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Measurement of Radon Gas Concentrations in Tap Water Samples for Anbar Governorate by Using Nuclear Track Detector (CR-39)

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***Abstract* - In the present work, we have measured the radon gas concentrations in tap water samples for selected regions (some of them were measured for the first time as far as authors know) in Anbar governorate by using alpha-emitters registrations which are emitted from radon gas in (CR-39) nuclear track detector. The results of measurements have shown that the highest average radon gas concentration in water samples was found in A_7 [Al-Falluja (AL-Jolan district)] region which was equal to (0.195±0.01 Bq/L), while the lowest average radon concentration was found in A_{15} [Hit (Zuea district)] region which was equal to (0.065±0.01 Bq/L), with an average value of (0.139±0.03 Bq/L). The highest value of annual effective dose (AED) obtained by using the relation (3) in tap water samples was found in (A_7 region) which was equal to (0.712 µSv/y), while the lowest value of annual effective dose was found in (A_{15} region) which was equal to (0.237 µSv/y), with an average value of (0.506±0.12 µSv/y), The present results have shown that radon gas concentrations in tap water samples were less than the recommended value (11.1 Bq/L) given by (USEPA,2012). There for tap water in all the studied sites in Anbar governorate are safe as for as radon concentration is concerned.**

***Keywords*: radon concentration , water sample, tap water , CR-39 detector.**

I. INTRODUCTION

Radon is produced during the radioactive decay chain of uranium, and it is found naturally in traces in the earth's crust. This noble gas produced by the decay of radium is emitted continuously from the earth's crust and can reach the earth's surface by different processes [1]. Radon gas can dissolve and accumulate in groundwater. If these radon containing types of water are frequently used in household (for showering, dishwashing and laundry, etc), radon gas is released into the dwellings. When radon accumulates in indoor air may represent an increased health risk, especially lung cancer [2]. Health implication of radon in tap water which refers to ingestion of dissolved radon will result in a radiation dose to the lining of the stomach. Moreover, inhalation of radon gas that has been released from tap water will contribute to the radon content of indoor air and, if inhaled, will result in a radiation dose to the lung. Long-term exposure to high concentrations of radon in indoor air increases the risk of lung cancer [3].

In the present work, radon gas concentrations measurements in tap water samples to (sites) in selected regions Anbar governorate , using solid state nuclear track detectors (SSNTDs) were performed.

CR-39 detector was used during the currently conducted study because of its simplicity and long-term integrated read out, high sensitivity to alpha-particle radiation ruggedness, availability and ease of handling.

The principle of this technique is based on the production of track in the detector due to alpha particles emitted from radon and its progeny. After exposure, the tracks are made visible by chemical etching and counted manually under the optical microscope. The measurement track density is then converted into radon concentration [4].

II. EXPERIMENTAL PROCEDURE

A. The Detector

CR-39 plastic detector of thickness of about (500 µm) and area of about (1×1 cm^2) was used in the present study which is sensitive to alpha particles of energy up to 40 MeV .It was used as integrating detector of α-particles from ^{222}Rn its and daughters nuclei.

When an α-particle penetrates the detector, the particle causes damage along its path, the damage is then made visible by chemical etching. The etching produces a hole in the detector along the path of the particle. The hole can be easily observed in a light transmission microscope with a moderate magnification [5].

B. Description of Study Area

Anbar governorate is the largest province in Iraq geographically. Encompassing much of the country's western territory, it shares borders with Syria, Jordan, and Kingdom Saudi Arabia as shown in fig. 1. Table I shows symbol and location name for the different studied sites in Anbar governorate. Geographically, Anbar province consider part of the arabian peninsula. Characterized by desert climate, and low rainfall and high variation of heat between day and night, where summer temperatures rises to about (50 ^oC), and in the winter down to about (0 ^oC). The northwesterly winds and the south-west winds sometimes amounting to a maximum speed of about (21 m/s). The latitude and longitude of Anbar governorate are (31.5^o-35^o N) and (39^o- 44^o E) respectively. It is located about (60 m) above the sea level, with a total area of approximately of about (140000 km^2) [6].

C. The Exposure

(1/4 litter) in volume of tap water samples were collected from different regions in Anbar governorate. The drinking water samples were obtained from the water networks in dwellings ,(four samples were taken from each of the twenty studies regions).

The radon gas concentrations in tap water samples were obtained using the sealed-cup (can) technique as shown in fig. 2.

After one month of exposure the detectors were etched chemically in NaOH solution for 6.25 N at temperature 60°C for 6 hours. After etching, the detectors were washed for 30 minutes with running cold water, then with distilled water and finally with a 50% water/alcohol solution. After a few minutes of drying in the air, the detectors were ready for track counting. The tracks were then counted using an optical microscope having a magnification of 400x.

D. Radon Concentration Measurement

The density of the tracks (ρ) in of the samples were obtained according to the following relation [7] :

$$\text{Tracks density } (\rho) = \frac{\text{Average number of total pits (track)}}{\text{Area of field view}} \quad (1)$$

The radon gas concentrations in water samples were obtained by the comparison between track densities registered on the detectors of the samples and that of the standard water samples, which are shown in fig. 3, using the relation [8]:

$$C_X = \rho_X \,.\, (C_S / \rho_S) \quad (2)$$

where:

C_X : is the radon gas concentration in the unknown sample.

C_S : is the radon gas concentration in the standard sample.

ρ_X : is the track density of the unknown sample ($track/mm^2$).

ρ_S : is the track density of the standard sample ($track/mm^2$).

Fig. 3 shows the relation between radon gas concentration and track density in standard water samples.

E. The annual effective dose in water

The annual effective dose (AED) of an individual consumer due to intake of radon from tap water in terms of (μSv/y) units was obtained using the relation [9]:

$$AED\ (\mu Sv/y) = C_{Rn}\, C_{Rw}\, D_{cw} \quad (3)$$

Where C_{Rn} is the concentration of radon in the ingested tap water in (Bq/L) units, C_{Rw} is consumption rate of water and it is equal to 730 L/y and D_{cw} is the dose conversion factor and it is equal to (5×10^{-9} Sv/Bq) [10].

F. Determination of radon exhalation rate in soil and water samples

The radon exhalation rate (RER) or (E_A) of any sample is defined as the flux of radon released from the surface of material. The radon exhalation rate in terms of area (surface exhalation rate) in units of $Bq.m^{-2}.h^{-1}$ can be obtained by the relation [11]:

$$RER = \frac{C\,V\,\lambda}{A\ [T + \lambda^{-1}(e^{-\lambda T} - 1)]} \qquad (4)$$

where:

C: is the integrated radon exposure ($Bq.m^{-3}.h$).

V: is the volume of air in the cup (m^3).

λ: is the decay constant for ^{222}Rn (h^{-1})

A : is the surface area of the sample (m^2).

T : is the exposure time (h).

G. Determination of dissolved radon concentration

The dissolved radon concentration in tap water in terms of (Bq/L) units was obtained using the relation [12].

$$C_d\,(Bq/L) = C_{Rn}\,\lambda\,h\,T\,/\,L \qquad (5)$$

where :

C_{Rn} : is the concentration of radon in the ingested tap water in (Bq/L) units

λ : is the decay constant for ^{222}Rn (h^{-1})

h : is the distance from the surface of water to the detector (m)

T : is the exposure time (h)

L : is the depth of the sample (m)

III. RESULTS AND DISCUSSION

Table II presents radon gas concentrations in tap water samples for selected regions in Anbar governorate (obtained by using relation (2)). It can be noticed that, the highest average radon concentration in water samples was found in A_7 [Al-Falluja (AL-Jolan district)] region which was equal to (0.195±0.01 Bq/L), while the lowest average radon concentration was found in A_{15} [Hit (Zuea district)] region which was equal to (0.065±0.01 Bq/L), with an average value of (0.139±0.03 Bq/L) (Fig. 4).

The highest value of annual effective dose (AED) (obtained by using relation (3)) in water samples was found in (A_7 region) which was equal to (0.712 μSv/y), while the lowest value of annual effective dose was found in (A_{15} region) which was equal to (0.237 μSv/y), with an average value of (0.506±0.12 μSv/y) (Fig.5).

The highest value of radon exhalation rate (RER) (obtained by using relation (4)) in tap water samples was found in (A_7 region) which was equal to (162.226 $\mu Bq/m^2h$), while the lowest value of radon exhalation rate in tap water samples was found in (A_{15} region) which was equal to (54.075 $\mu Bq/m^2h$), with an average value of (115.264±29.52 $\mu Bq/m^2h$) (Fig.6).

The highest value of dissolved radon concentration (C_d) (obtained by using the relation (5)) in tap water samples was found in (A_7 region) which was equal to (2.385 Bq/L), while the lowest dissolved radon concentration in tap water samples was found in (A_{15} region) which was equal to (0.795 Bq/L), with an average value of (1.695±0.43 Bq/L) (fig. 7). It is interesting to mention that ,some of the present results concerning the radon gas concentrations and dissolved radon gas concentrations for tap water samples , such as [AL-Ramadi (5 kilo), Al-Qaim (AL-Resala district), Hadetha] regions in Anbar governorate ,were obtained for the first time as for as authors know.

The present results for Anbar governorate have shown that the radon gas concentration in all tap water samples were found to be less than the recommended value given by (USEPA,2012) which was equal to (11.1 Bq/L) [13]. Also the annual effective dose in all studied samples were found to be less than the recommended value (1 mSv/y) given by (EPA, 2000) [14]. Therefore , the tap water in all the studied regions in Anbar governorate are safe as far as radon concentration is concerned.

IV. CONCLUSION

The highest average radon gas concentration in tap water samples was found in A_7 [Al-Falluja (AL-Jolan district)] region, which was equal to (0.195±0.01 Bq/L), while the lowest average radon gas concentration was found in A_{15} [Hit (Zuea district)] region which was equal to (0.065±0.01 Bq/L)**,** with an average value of (0.139±0.03 Bq/L). The radon gas concentration in tap water samples were found to be less than the recommended value of (11.1 Bq/L) given by (USEPA,2012). Therefore, the tap water in all the studied regions in Anbar governorate are safe as far as radon concentration is concerned.

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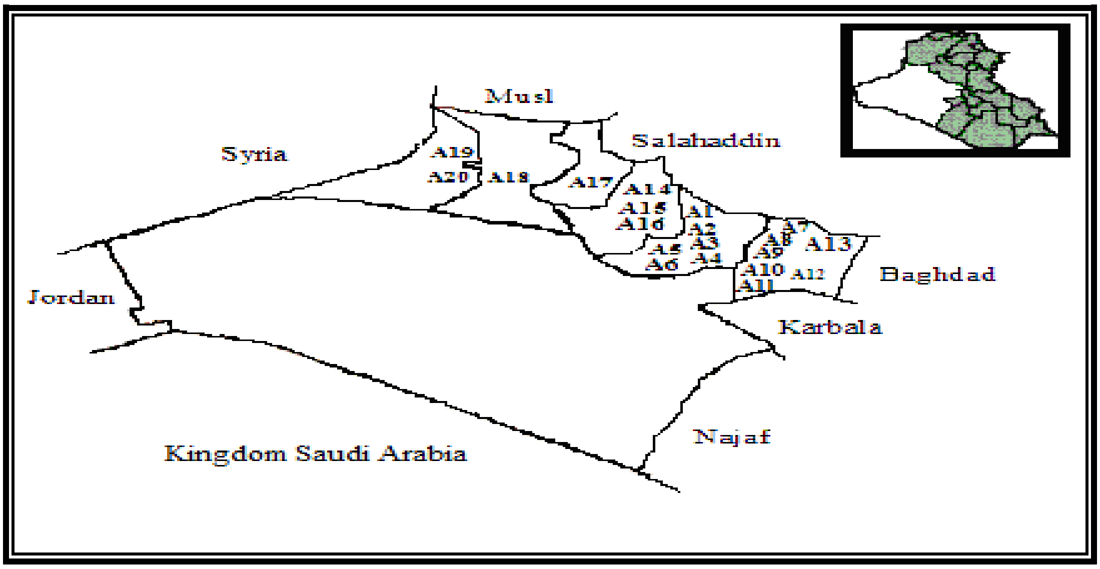

Fig. 1. Sketch map showing locations for the studied sites in Anbar governorate

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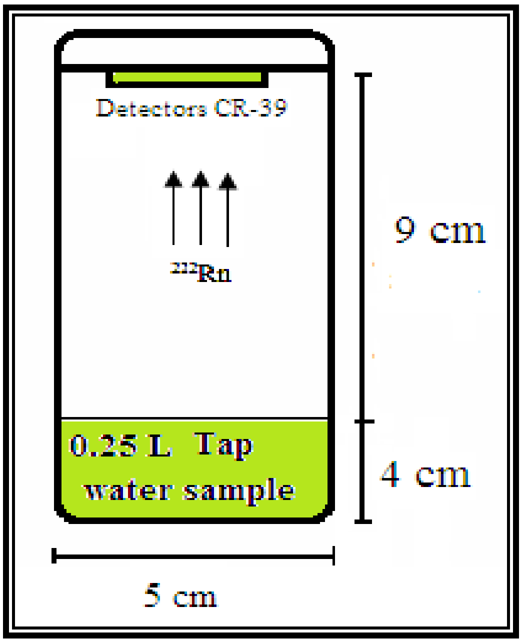

Fig. 2. Sealed-cup technique used for water samples

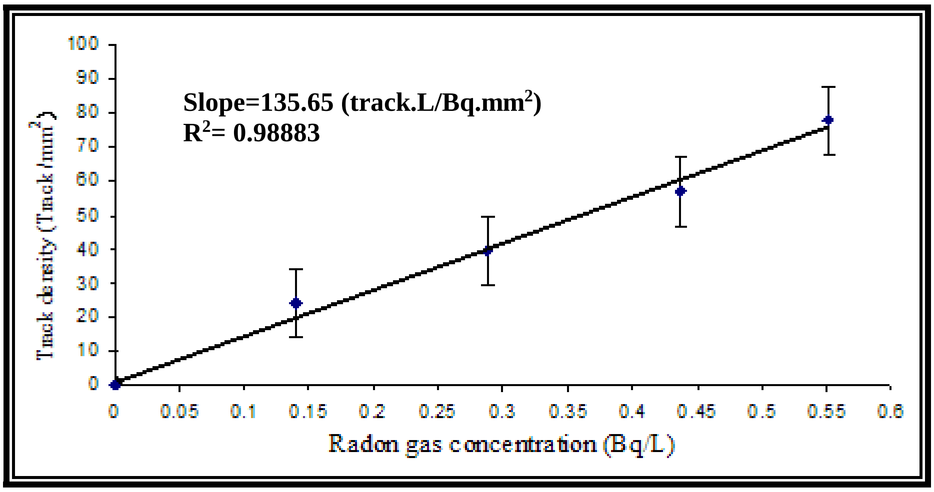

Fig. 3. Relation between radon gas concentration and track density in standard water samples

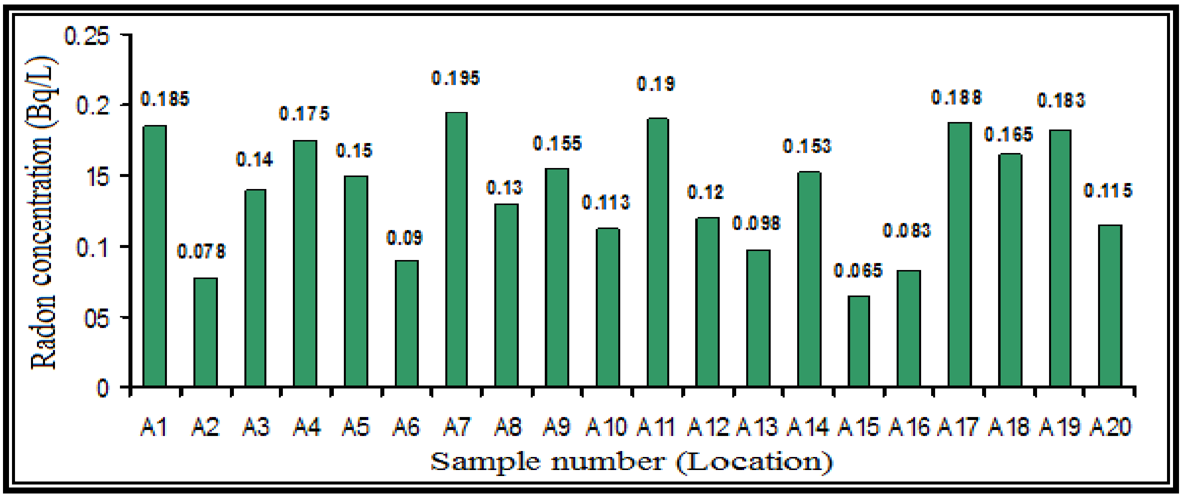

Fig. 4. A histogram illustrating the change in radon gas concentration (C_{Rn}) in tap water samples for all regions studied in Anbar governorate.

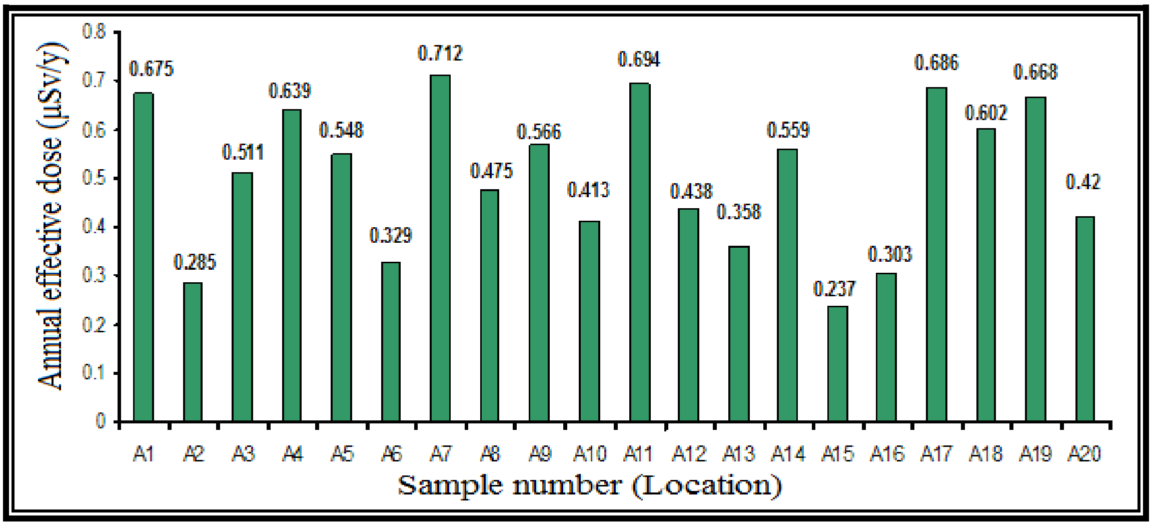

Fig. 5 A histogram illustrating the change in annual effective dose (AED) in tap water samples for all regions studied in Anbar governorate.

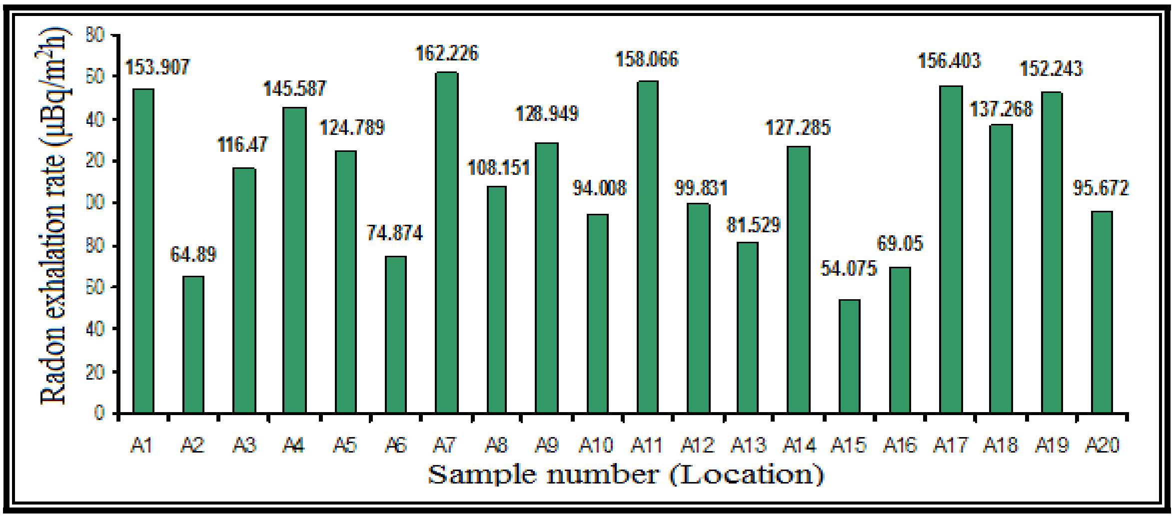

Fig.6. A histogram illustrating the change in radon exhalation rate (RER) in tap water samples for all regions studied in Anbar governorate.

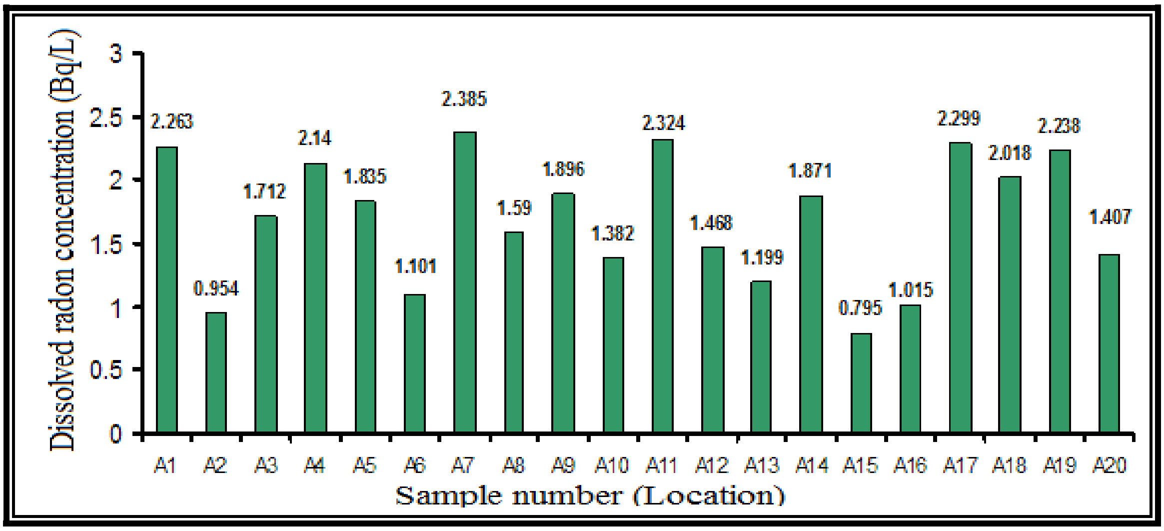

Fig.7. A histogram illustrating the change in dissolved radon concentration (C_d) in tap water samples for all regions studied in Anbar governorate.

Table I

Symbol and location name for samples sites in Anbar governorate

Symbol	Location name	Symbol	Location name
A_1	AL-Ramadi (AL-Taimeem district)	A_{11}	AL-Falluja (AL-Resala district)
A_2	AL-Ramadi (AL-Andalus district)	A_{12}	AL-Falluja (AL- Garma district)
A_3	AL-Ramadi (AL-shurta district)	A_{13}	AL-Falluja (AL-Saqlawia district)
A_4	AL-Ramadi (AL-Warar district)	A_{14}	Hit (Kabesa district)
A_5	AL-Ramadi (5 kilo)	A_{15}	Hit (Zuea district)
A_6	AL-Ramadi (AL-Mualimeen district)	A_{16}	Hit (Muradea district)
A_7	AL-Falluja (AL-Jolan district)	A_{17}	Hadetha
A_8	AL-Falluja (AL-Kadesea district)	A_{18}	Anah
A_9	AL-Falluja (AL-Ameen district)	A_{19}	Al-Qaim (AL-Obaydi district)
A_{10}	AL-Falluja (AL-Mansour district)	A_{20}	Al-Qaim (AL-Resala district)

Table II

Symbol, radon gas concentration C_{Rn} ($Bq.L^{-1}$), annual effective dose (AED), radon exhalation rate (RER), radon concentration dissolved in water (C_d), for water samples in Anbar governorate

Sample location	C_{Rn} ($Bq.L^{-1}$)				Mean of C_{Rn} ($Bq.L^{-1}$)	(AED) (μSv/y)	(RER) ($μBq/m^2h$)	C_d ($Bq.L^{-1}$)
	1	2	3	4				
A_1	0.21	0. 19	0.17	0.17	0.185±0.01	0.675	153.907	2.263
A_2	0.11	0.09	0.06	0.05	0.078±0.02	0.285	64.890	0.954
A_3	0.17	0.14	0.13	0.12	0.140±0.01	0.511	116.470	1.712
A_4	0.20	0.18	0.18	0.14	0.175±0.01	0.639	145.587	2.140
A_5	0.18	0.14	0.13	0.15	0.150±0.01	0.548	124.789	1.835
A_6	0.11	0.09	0.09	0.07	0.090±0.01	0.329	74.874	1.101
A_7	0.21	0.21	0.19	0.17	0.195±0.01	0.712	162.226	2.385
A_8	0.15	0.13	0.14	0.10	0.130±0.02	0.475	108.151	1.590
A_9	0.18	0.15	0.15	0.14	0.155±0.01	0.566	128.949	1.896
A_{10}	0.13	0.11	0.11	0.10	0.113±0.01	0.413	94.008	1.382
A_{11}	0.20	0.20	0.19	0.17	0.190±0.01	0.694	158.066	2.324
A_{12}	0.12	0.13	0.14	0.09	0.120±0.02	0.438	99.831	1.468
A_{13}	0.12	0.10	0.08	0.09	0.098±0.01	0.358	81.529	1.199
A_{14}	0.17	0.19	0.13	0.12	0.153±0.02	0.559	127.285	1.871
A_{15}	0.09	0.07	0.06	0.04	0.065±0.01	0.237	54.075	0.795
A_{16}	0.10	0.08	0.09	0.06	0.083±0.01	0.303	69.050	1.015
A_{17}	0.23	0.19	0.18	0.15	0.188±0.02	0.686	156.403	2.299
A_{18}	0.19	0.17	0.16	0.14	0.165±0.02	0.602	137.268	2.018
A_{19}	0.21	0.20	0.18	0.14	0.183±0.02	0.668	152.243	2.238
A_{20}	0.15	0.11	0.12	0.08	0.115±0.02	0.420	95.672	1.407
Average					**0.139±0.03**	**0.506±0.12**	**115.264±29.52**	**1.695±0.43**