uranium) of ( $0.5 - 7.00 mSv^{-1}$ ) [7].

The excess lifetime cancer risk (ELCR) was calculated using Eqn. (3), and the results are given in Table (1). The (ELCR) due to  $R_n^{222}$  progeny in the Samawa saltern varies from ( $0.06$ ) to ( $0.43\%$ ) with an average of ( $0.21\%$ ) which is less than the estimated lifetime cancer risk of ( $1.3\%$ ) due to a radon exposure of  $148 Bq/m^3$ , as recommended by EPA for the entire population [6].

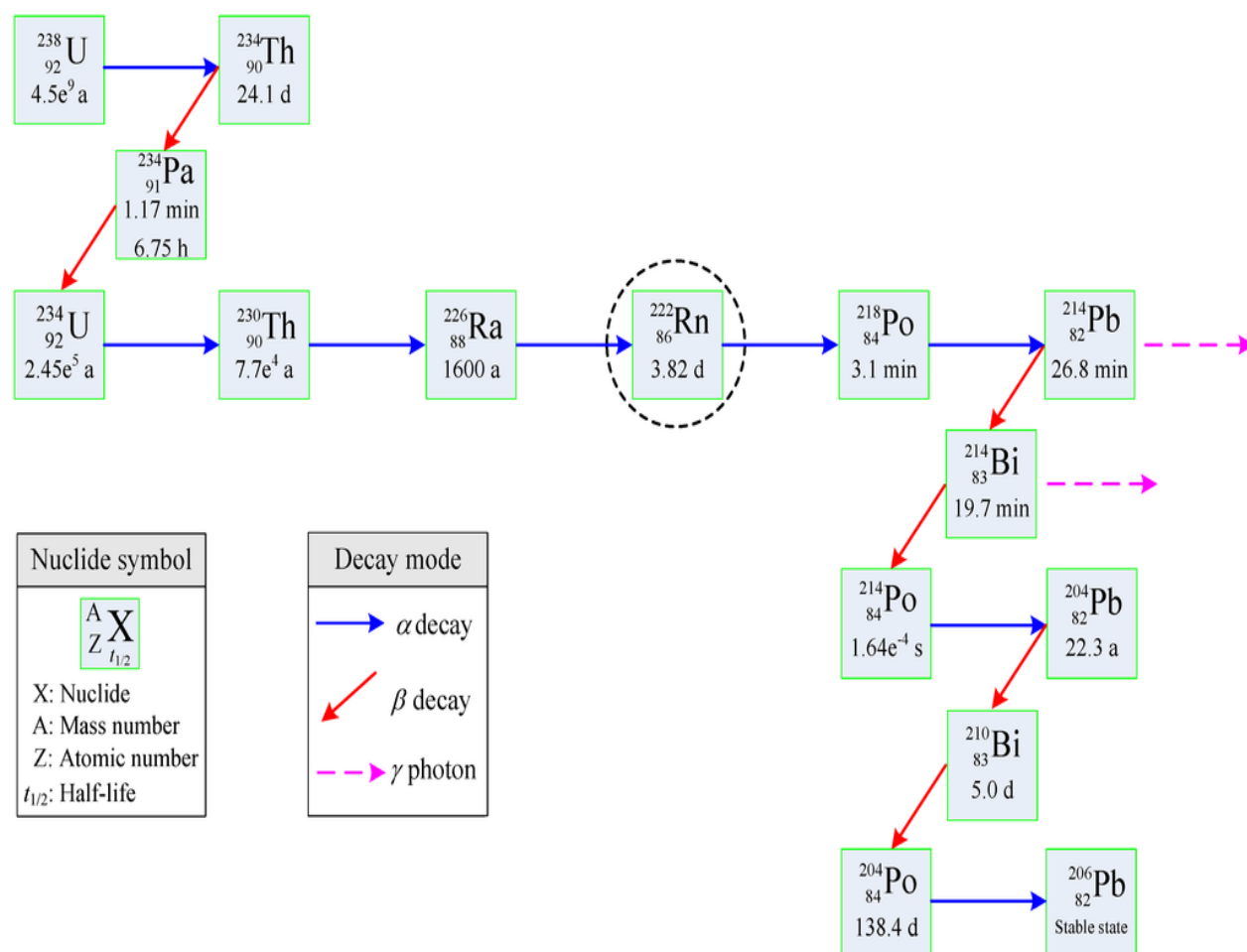
However, in the scope of the above results, the average of exposure to radon daughters and annual inhalation dose due to radon daughter is much lower than the values reported for other salt mines in the world as given in Table (2). The estimated average annual inhalation dose due to radon daughters for the present study, however, is well below the effective doses of ( $20 \text{ mSv}^{-1}$ ) recommended by ICRP [16] due to radon in work place. As per the above results, the Samawa saltern and the salt extracted from it are very safe for the salt extraction workers and general public from radiological hazard point of view, and does not pose any kind of internal hazard to the consumers.

### Conclusions:-

Using active method (radon alpha detector RAD-7), radon concentration levels have been measured in the salt samples extracted from Samawa saltern – south of Iraq. On the basis of the measured radon concentration, the exposure to radon daughters, annual inhalation dose and excessive lifetime cancer risk were estimated. The results of this study showed that the radon concentrations are low enough and below the permissible level as per recommendation of ICRP and UNSCEAR.

The average of the annual inhalation dose received by members of the salt extraction workers was found to be ( $0.429 \text{ mSv}^{-1}$ ) which gives an ELCR of (0.21%). Consequently, the estimated risk has no significant health hazard, and the studied salt samples are radiologically safe, as per international standards, and that harmful effects are not expected.

Howeve, The present study is the first at the national level (in Iraq ) to investigate radon ( $\text{Rn}^{222}$ ) concentrations in salt samples extracted from Samawa saltern.



**Figure 1:-** Uranium-238 decay series, showing radon (the only gaseous member of the series) and related nuclides which is an important source of indoor radioactive pollution.

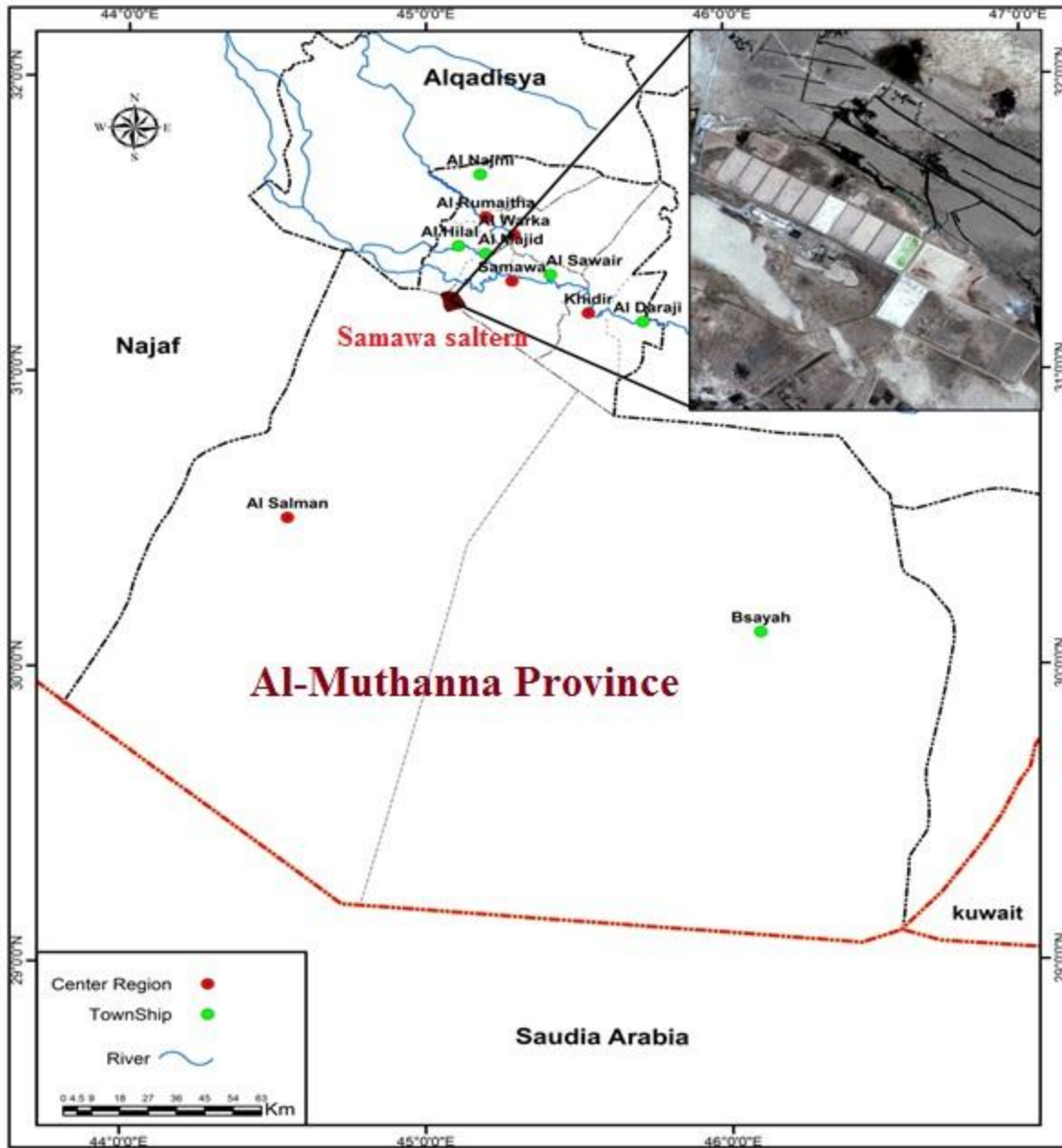


Figure (2): Map of Al-Muthanna Province showing the location of the Samawa saltern (the origins of the salt samples studied).

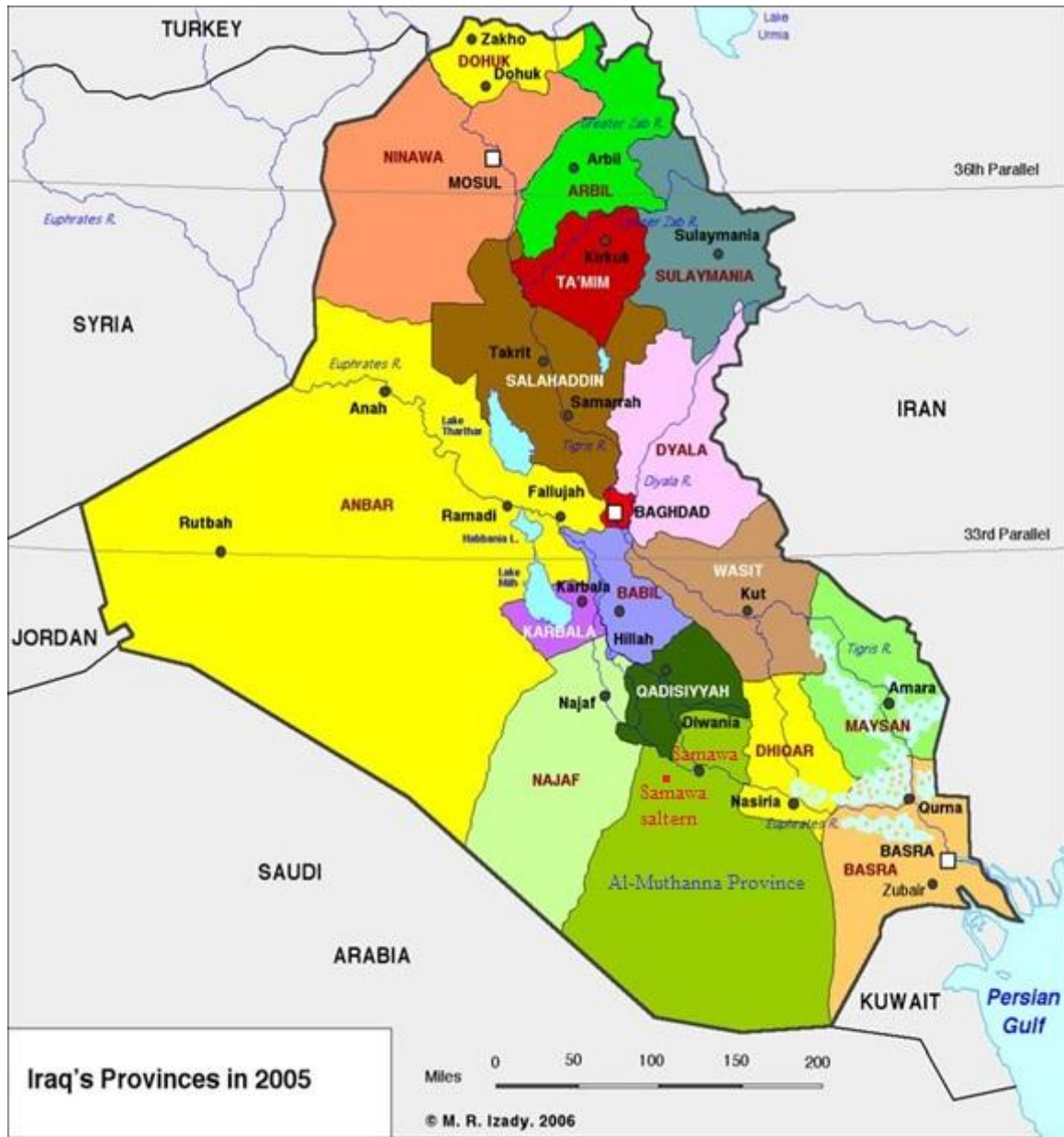


Figure (3):- Map of Iraq showing location of Samawa city and Samawa saltern in the Al-Muthanna Province.



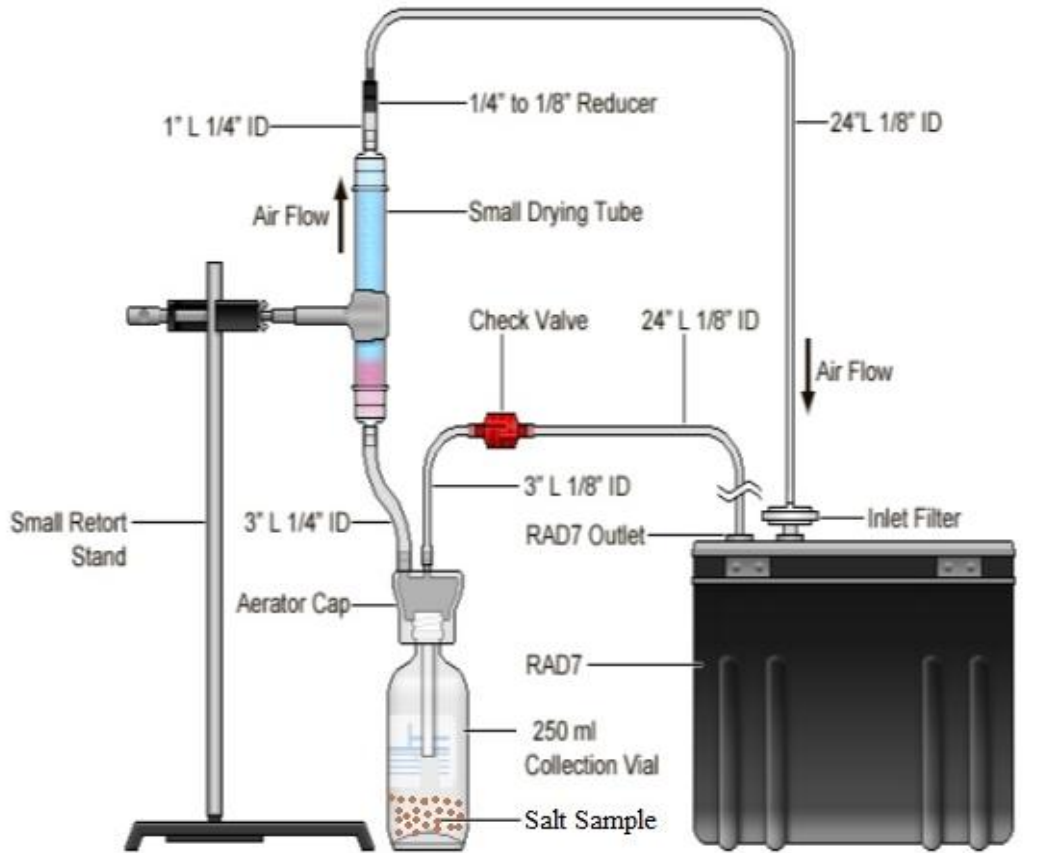


Figure (4):- Schematic diagram of the RAD-7 experimental system.

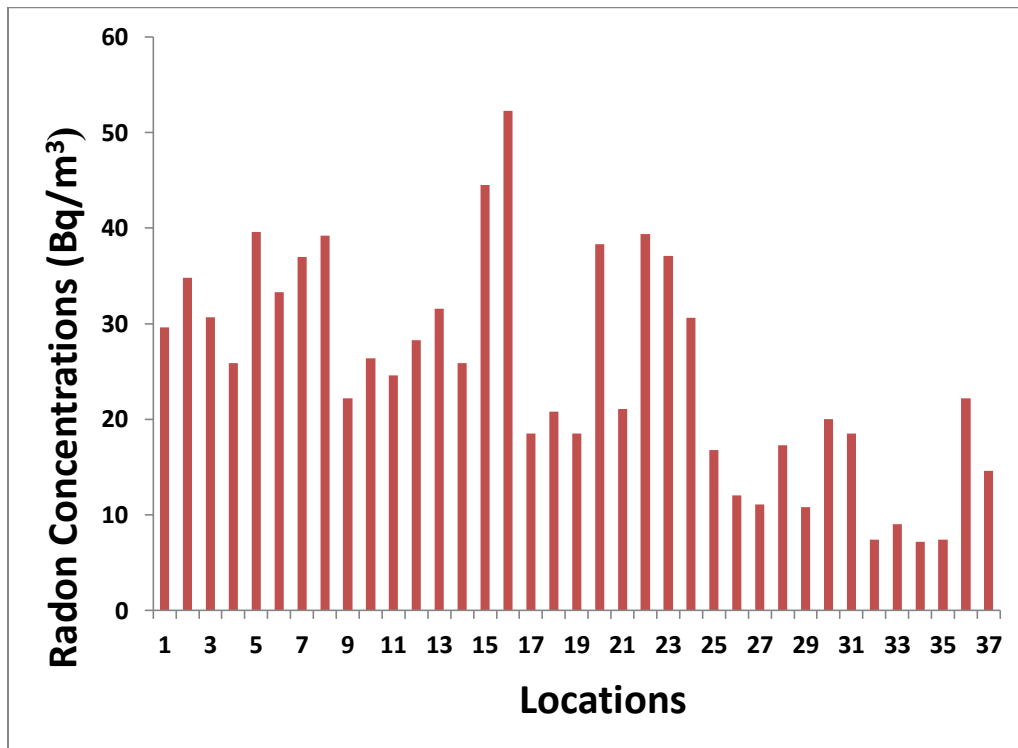


Figure (5):- Radon concentration in Samawa saltern according to the location criterion.

**Table 1:-** Radon ( $Rn^{222}$ ) Concentration, Radon Daughters Exposure, Annual Inhalation Dose, and Excess Life Time Cancer Risk (%) in the Samawa Saltern – Iraq.

Sample No.	Location	Radon concentration $R_c$ ( $Bq/m^3$ )	Radon Daughters Exposure ( $WLMY^{-1}$ )	Annual inhalation Dose $D$ (mSv/yr)	Excess Life Time Cancer Risk (ELCR%)
1.	Middle canal edge	29.6	0.06923	0.5082	0.244
2.	Middle canal edge	34.8	0.08139	0.5975	0.286
3.	Middle canal edge	30.7	0.07181	0.5271	0.253
4.	Middle canal edge	25.9	0.06058	0.4447	0.213
5.	Middle canal edge	39.6	0.09262	0.6799	0.326
6.	Middle canal edge	33.3	0.07789	0.5718	0.274
7.	Middle canal edge	37	0.08654	0.6353	0.305
8.	Middle canal edge	39.2	0.09169	0.6731	0.323
9.	Middle canal edge	22.2	0.05193	0.3812	0.183
10.	Middle canal edge	26.4	0.06175	0.4533	0.217
11.	Middle canal edge	24.6	0.05754	0.4224	0.203
12.	Middle canal edge	28.3	0.06619	0.4859	0.233
13.	Middle canal	31.6	0.07391	0.5426	0.260
14.	Middle canal	25.9	0.06058	0.4447	0.213
15.	Middle canal	44.5	0.10408	0.7641	0.366
16.	Middle canal	52.3	0.12233	0.8979	0.431
17.	Middle canal	18.5	0.04327	0.3176	0.152
18.	Middle canal	20.8	0.04865	0.3571	0.171
19.	Raw salt	18.5	0.04327	0.3176	0.152
20.	Raw salt	38.3	0.08958	0.6576	0.315
21.	Raw salt	21.06	0.04926	0.3616	0.173
22.	Raw salt	39.4	0.09216	0.6765	0.324
23.	Raw salt	37.1	0.08678	0.6370	0.305
24.	Raw salt	30.6	0.07157	0.5254	0.252
25.	Crystal pool	16.8	0.03929	0.2885	0.138
26.	Crystal pool	12.05	0.02818	0.2069	0.099
27.	Crystal pool	11.1	0.02596	0.1906	0.091
28.	Crystal pool	17.3	0.04046	0.2970	0.142
29.	Crystal pool	10.8	0.02526	0.1854	0.089
30.	Injection unit	20.04	0.04687	0.3441	0.165
31.	Injection unit	18.5	0.04327	0.3176	0.152
32.	Injection unit edge	7.4	0.01731	0.1271	0.061
33.	Injection unit edge	9.03	0.02112	0.1550	0.074
34.	Loading site (washed raw salt)	7.2	0.01684	0.124	0.059
35.	Loading site (washed raw salt)	7.4	0.01731	0.127	0.061
36.	Loading site (washed raw salt)	22.2	0.05193	0.3812	0.183
37.	Loading site (washed raw salt)	14.6	0.03415	0.2507	0.120
Average	.....	24.99	0.05845	0.4291	0.21
Range	.....	(7.2 - 52.3)	(0.01684 - 0.12233)	(0.124 - 0.8979)	(0.06 - 0.43)



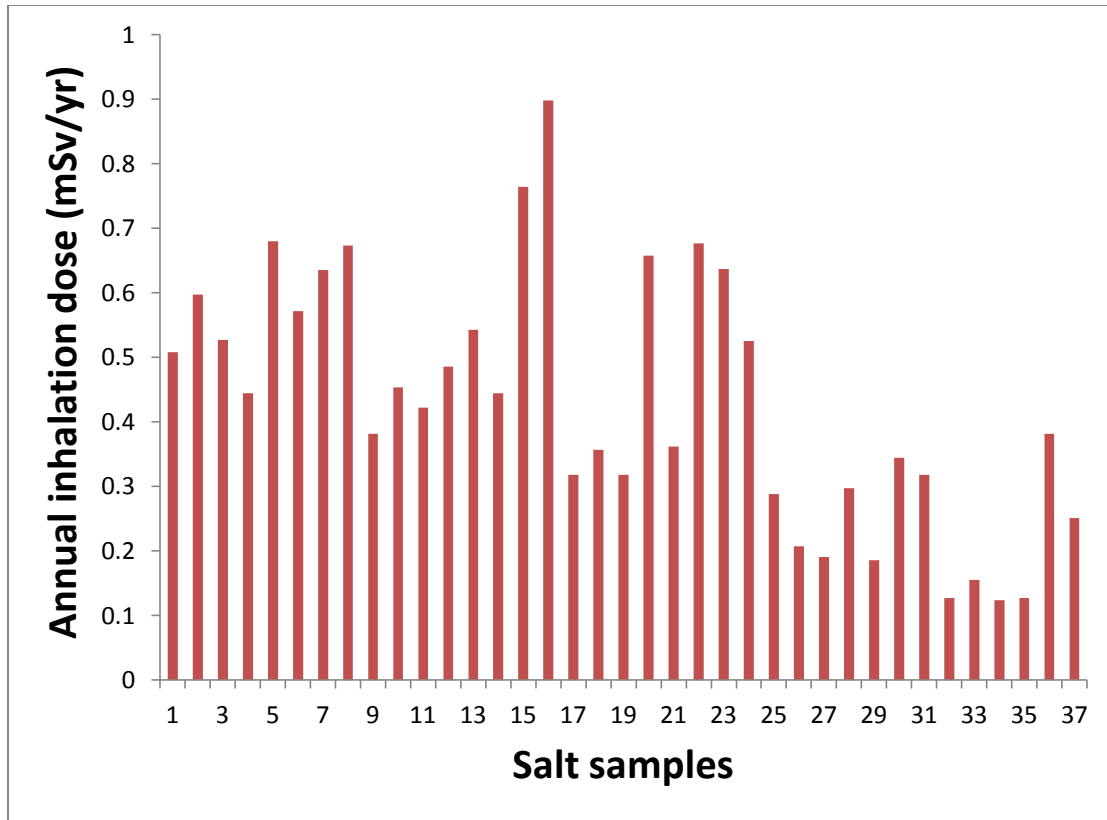


Figure (6):- Annual inhalation dose due to (Rn<sup>222</sup>) exposure from the salt samples in the study area.

Table 2:- Values of (Rn<sup>222</sup>) Concentration, Radon Daughters Exposure, Annual Inhalation Dose, And Excess Life Time Cancer Risk (%) in present study and their comparison with the measured values in other countries.

Country	Radon concentration R <sub>c</sub> (Bq/m <sup>3</sup> )	Radon Daughters Exposure (WLMY <sup>-1</sup> )	Annual inhalation Dose D (mSv/yr)	Excess Life Time Cancer Risk (ELCR%)	Reference
Romania (Ocna Dej)	18 ± 2	.....	0.22 ± 0.01	.....	[ 17 ]
Romania (Cacica)	69 ± 1	.....	.....	.....	[ 18 ]
Pakistan (Khewra)	38 ± 7		0.53 ± 0.09		[ 19 ]
Pakistan (Khewra)	43 ± 8	0.10 ± 0.01	0.56 ± 0.10	0.33 ± 0.5	[ 20 ]
Iraq (Samawa Saltern)	24.99	0.05845	0.4291	0.21	Present study
Typical Range of World Wide Inhalation Dose in mines excluding uranium mines			(0.20 - 10.00)		[ 7 ]
Reference level recommended by ICRP due to Radon in workplaces			20		[ 13 ]

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