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# Radon Content of Recent Sediments in Relation to Tectonic Features at Mosul City and Neighboring Area

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## ABSTRACT

Thirty Three recent sediment ( 5 surface wadi filling and 13 flood plain + 15 soil at 0.7m depth) samples were selected from different localities namely ( from south to north ) : Al-Sallamya + Lazzaga villages, Hawi Al-Kanessa, Shuraikhan, Al-Mallaeen Quarter, Tel-Kief, Wadi Al-Malah, and Fifeal area. The collected samples were subjected to traditional geochemical test and analysis in aaddition to Radon gas measurement using solid plastic nuclear detector CR-39 ( Columbia Resin ) in the field( cup irradiation technique ) and in the laboratory ( test tube irradiation technique ). Sodium hydroxide etched detector were investigated under optical microscope to count the track density and later Radon gas exhalation measurements (Bq.m$^{-3}$) were calculated. Variation in Radon gas measurements were displayed and followed in contour maps and discussed in relation to the obtained geochemical data and to know faults and other structural features in the studied area.

**Keywords:** Rn measurement techniques, Rn content in recent sediment, Rn-geochemical properties relation, Rn - tectonism and seismicity relations.

# محتوى غاز الرادون في الرواسب الحديثة وعلاقته بالمظاهر التكتونية في مدينة الموصل وجوارها / شمال العراق

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## الملخص

تضمنت الدراسة الحالية اختيار **33** نموذج من الرواسب الحديثة بواقع **5** نماذج سطحية لملء الوادي و**13** من السهل الفيضي **15** نموذج من التربة بعمق **0.7** متر في مناطق من الجنوب الى الشمال: السلامية وقرى لازاكة وحاوي الكنيسة وشريخان وحي الملايين وتلكيف ووادي الملح وفلفيل . خضعت النماذج المختارةالى الفحوصات والتحاليل الجيوكيميائية التقليدية فضلا عن قياسات غاز الرادون باستخدام الكاشف البلاستيكي الصلب (**CR-39** كولومبيا ريزن ) وذلك بتقنية تشعيع الوعاء حقليا وتقنية تشعيع انبوبة الاختبار مختبريا . وجرى دراسة الكواشف المعالجة بهيدروكسيد الكالسيوم باستخدام المجهر الضوئي لحساب كثافة اثار الرادون على الكواشف والتالي حساب غاز الرادون بالوحدة (**$Bq/m^3$**) . وبمقارنة البيانات المستحصلة لوحظ وجود تباين في قياسات الرادون كما تعرضها الخرائط الكنتورية والتي جى مناقشة علاقتها بالمعطيات الجيوكيميائية وبالفوالق والمظاهر البنائية الاخرى المعروفة في منطقة الدراسة

كلمات دالة: تقنيات قياس الرادون ، محتوى غاز الرادون في الرواسب الحديثة ، علاقة الرادون بالمعطيات الجيوكيميائية ، علاقة الرادون بتكتونية وزلزالية منطقة الدراسة .

## 1. INTRODUCTION

Radon is a colorless, odorless and tasteless noble gas produced by radioactive decay of uranium $^{238}U$ chain and through radium $^{226}Ra$. There are two main isotopes

($^{222}Rn_{214}$ ; $T_{1/2}$ =3.82d, called radon and thoron $^{220}Rn_{214}$ ; $T_{1/2=}$ 55.60s. ) and the radiation of radon isotopes and their progenies comprise nearly half the natural dose received by man[1]. This fact made radon the most popular subject of the environmental studies. On the other hand, the natural ( or geogenic ) radioactivity of radon gas have led to its use as a geophysical tracer for locating buried faults, shears, cracks and fractures and are commonly used as precursors for earthquake and volcanic activity [2 ;3 ; 4] which represent the immediate concern and the ultimate designed goal of the present study. Radon $^{226}Rn$ originates from radioactive transformation of radium $^{226}Ra$ in the Earth's crust. Not all the radon so created leaves the mineral grains to the available void space. Depending on geophysical and geochemical parameters, radon moves further by diffusion and advection to longer distant as dissolved species either in water or in carrier gases like carbon dioxide, nitrogen, methane, etc. Finally, radon exhales in to the atmosphere. Emanation of radon is mainly controlled by $^{226}Ra$ content and mineral grain size. Sudden changes in radon concentration is found to be related to seismic, volcanic and tectonic activities (for example: surface expressed or hidden fault.)[3].

Literature survey show that such study, i.e. geogenic radon study, is rare or absent in published work of the geological survey in Iraq. Therefore, the present work faces limitations which preclude data comparison of previous studies. The present measurements were mostly conducted at less secure and safe sites because of security reasons and in-fact few measurement facilities were spoiled by astray local inhabitants. The last remark forced the present study to diverts the field measurement method to laboratory measurement technique in order to analyze all selected samples.

## 2. STUDY AREA

It is part of the foot hill zone of northern Iraq [5] and sited within longitudes ($43^{o}$ $00^{'}$ 00" and $43^{o}$ 06' 00") east and latitude ($36^{o}$07'00" and $36^{o}$33'00") north as shown in

(Fig. 1). It is featured by the presence of a number of anticlines separated by long distance not showing syncline structures where Mosul city is located (Fig. 2). The nature of such structural feature suggests the presence of deep seated strike slip faults

[6]. In the study area, faults ( as seen in Fig. 3 & 4 ) can be classified in-to : longitudinal faults relative to the flow direction of river Tigris ( Mosul - Hammam Al-Allil, Hawi Alkanisa ) ; faults of east – west trend direction ( Musherfa, Bawizah – Badush ) and Transverse faults ( Ibn Al-Atheer ) [7 ; 8 ].

Sediments and sedimentary rock successions of clastic and non – clastic nature are exposed in the area. The exposed Successions ranged in age from middle Miocene up to Recent time and they belong to Fat'ha lagoonal and Injana clastic formations and Quaternary deposits as river terraces, flood plain, soil, and valley filling deposits.

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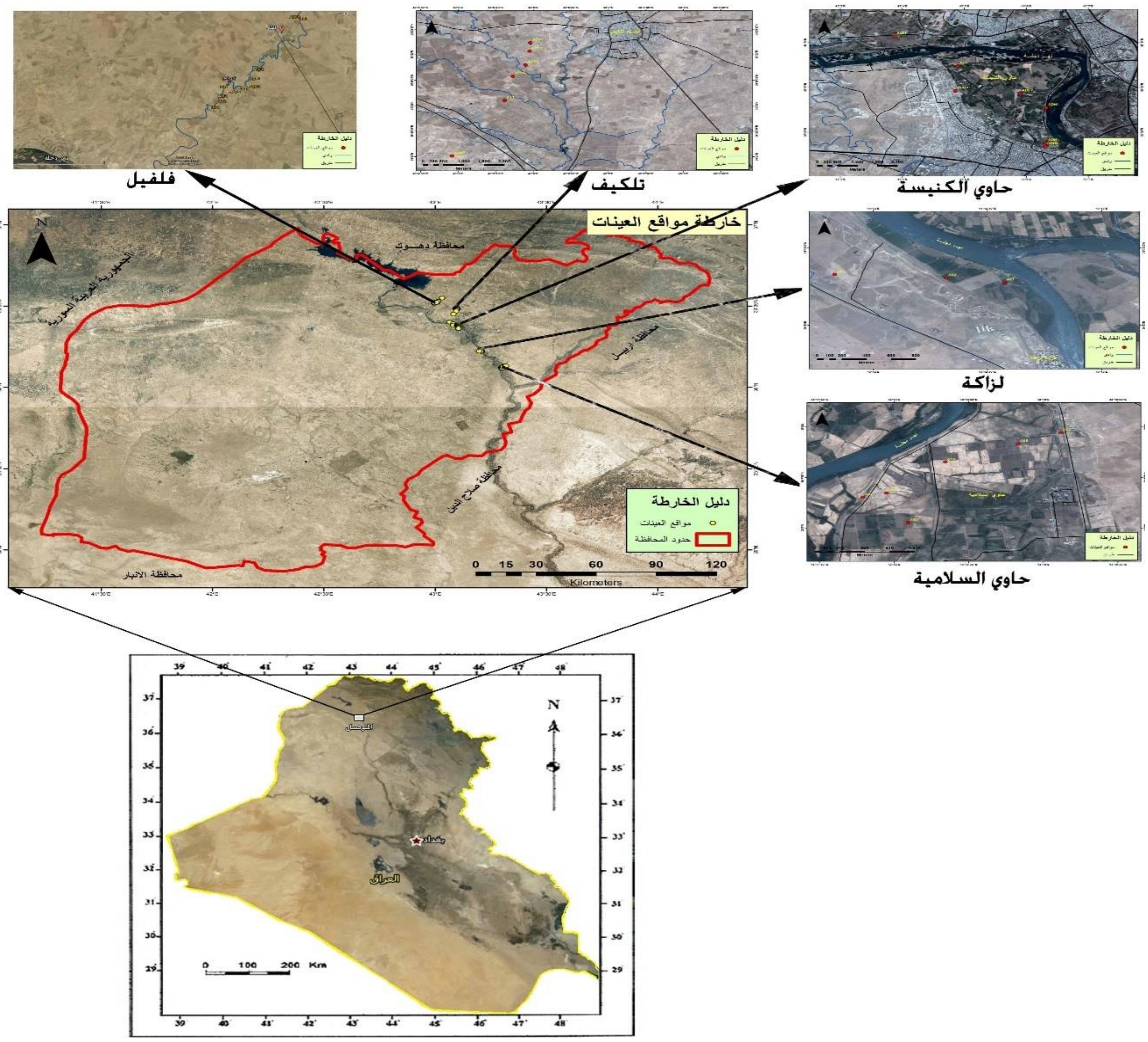


**Figure 1 Studied area locations**

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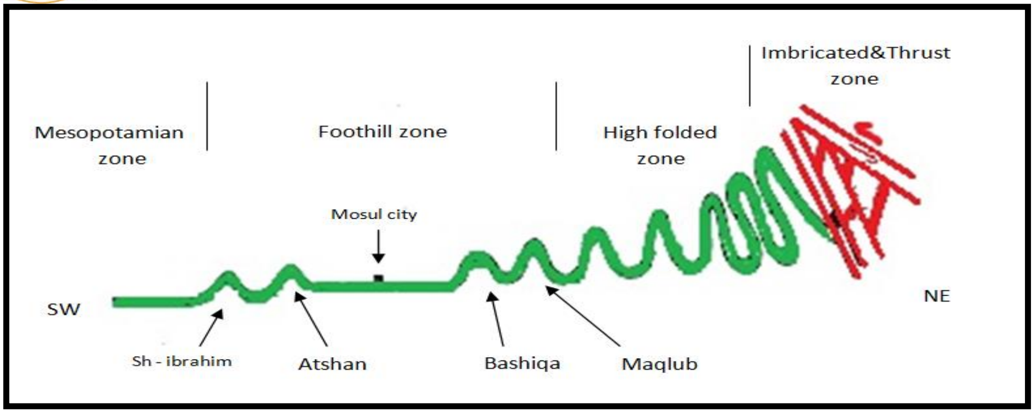


**Figure 2 Sketch showing the structural setting of the Foot Hill zone and the location of Mosul city [7]**

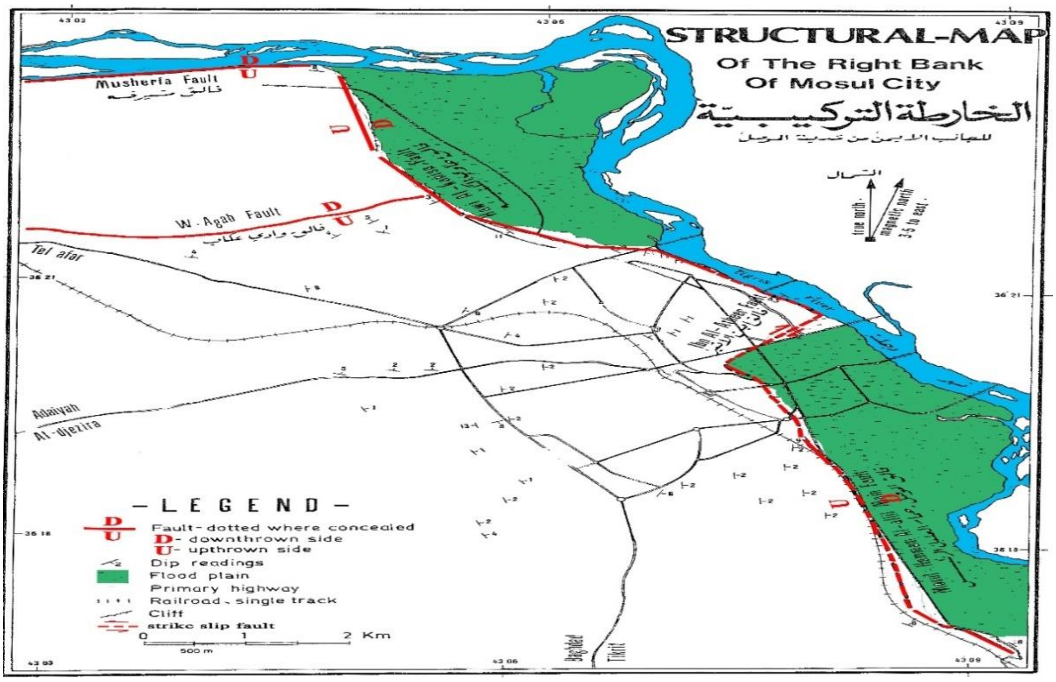


**Figure 3 Structural map of the right bank of Mosul city [7]**

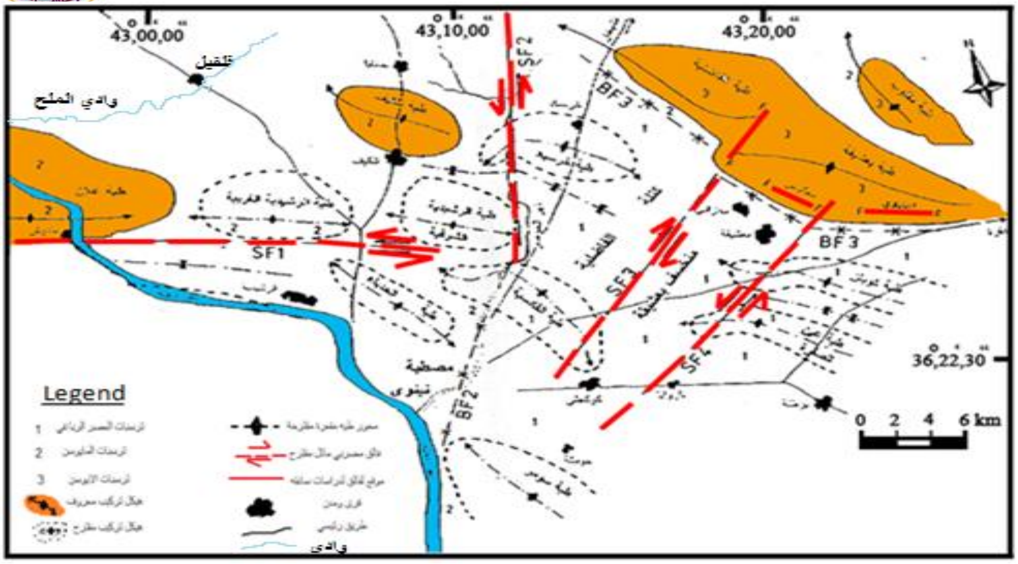


**Figure4 Structural map of left bank of Mosul city. [8]**

## 3. MEASUREMENT TECHNIQUES

Radon ( $^{222}Rn$ ) gas content in recent sediments of the present study were analyzed by deployment of Columbia Resin detector ( CR-39 ) and looking at the track image left on the detector by alpha particle emitted from radon nuclear decay. The advantages of this polymer plastic detector is easy at use, highly sensitive, homogeneous, of ordered composition, resistance to storage conditions, thermoset, cross linked and of low cost [9 ;10 ;11 ]. The detector plastic is available in large size ( A4 size with 274 µm thickness) and it has to be cut in to smaller size ( 1 cm X 1 cm ) for use in actual analysis. In order to check for detector validity, few pieces ( 1 cm X 1 cm ) were exposed to radiation of standard source Am 241 ( activity of 0.11 mCi at 10 / 1 / 1980 ) for 5 and 30 seconds and for 1 and 2 minutes. Later, the exposed pieces of detector were chemically etched (to be described later) and investigation of track shape (Fig. 5) and counting were made using binocular microscope.Between time interval of 10$^{th}$ July and 5$^{th}$ Nov. 2011, thirty three sites were selected and each site coordination were documented using GPS and later, a soil auger were used to drill a hole of 0.1 Meter diameter and 0.7 meter depth in recent sediment ( soil and flood plain ) as shown in Fig.6. At the specified depth, twenty eight samples were collected and described in the field as consolidated to friable sediments of various shades of color according to Munsell color chart as shown by [12] which also includes the description of five surface sediment (wadi filling). The samples were placed in firmly closed polyethyllen bags and labeled.

It was intended first that all radon measurement to be done in the field using cup technique. So, a plastic cup with labeled detector (CR-39) piece of 1 cm X 1 cm size were fixed at the cup bottom and carefully placed upside down in the hole as shown in (Fig.7). Then, the measurement sites were covered, photographed and marked with few symbols and left over for 30 days. At the end of 30 days period, the measurement sites revisited to collect back the plastic cup, and the C-39 detector pieces from each cup were removed for chemical etching to study and, counting the alpha track.

As mentioned earlier, three out of ten batch measurement facility sites were spoiled by local inhabitants, therefore, radon measurements were diverted to laboratory method represented by test tube technique [13] as shown in ( Fig.8 ). This technique involves grinding of the sediment sample to finer size and weighing of about 20 gm into the measurement test tube and the added powder were packed to keep a distance of 9.5 cm between the surface of the packed sample below and the labeled detector side to be exposed to radiation. Later the measurement tubes were left in the wood rack at laboratory conditions for 30 days. After this period of time, the test tubes were reopened and the detector pieces were removed and made them ready for chemical etching.

Chemical etching process includes the immersion of the irradiated detector (C-39) pieces (both techniques) into etching solution (sodium hydroxide of 6.25 molar) in a covered cups placed in a water bath at (70 $C^0$ ± 1 for 4 hours) [10].

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Afterward, the etched detector pieces were removed from the etching solution and cleaned by washing with distil water several time to insure the detector pieces are free from deposits of the etching solution. Then detector pices were dry using fine and light paper. The dried detector pieces were subjected to microscopic viewing using Japan made Olympus microscope (400 magnification) available at the Department of Biology/Science College/ Mosul University. The track density of each sample were calculated using view zone division method of calculation. The background radiation were accounted for by subtracting 566 Track/cm$^2$ from the calculated track density of each sample. The data of track density ( Track/cm$^2$ ) determined by cup technique were recalculated on the basis of measurement data of the test tube technique using a factor which unified measurement data ( Track/cm$^2$ ) of all samples ( Table 1 ). This table also show the concentration of uranium (CU) and radon content of the studied samples All parameters were calculated according to (14) and displayed by (12).

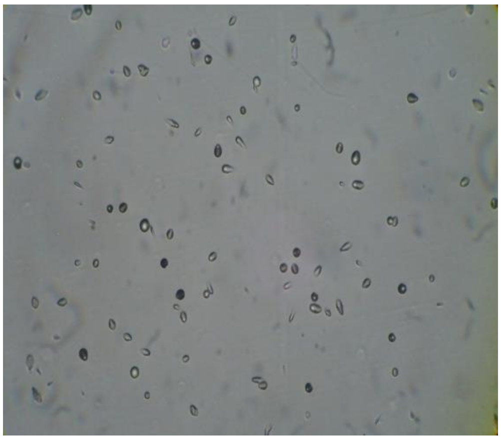

**Figure 5 Alpha track shape and density using cup technique ( sample ADT3).**

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Figure 6 Soil Auger drilling in the study area.

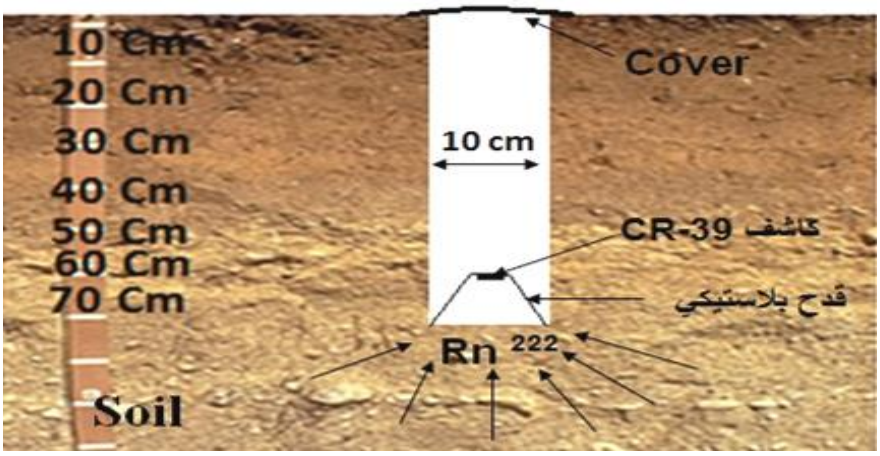


**Figure 7 Cup technique for radon measuremen**

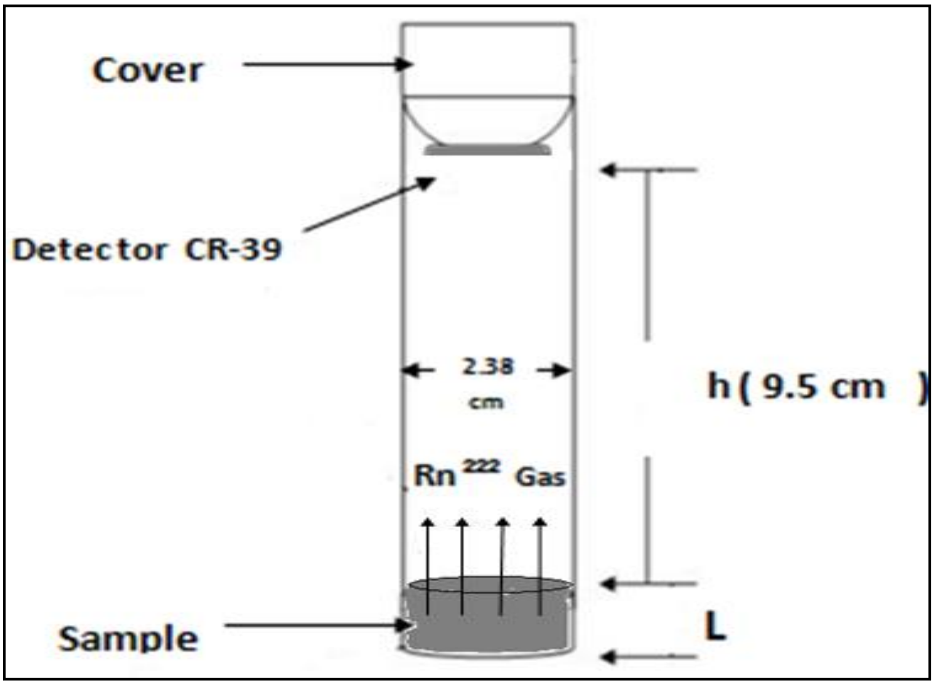


**Figure 8 Test tube technique used in the present study [ 13]**

**Table 1 Rack density ( Tr/cm$^2$ = Average number of total track/Area of field view ), Uranium concentration ( ppm ) and Radon content ( kBq.m$^{-3}$)**

| ample Number | Tr/cm² | CU ppm | Cs Bq.m⁻³ k | Sample Number | Tr/cm² | CU ppm | Cs Bq.m⁻³ k |
|---|---|---|---|---|---|---|---|
| Tel-Kief Area | | | | ADH2 | 7120 | 2.8 | 29 |
| ADT1 | 22179 | 3.6 | 37 | ADH3 | 20405 | 3.5 | 36 |
| ADT2 | 34809 | 4.3 | 43 | ADN1 | 19008 | 3.4 | 35 |
| ADT3 | 36407 | 4.3 | 44 | ADN2 | 26280 | 3.8 | 39 |
| ADT4 | 33828 | 4.2 | 43 | AH1 | 4214 | 3.9 | 40 |
| AT1 | 4529 | 4.2 | 43 | ASh1 | 2881 | 2.6 | 27 |
| ADM1 | 19147 | 3.4 | 35 | Av. | 12391 | 3.2 | 33 |
| Av. | 25150 | 4.0 | 41 | Lazzaga Villge Area | | | |
| Filfiel area | | | | AZ1 | 3963 | 3.7 | 38 |
| ADF1 | 14731 | 3.2 | 33 | AZ2 | 3724 | 3.4 | 35 |
| ADF2 | 15184 | 3.2 | 33 | AZ3 | 4063 | 3.8 | 38 |
| ADF3 | 19084 | 3.4 | 35 | Av. | 3917 | 3.6 | 37 |
| ADF4 | 17121 | 3.3 | 34 | Al-Sallamya Area | | | |
| ADF5 | 12303 | 3.0 | 31 | AS1 | 3787 | 3.5 | 36 |
| SS1 | 2428 | 2.2 | 23 | AS2 | 3258 | 3.0 | 31 |
| SS2 | 2390 | 2.2 | 23 | AS3 | 2893 | 2.7 | 27 |
| SS3 | 3334 | 3.1 | 32 | AS4 | 2503 | 2.3 | 24 |
| SS4 | 4151 | 3.8 | 39 | AS5 | 2076 | 1.9 | 20 |
| SS5 | 2768 | 2.5 | 26 | AS6 | 2755 | 2.5 | 26 |
| Av. | 93450 | 3.0 | 31 | Av. | 2879 | 2.6 | 27 |
| Hawi Al-Kanessa Area | | | | | | | |
| ADH1 | 6831 | 2.7 | 28 | | | | |

## 4.DISCUSSION

Radon content in the sediment varies at different locality , but the values are within 10 – 100 k Bq.cm$^{-3}$ and therefore radon distribution in the study area can be classified as low to medium in value according to [15]. The obtained radon data show general trend of increase in radon content from southern part i.e. Al-Sallamya area, to the northern parts at Tel-Kief area ( Fig 9 ). In fact the lowest radon value in the area is found in sample number AS5 of Al-Sallamya area, where as the highest radon value is shown by the sample number ADT3 of Tel-Kief area. The preceding remarks may indicate to the possible tectonic and seismic activity at Tel-Kief and neighboring area. In fact the Area of Tel-Kief witnessed lately several seismic events such as the earthquake of 9$^{th}$ September 2010 at 21:52:3.0 UTC with Tel-Kief area focus of 43.01 East and 36.50 North struck at depth of 11 km. with magnitude of 3.4 on Riechter scale. On 21$^{st}$ may 2012 at 11 : 57 : 58 UTC a second earthquake with magnitude of 3.8 on Riechter scale struck at depth of 11.4 km inTel-Kief area located at 43.18 East and 36.4 North. On 2$^{nd}$ of Nov. 2011, the same area witnessed a series of earthquake with magnitude ranged ( 3.1 – 4.8 on Reichter scale struck Duhok area. In the present study, sample selection and field and laboratory measurements of radon gas are not far in time from the events of earthquake described above.Detail investigation of the radon distribution in Tel-Kief area may suggest the presence of a fault system of north west trend – south east direction with the ADT3 near the fault zone and ADT4, AT1, ADM1 and ADT2, ADT1 samples at increasing distance ( Fig 10 ) away from the suggested buried fault sets Fig. 11).

At Filfeel area, Radon content in sediment ranged between 23 kBq.cm$^{-3}$ – 39 k Bq cm$^{-3}$ with an average of 31 kBq.cm$^{-3}$. The highest value is in sample SS4 ( 39 Bq. cm$^{-3}$ ) and ADF3 ( 35 k Bq. cm$^{-3}$ ). These two samples located at an area where Al-Malah wadi change direction ( Fig. 12 )which my suggests tectonic activity (?) that crossed the wadi of Al-Malah. With regards to Hawi Al-Kanessa area, the average radon content amout to ( 33 kBq. cm$^{-3}$ ) with a range ( 27 kBq. cm$^{-3}$ - 40 kBq. cm$^{-3}$ ). The samples near fault zone show higher radon content [3], as the case with samples AH1, ADH3, ADN2 with the highest value in radon content.

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In sample AH1 which may indicate to a possible extension of Musherfa fault to nearest point to the Tigris river. Comparable range ( 35 kBq. $cm^{-3}$ - 38 kBq. $cm^{-3}$ ) and average radon content ( 37 kBq. $cm^{-}$) is found in sediment of Lazzaga area. Such values can be explained by the presence of Mosul Hamam Al-Aleel fault in addition the contamination by gas emanation of mineral spring present along the fault. The Al-Salamya is considered as the least tectonic activity area as shown by the lowest average radon content ( 27 kBq. $cm^{-3}$ ) in sediment with the exception of sample AS1 which contain ( 36 kBq. $cm^{-3}$ ) because it is located near the fault zone of Mosul – Hamam Al-Aleel.

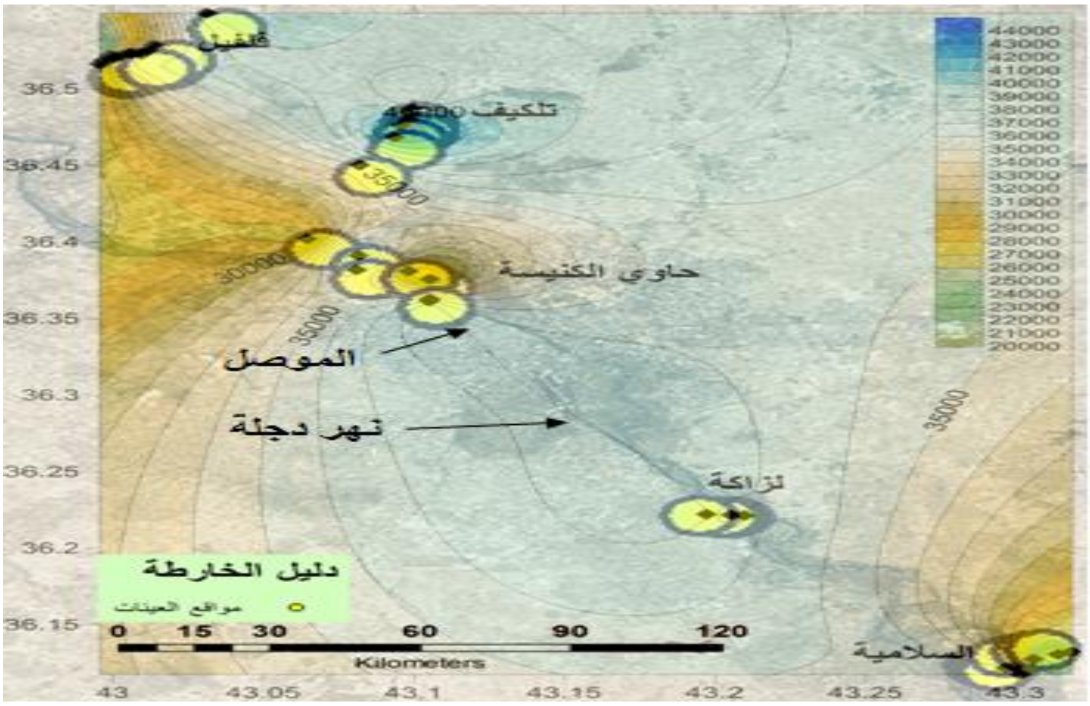


Figure 9 Spatial distribution of radon gas ( $Bq.cm^{-3}$ ) in the study area.

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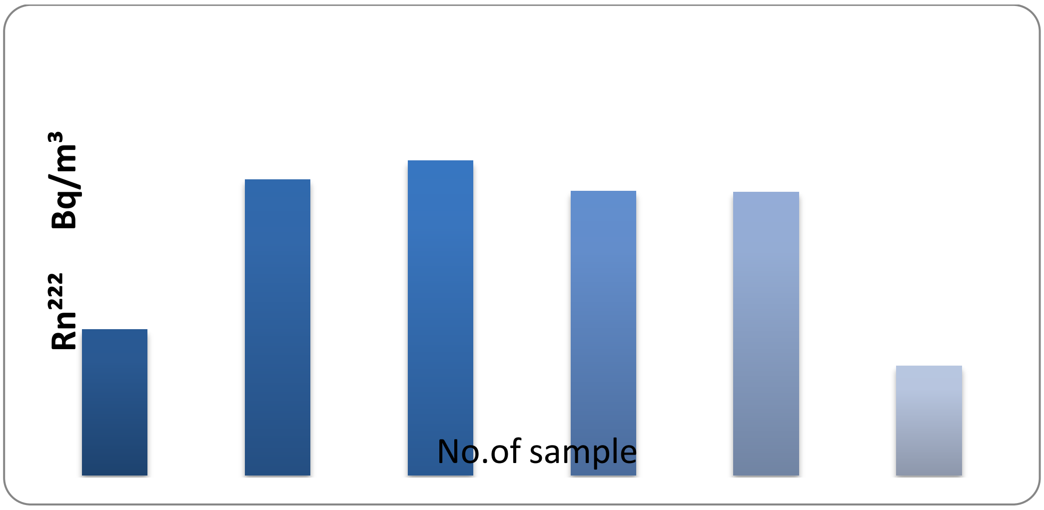


**Figure 10 Variation of radon content in samples of Tel-Kief area**

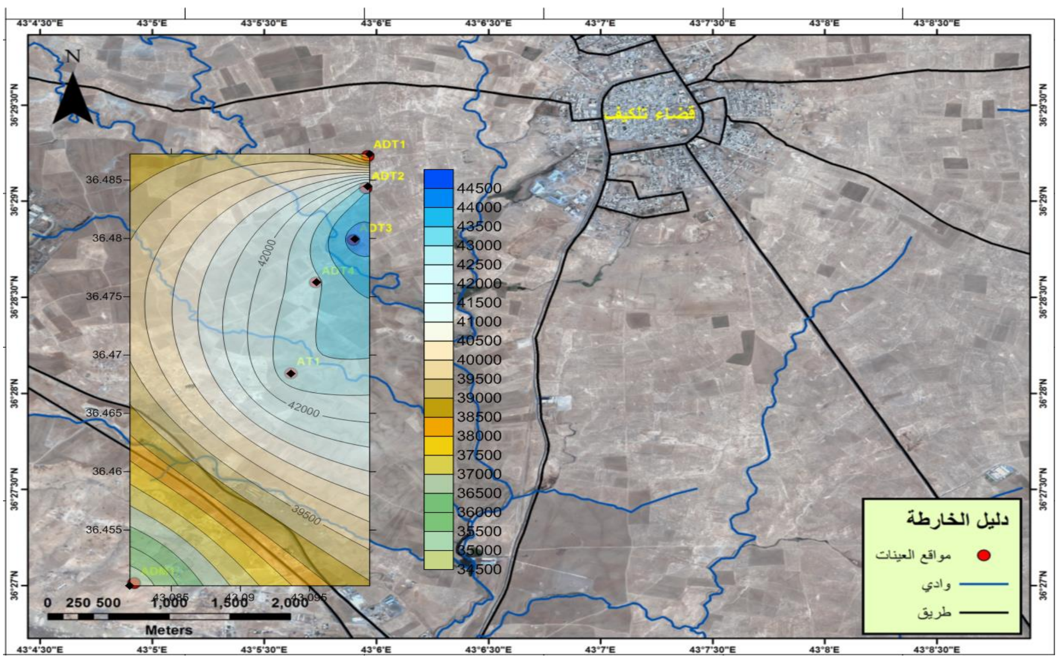


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**Figure 11 contour map of radon distribution of radon content in sediment of Tel-Kief area.**

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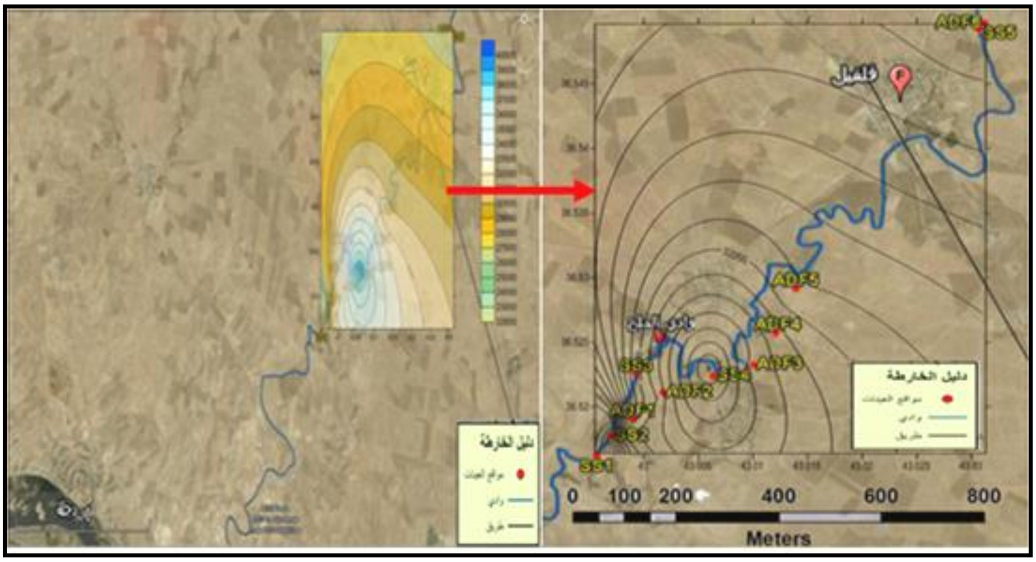


**Figure 12 Contour map of the distribution of radon content in in sediment of Filfeel area**

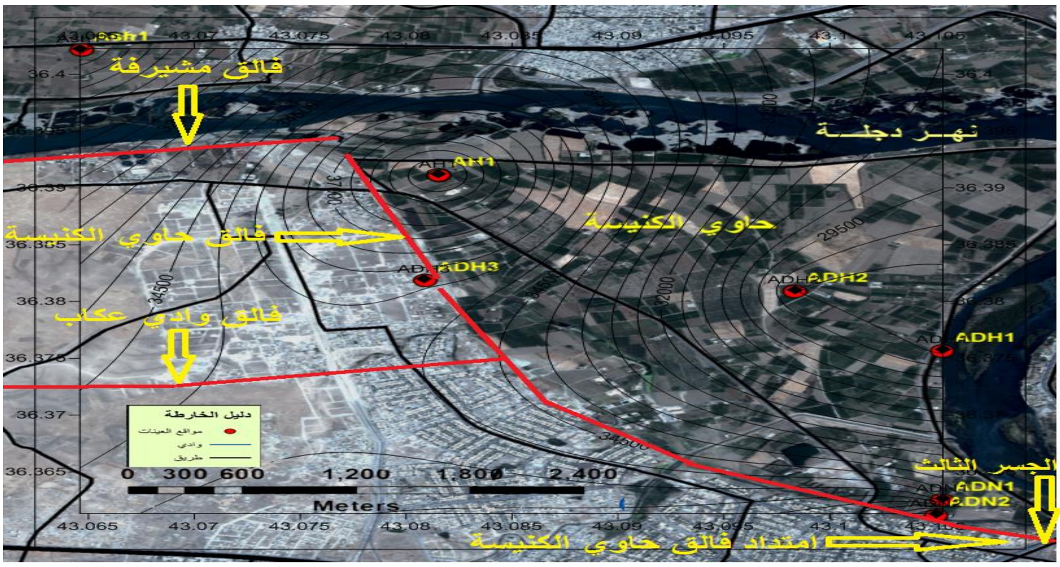


**Figure 13 Contour map of radon distribution at Hawi Al-Kanessa area.**

## 5.CONCLUSION & RECOMMENDATION

- The present study concluded that variation in radon content is not related to type of recent sediment ( soil, wadi filling or flood plain ), but it is rather related to the seismic, tectonic activities and to some extent, gas contamination emanated from mineral springs present in the area. Further work on radon survey at more comfortable and secure conditions is recommended.

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