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Detecting the Possibility of Soil Pollution with Radon Emissions for an Area Located within Baghdad University Campus- AL-Jadiriyah

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Abstract
This research deals with the detection of possible surface soil pollution by radon emissions for an area located inside the university of Baghdad campus at AL-Jadiriyah / Baghdad. The area is about 5625 m^2 and located near the College of Science for Women. The area used as construction rubbles dump yard in the past, while recently it is covered with Silty - Clayey soil furnished with grass and used as a playground. A surface survey performed on October 2018 by gridding the area into 36 stations where surface radiometric pollution readings recorded and soil samples collected by using an auger for the top 30 Cm which represents the root zone of the area. Soil samples tested in the laboratory by using can technique with CR-39 type track detectors, while surface readings performed by using a portable Geiger counter device. Soil surface readings and laboratory analysis results were processed by computer in order to draw contour maps which showed the variation of radon emission anomalies across the area. The aim behind this processing and interpretation is to provide an evaluation for the health environmental impact related to the radioactivity of the top soil and the area surface. The results of this study showed that radon emissions were below the standard limits and this makes it possible to invest the area for future human housing and other activities.

Keywords: Anomalies; Can technique; Dose; Radon concentration; Silty – clayey soil.

الكشف عن إمكانية تلوث التربة بانبعاثات غاز الرادون لمنطقة تقع داخل حرم جامعة بغداد – الجادرية

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الخلاصة
تتناول هذه الدراسة البحثية احتمال تلوث التربة السطحية بانبعاثات غاز الرادون في منطقة تقع داخل حرم جامعة بغداد في الجادرية / بغداد. تبلغ مساحتها حوالي 5625 متر مربع وتقع بالقرب من كلية العلوم للبنات. في الماضي، كانت المنطقة تُستخدم كمكب لنفايات البناء في ساحة الفناء، وهي مغطاة بتربة طينية – غرينية مزروعة بالأعشاب وتستخدم كملعب. تم إجراء مسح سطحي في أكتوبر 2018 عن طريق تقسيم المنطقة إلى 36 محطة حيث سجلت قراءات التلوث الإشعاعي السطحي وعينات التربة التي تم جمعها باستخدام اوجير لعمق 30 سم والتي تمثل منطقة الجذر في المنطقة. عينات التربة المختبرة في المختبر باستخدام تقنية Can مع كاشف CR-39، بينما يتم إجراء قراءات السطح باستخدام جهاز عداد جايجر محمول. تمت معالجة قراءات سطح التربة ونتائج التحليل المختبري بواسطة الكمبيوتر من أجل رسم خرائط الكنتور التي أظهرت

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تباين شذوذ انبعاثات الرادون في جميع أنحاء المنطقة. الهدف من هذه المعالجة والتفسير هو تقديم تقييم للأثر البيئي على الصحة الذي يتعلق بالإشعاع في التربة العلوية وسطح المنطقة. أظهرت نتائج هذه الدراسة أن انبعاثات غاز الرادون كانت أقل من الحدود القياسية، وهذا يجعل من الممكن استثمار مجال الإسكان البشري في المستقبل وغيرها من الأنشطة.

Introduction

Radon 222 is one of the periodic table elements located within the range noble elements (Noble gases) (helium-neon-xenon, etc.), the gas is invisible and tasteless and odorless, this component is generated within the intermediate stage of decomposition for uranium- 238 which includes the produce of radon generating several other radioactive elements, the series decays for this element ends by producing lead [1], where α is the gross alpha:

$$^{226}Ra \xrightarrow{\alpha} {}^{222}Rn \xrightarrow{\alpha} {}^{218}Po \xrightarrow{\alpha} {}^{214}Pb$$

Radon is one of the inert gases which has an atomic number 86, while it is mass number of his most stable state is 222 with a density of 9.7 $kg.m^{-3}$ and boiling point of -61.8 C^o, its degree of freezing is about -71 C^o [2]. This gas is heavier than air seven times but generally, it is about one and a half and it exists in all the places at all the times [3].

The Ra 222 natural nuclear radiation is mainly generated by the natural decay of a series of uranium sources ^{238}U, thorium ^{232}Th and uranium ^{235}U which considered the only metal that exists in the gaseous state [4]. Radon has three radioactive isotopes which are radon ^{222}Rn, thoron ^{220}Rn, and actinon ^{219}Rn. The counterpart which is usually taken in consideration in most geological and environmental studies is the ^{222}Rn due to its relatively long half-life (3.82 days), while the effects of other isotopes ^{220}Rn and ^{219}Rn are neglected because they possess shortest half-life (5.66 and 3.92 second), respectively [4]. The US Environmental Protection Agency EPA has proposed the maximum concentration of radon in drinking water is 1100 Bq/m^3 [5].

The radon leads to health risks via two paths, first is the inhalation of radon and its decay products after liberation from water to the air of houses, and second is the direct ingestion of radon in drinking water. The inhalation of radon decay products increases the risk of lung cancer, the radon gas was not linked to other more types of cancer and the risk of inhalation may exceed that of ingestion [6].

The fact is that alpha particles are usually emitted during radon decay, it represents a heavy charged particles which occur by colliding atoms. This type of radiation is able to produce a defect to the tissues of organs and body cells in addition to the large disturbances which are mainly chemical effects at the molecular level. The average length of the path of alpha particles in soft tissue is about 40µm. The capacity of ionizing increases to more than 1000 times when it is caused by beta particles energy, therefore it could be more destructive to human tissues as compared with the exposure to radon decay products [7, 8]. The annual effective equivalent dose for humans according to the WHO was estimated up to $2mSv.y^{-1}$, while radioactive background unusual environment for human inhalation of ^{222}Rn is at a rate of 0.8 $mSv. y^{-1}$ [9].

The Study is area located inside the university of Baghdad Scientific complex at AL-Jadiriyah / Baghdad as it shown in the Figure1.

Figure 1-Google earth map view showing the location of the study area

Recently, the area is rehabilitated and furnished with silty – clayey soil then planted with grass. The origin of the area and surroundings is the sediments of Tigris River which are mostly alluvium deposits.

This study aims to detect any radon gas radioactivity in the area which may produce environmental impact during the present and future investment for this area.

Materials and Method

The surface top soil surveying was achieved on October 2018 by using a portable Geiger counter device, Figure-2.

Figure 2: Portable Geiger counter which used in achieving the surface soil survey for the study area.

The area was gridded into square nods with a distance of 12.5 m between one station and another. GPS coordinates; surface radioactivity reading and soil sample of 30 Cm depth have been taken from each station. The diagram in Figure-3 shows the survey design which maintained during this study.

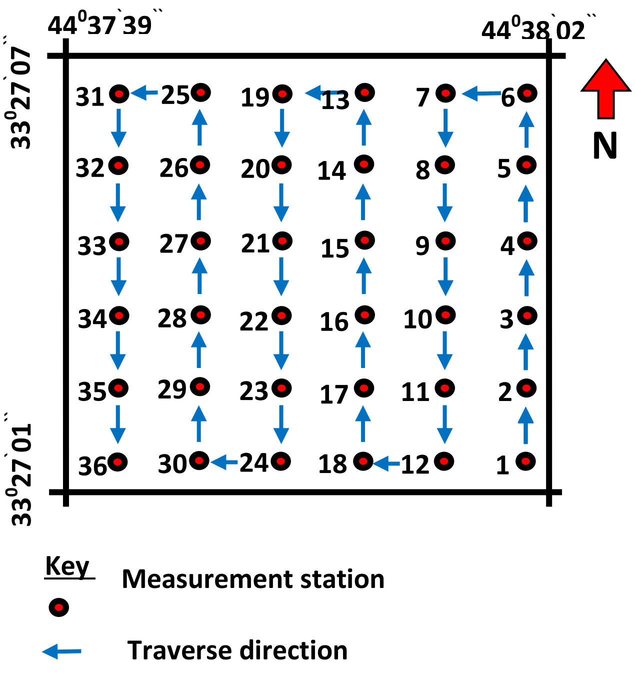


Figure 3-A plot showing the surveying design for the study area.

Can technique with CR-39 type track detectors , 200μm thickness and dimensions of 1cm×1cm was used in the present study. Dosimeters, was shown in Figure-4, after an exposure time of 30 days, the dosimeters were collected and chemically etched (6.25N NaOH at 70 C^o over 4 hour period) [10]. To account the number of tracks per cm^2 occurred in each detector an optical microscope with a magnification of 40X was used with CCD camera (Figure-5).

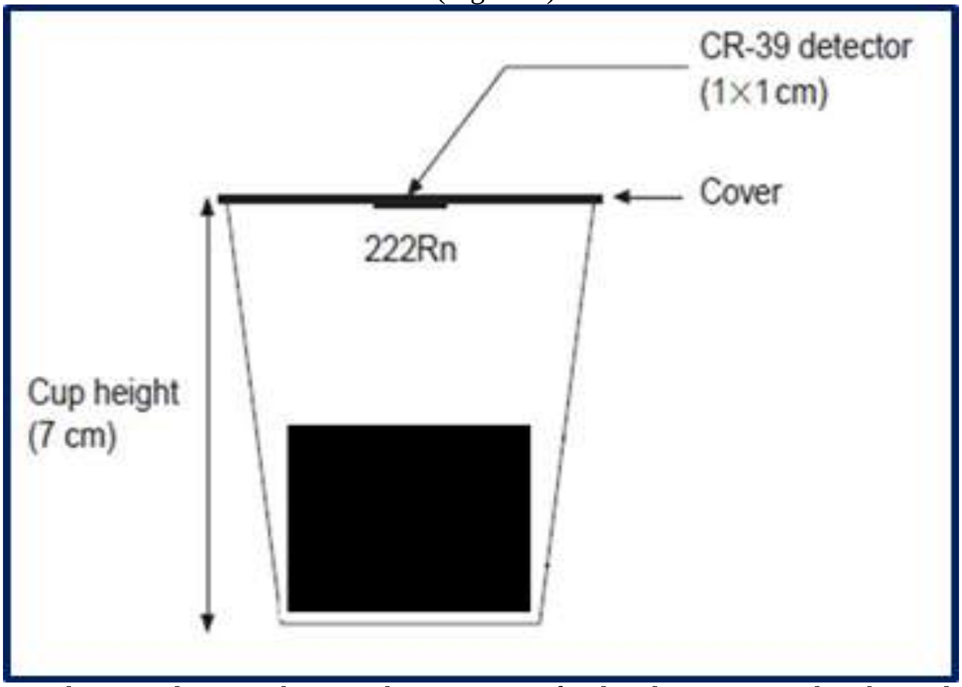


Figure 4-Schematic diagram showing the geometry of radon dosimeter used in the study.

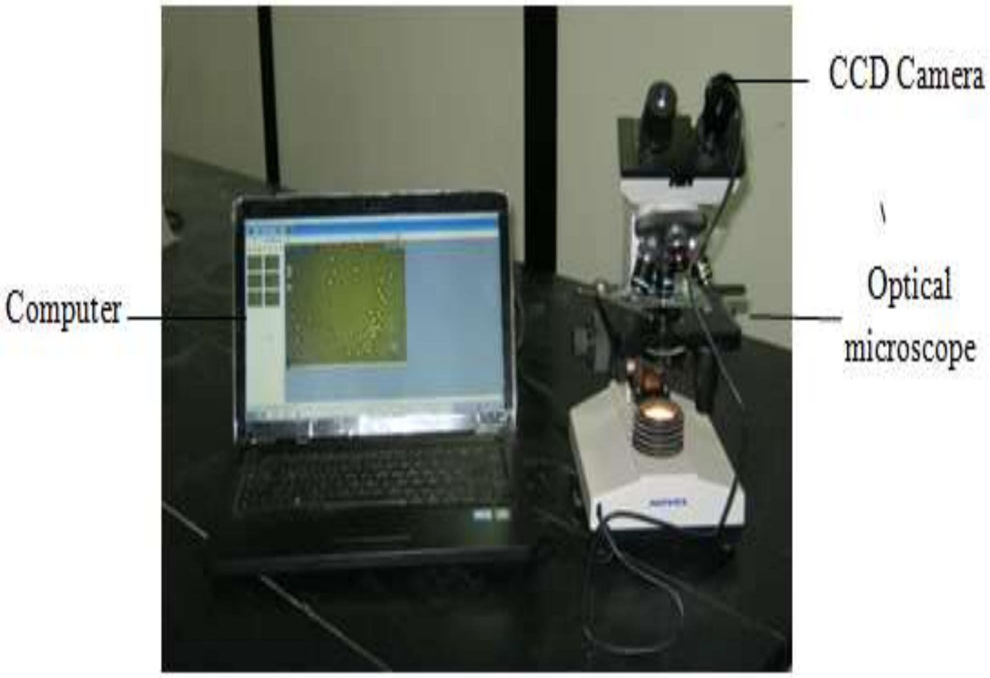


Figure 5-The track counting system

The CR-39 detectors exposed to the samples which are affected by radon and its daughters in the volume of air around them. In relating the observed track densities to the radon and its daughter activities per unit volume of air, the following equation has been used [11].

$$\rho = x\,A \qquad (1)$$

where ρ, is the number of tracks per cm^3.
x, is a constant with dimension of length (cm).
A, is the alpha activity per unit volume (disintegrations per unit time per cm^3).

The value of the constant x is the sum of separate constants calculated for all isotopes (^{222}Rn, ^{218}Po and ^{214}Po). In order to estimate the radon concentration, experimental method for radon detection and measurement are based on alpha-counting of radon and its daughters. The track density was calculated in terms of number of tracks per mm^2, and then the average number of tracks was determined by processing an unexposed films CR-39 detector under identical etching condition. The signal measured by etched track detectors is integrated track density, ρ (track. mm^{-2}) recorded on the detector, K_i the average value of the calibration factor of ^{222}Rn in (Bq. day m^{-3}) per (tracks. mm^{-2}) and T exposure time (day) has been applied to determine the activity of ^{222}Rn concentration (C_{Rn}) in Bq/m^3 by using the following Equation [12]:

$$C_{Rn} = \frac{\rho}{TK_i} \qquad (2)$$

Where: Ki, is the calibration factor with the dimension of length or equivalent to (tracks.m^{-2}.d^{-1} per Bq.m^{-3}) and ρ is the Track Density.

Usually, all measurements of radon levels in the home or outdoors are expressed as the concentration of radon in units of picocuries per liter of air (pCi/liter), or in SI units as Becquerel per cubic meter (Bq/m^3). The radon daughters are expressed in Working Levels (WL), which is given by [13]:

$$C_p(WL) = \frac{F * C_{Rn}}{3700} \qquad (3)$$

Where: F is the equilibrium factor and recommended as FC_{Rn} = 0.4 [14].

Furthermore, Qureshi. [15], proposed a method to calculate the annual effective dose of Working Level Month (WLM) units, which is given by:

$$WLM = \frac{F * t * C_{Rn}}{170 * 3700} \qquad (4)$$

Therefore, the relation between the effective dose and Radon concentration is given by:

$$E_{ff} = G\,C_{Rn} \qquad (5)$$

Where: G is a constant (conversion factor).

In this study measurement of indoor radon concentration (C_{Rn}), potential alpha energy concentration (PAEC) and annual effective dose (HE) have been performed. The potential alpha energy concentration (WL) was calculated using Eq. (3), annual effective dose equivalent (WLM/year) and effective dose also have been calculated using Eqs.(4) and (5) respectively. Radon exhalation rate was also calculated using the following equation [11]:

$$E_x = \frac{C_t \lambda V}{S[t - 1/\lambda(1 - e^{-\lambda t})]} \qquad (6)$$

Where: E_x is radon exhalation rate (mBq/m^2.h), C_t is mean radon concentration as measured by CR-39 detector (Bq/m^3), V is volume of the can (m^3), t is the exposure time, λ is the radon decay constant and S is the surface area from which radon is exhaled into the closed can.

Results and discussion

The overall results for radon concentrations in Bq/m^3, radon exhalation rates in Bq/m^2.h, the equilibrium equivalent ^{222}Rn concentration (CEEC in Bq/m^3), and the Annual Effective Dose Eff (in mSv/y) for thirty six soil samples were given in the Table 1. Radon concentrations were measured by making dosimeter from closed can technique, as shown in Figure-1, which means that the air at the whole exposure time was confined within the container.

Table 1-The overall results of radon measurements of soil samples

Sample	Track average	density	CRn	F	CEEC	WL	WLM	$E_{ff.}$	ECR	Excess Lung Cancer per Million Persons per Year	Ex. Rate
1	629	349.44	1732.83	0.4	693.13	0.187	9.64	43.72	0.026	26230.35	0.199
2	546	303.33	1504.17	0.4	601.66	0.162	8.37	37.95	0.022	22769.11	0.172
3	654	363.33	1801.70	0.4	720.68	0.194	10.03	45.45	0.027	27272.89	0.207
4	457	253.88	1258.98	0.4	503.59	0.135	7.01	31.76	0.019	19057.66	0.144
5	673	373.88	1854.04	0.4	741.61	0.200	10.32	46.78	0.028	28065.22	0.213
6	564	313.33	1553.76	0.4	621.50	0.167	8.65	39.20	0.023	23519.74	0.178
7	678	376.66	1867.82	0.4	747.12	0.201	10.39	47.12	0.028	28273.73	0.214
8	765	425	2107.49	0.4	842.99	0.227	11.73	53.17	0.031	31901.78	0.242
9	612	340	1685.99	0.4	674.39	0.182	9.38	42.54	0.025	25521.42	0.193
10	678	376.66	1867.82	0.4	747.12	0.201	10.39	47.12	0.028	28273.73	0.214
11	599	332.77	1650.18	0.4	660.07	0.178	9.18	41.63	0.024	24979.30	0.189
12	622	345.55	1713.54	0.4	685.41	0.185	9.54	43.23	0.025	25938.44	0.197
13	608	337.77	1674.97	0.4	669.99	0.180	9.32	42.26	0.025	25354.61	0.192
14	588	326.66	1619.88	0.4	647.95	0.174	9.01	40.87	0.024	24520.58	0.186
15	756	420	2082.70	0.4	833.08	0.224	11.59	52.54	0.031	31526.46	0.239
16	655	363.88	1804.45	0.4	721.78	0.194	10.04	45.52	0.027	27314.59	0.207
17	676	375.55	1862.31	0.4	744.92	0.201	10.36	46.98	0.028	28190.33	0.214
18	657	365	1809.96	0.4	723.98	0.195	10.07	45.66	0.027	27398.00	0.208
19	684	380	1884.35	0.4	753.74	0.203	10.49	47.54	0.028	28523.94	0.216
20	723	401.66	1991.79	0.4	796.71	0.215	11.08	50.25	0.030	30150.31	0.229
21	732	406.66	2016.58	0.4	806.63	0.217	11.22	50.88	0.030	30525.62	0.231
22	645	358.33	1776.90	0.4	710.76	0.191	9.89	44.83	0.026	26897.58	0.204
23	712	395.55	1961.48	0.4	784.59	0.211	10.92	49.49	0.029	29691.59	0.225
24	690	383.33	1900.87	0.4	760.35	0.205	10.58	47.96	0.028	28774.15	0.218
25	733	407.22	2019.34	0.4	807.73	0.218	11.24	50.95	0.030	30567.32	0.232
26	721	400.55	1986.28	0.4	794.51	0.214	11.05	50.11	0.030	30066.90	0.228
27	698	387.77	1922.91	0.4	769.16	0.207	10.70	48.51	0.029	29107.76	0.221
28	690	383.33	1900.87	0.4	760.35	0.205	10.58	47.96	0.028	28774.15	0.218
29	730	405.55	2011.07	0.4	804.43	0.217	11.19	50.74	0.030	30442.22	0.231
30	671	372.77	1848.53	0.4	739.41	0.199	10.29	46.64	0.027	27981.82	0.212
31	606	336.66	1669.46	0.4	667.78	0.180	9.29	42.12	0.025	25271.21	0.191
32	706	392.22	1944.95	0.4	777.98	0.210	10.82	49.07	0.029	29441.38	0.223
33	777	431.66	2140.55	0.4	856.22	0.231	11.91	54.00	0.032	32402.20	0.246
34	761	422.77	2096.47	0.4	838.59	0.226	11.67	52.89	0.031	31734.97	0.241
35	673	373.88	1854.04	0.4	741.61	0.200	10.32	46.78	0.028	28065.22	0.213
36	580	322.22	1597.84	0.4	639.13	0.172	8.89	40.31	0.024	24186.97	0.183
Average	665.25	369.58	1832.70		733.08	0.197	10.20	46.24	0.027	27742.03	0.210

The overall average value of the radon concentrations of ^{222}Rn for soil samples was 1832.7 Bq/m^3. The maximum concentration of ^{222}Rn was 2140.55 Bq/m^3 appeared in sample No. 33 and the minimum concentration was 1258.98 Bq/m^3 in sample No. 4 as shown in Figure-6. The calculated CEEC values showed that the maximum value was 856.22 Bq/m^3 in sample no. 33, and the minimum value was 503.59 Bq/m^3 in sample No. 4. The overall average value of CEEC for ^{222}Rn was 733.08

Bq/m^3, and this showed that the concentration of radon emitted from the samples does not depend on ^{226}Ra concentration only. The overall average value of the representative (WLM) of ^{222}Rn concentrations for the full soil samples set were determined to be 0.197. The highest value was 0.231 in sample No. 33 and the minimum value was 0.135 in sample No.4.

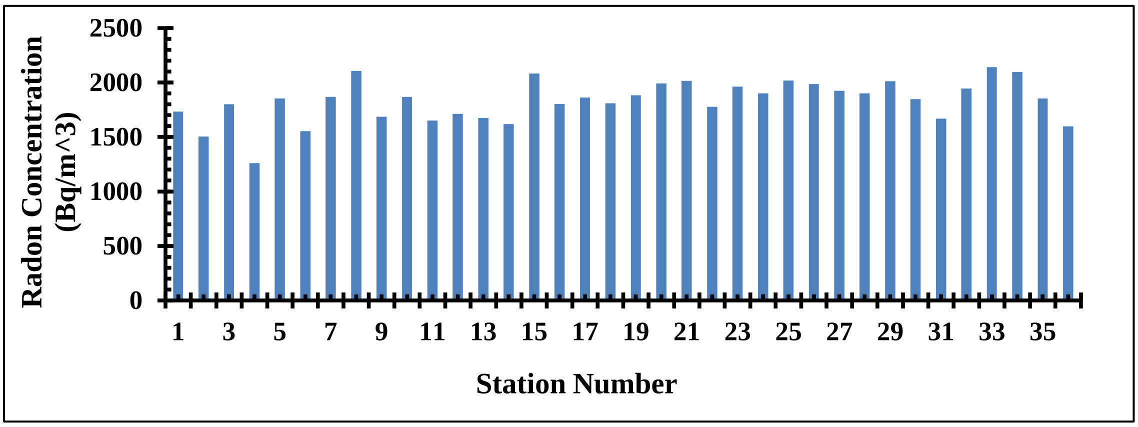


Figure 6-Radon concentration in all locations.

The overall average value of the annual effective dose $E_{ff.}$ obtained for soil samples set was 46.24 mSv/y, while the maximum value was 54 mSv/y in sample No. 33, and the minimum value was 31.76 mSv/y in sample No. 4 as shown in Figure-7.

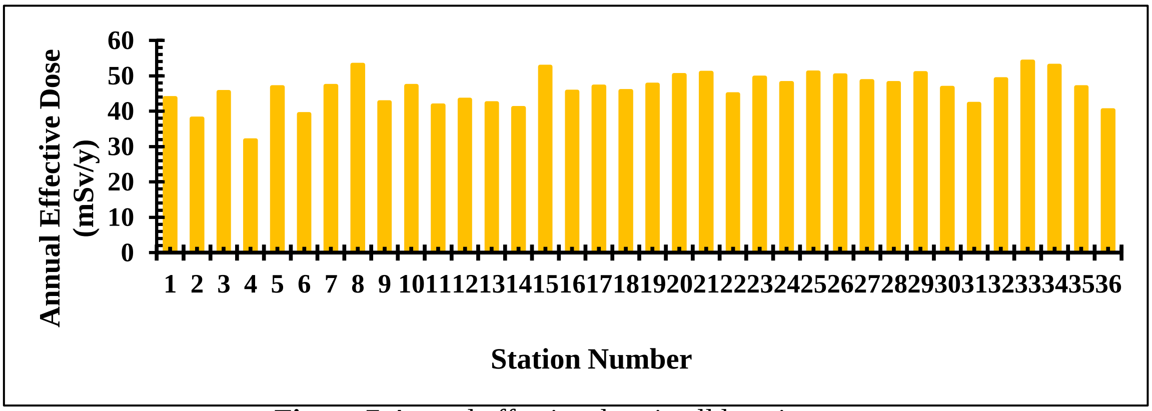


Figure 7-Annual effective dose in all locations.

The overall average value of radon exhalation rate in (mBq/m^2.h), for the full soil samples set, was 0.210. The highest value was 0.246 in sample No. 33 and the minimum value was 0.144 in sample No. 4 as shown in Figure-8. Additionally, this disparity in the values is due to differences in the nature of soil samples

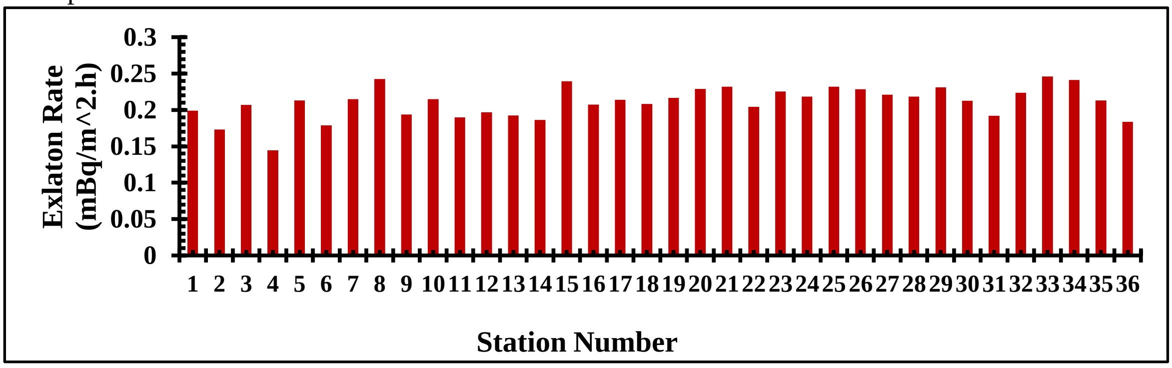


Figure 8-Radon exhalation rate in all locations.

An empirical relationship was built between the calculated radon concentrations (CRa) and the annual effective dose (E) as shown in Figure-9. Another relationship was built between radon concentrations and the possibility of human cancer with the possibility of million persons per year as shown in Figure-10.

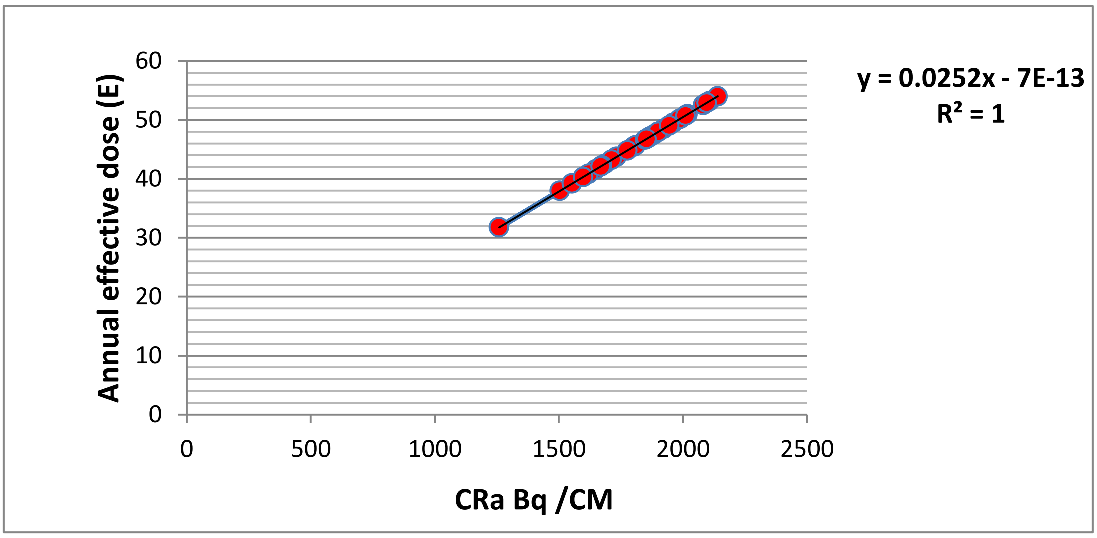


Figure 9- Empirical relation between the annual effective dose (E) and Radon concentration (CRa) in the study area.

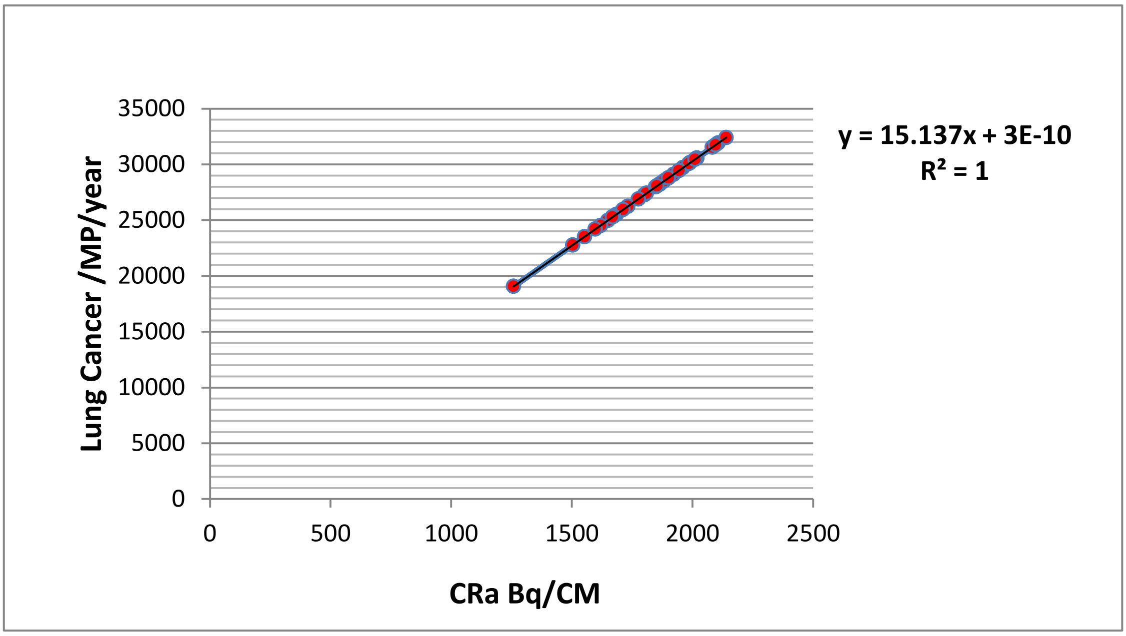


Figure 10-Empirical relation between Lung cancer disease possibility and Radon concentration (CRa) in the study area.

A linear positive relationships appeared as shown by the Figures-(9,10) with a maximum correlation coefficient (R=1).

The grid nodes data for the surveyed stations were input to computer software in order to construct contour maps by adopting the kriging interpolation method [16]. Contour maps were constructed to display the variation of the measured and calculated parameters across the study area as shown in the Figures-(11, 12 and13).

44°37`39``

33°27`07``

A

44°38`02``

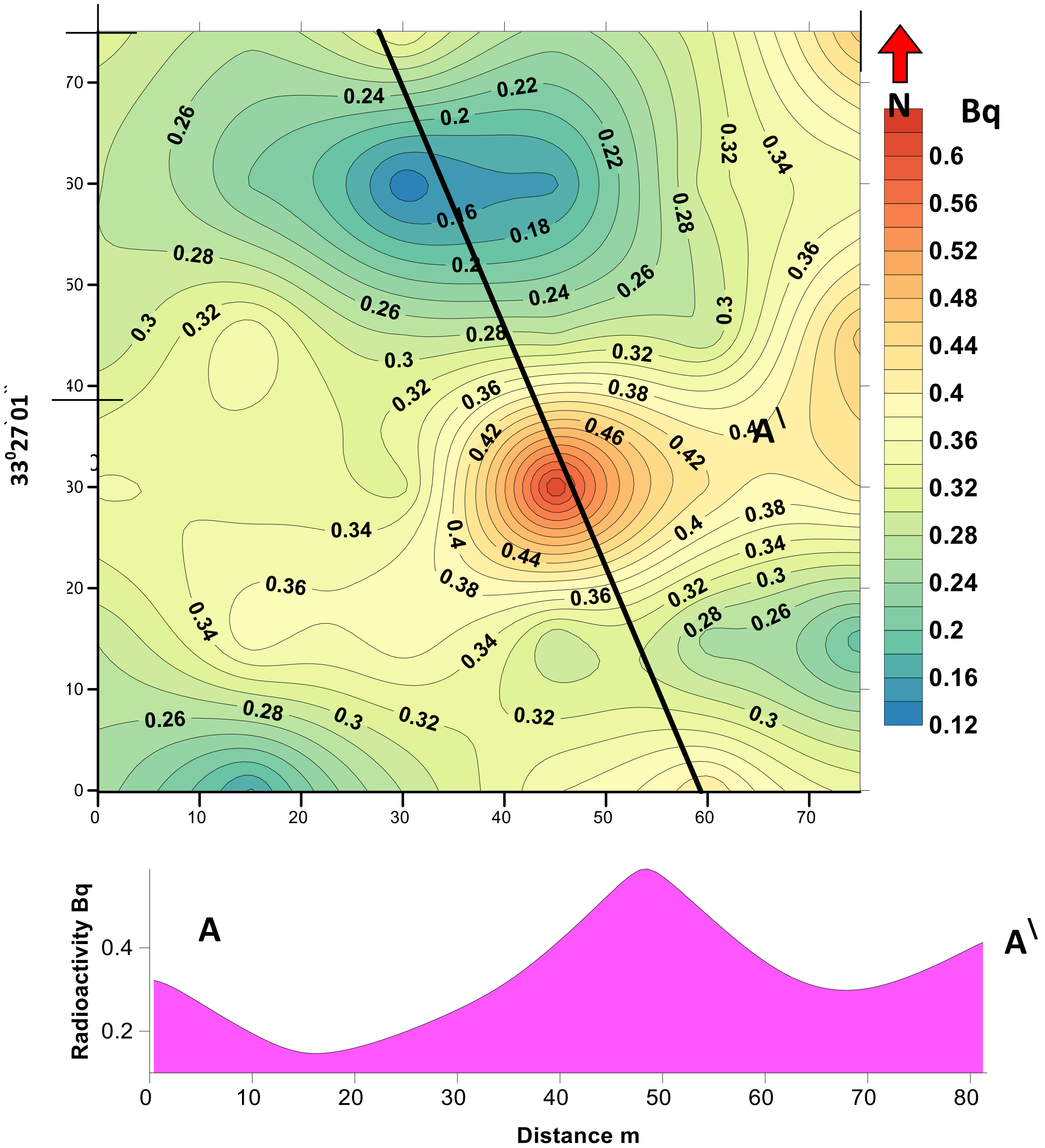
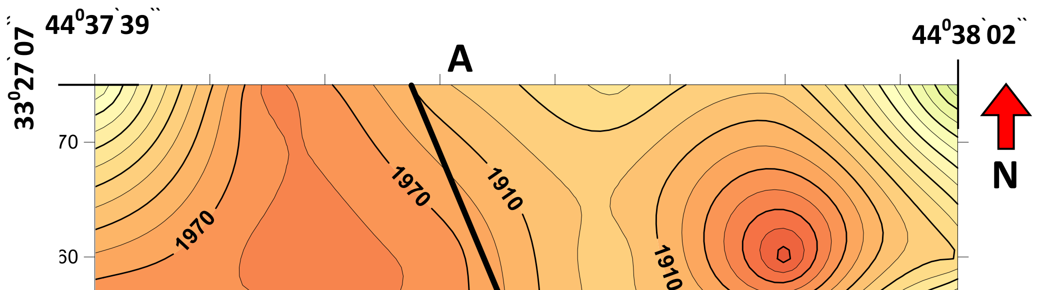


Figure 11- Soil surface radioactivity contour map, C.I.=0.02 Bq, with a profile along the traverse line A-A`.

A profile cross section along the line A-A\ built to cross a repetitive positive anomaly around the station No.16 which approximately located at the center of the area and also to display the maximum and minimum anomaly values as much as possible.



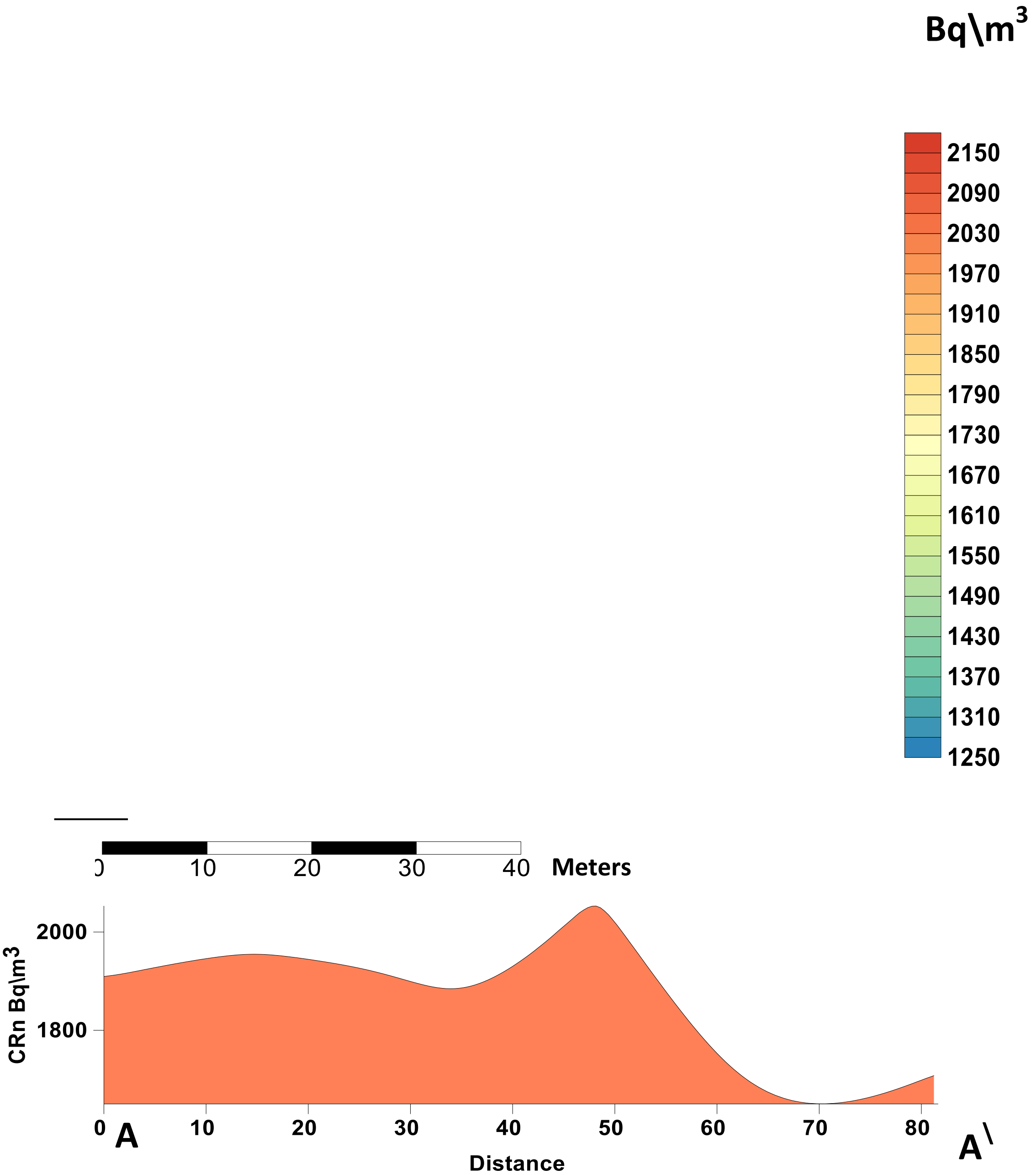


Figure 12- Radon Concentration contour map, C.I.=30 Bq\m^3 with a profile along the traverse line A-A`.

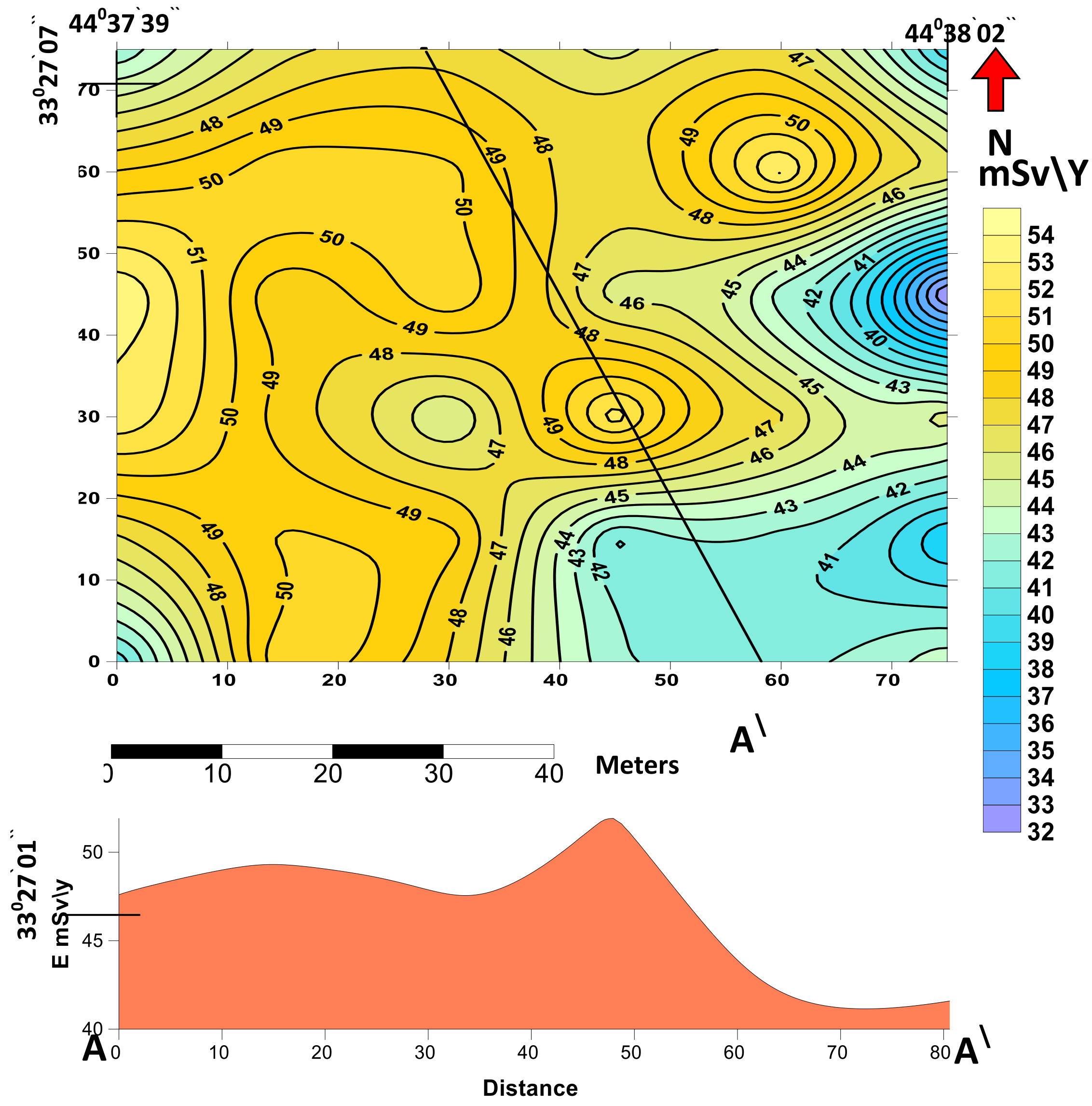


Figure 13- Annual Effective dose (E) contour map, C.I. =30 mSv\Y, with a profile along thetraverse line A-A\ .

The sections across the A-A\ profile lines show maximum anomaly at the scale distance of 50m which gives a primary indication for the source of maximum contaminated area with radon emissions.

Conclusions

The radon concentration values obtained were varied within the soil samples of the current studied area. The recorded values of radon concentration were lower than the standard limits. A linear relationship has been traced between the annual effective dose and the measured radon concentrations. The overall average value of the radon concentrations of ^{222}Rn for soil samples was 1832.7 Bq/m^3. The maximum concentration of ^{222}Rn appeared in station No. 33 and the minimum concentration appeared in station No. 4 as shown in Figure-6. The calculated CEEC values showed that the maximum value was in station No. 33, and the minimum value was 503.59 Bq/m^3 in sample No. 4. The overall average value of CEEC for ^{222}Rn was 733.08 Bq/m^3, and this showed that the concentration of radon emitted from the samples does not depend on ^{226}Ra concentration only. The overall average value of the representative (WLM) of ^{222}Rn concentrations for the full soil samples set were determined to be 0.197. The highest value was in station No. 33 and the minimum value was 0.135 in station No.4.

A repetitive positive anomaly of radon concentration has been monitored around the station No.16 at the profile line A-A\ distance of 50m. This anomaly may represent the source of Emissions and locate approximately in the middle of the area.

Recommendations

As the values of radon concentrations are below than the standards levels, therefore the area is suitable to be invested by human activities with low probability of radioactivity exposure risks.

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