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Research Article

Radon Concentrations in Selected Samples of Tap Water in Baghdad Government/Iraq

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Abstract: Radon gas is a significant health threat linked to thousands of preventable deaths each year. In this research, radon concentrations are measured in 136tap water samples collected from 34different places of Baghdad city, Iraq, using the electronic radon detector RAD-7 (Durridge Co., USA). The results of radon concentration varies from (0.012) to (0.283) Bq/L with a mean value of (0.111) Bq/L. The annual effective dose in Ingestion (stomach) and Inhalation (lungs) per person for children and adult is also calculated. The total annual effective dose of children and adults were (5.676) and (2.838) μSv/y respectively. At last may be concluded, the results of radon concentrations and annual effective dose in all samples show no significant radiological risk for the inhabitants in the reign study.

Keywords: Alpha emitting and Baghdad city, annual absorbed dose rate, radon concentration, RAD-7 detector

INTRODUCTION

Radon is a naturally occurring inert, radioactive, tasteless and odorless gas with half-life (3.824) days. Radon is produced from the radium (Ra-226), in decay series of U^{238}. It has a density 7.5 times higher than that of air. It dissolves in water and can readily diffuse with gases and water vapor. In recent decades, the studies are show that, under normal conditions more than 70% of total annual radioactive does received by people originates from natural sources of ionizing radiation, where by 54% is due to inhalation and ingestion of natural radioactive gas radon Rn^{222} and its decay products. Exposure to radon via inhalation in closed rooms is the cause of about 10% of all deaths from lung cancer (ICRP, 1993; Prasad *et al*., 2009). However, a very high level of radon in drinking water can also lead to a significant risk of stomach and gastrin testier cancer (Kendal and Smith, 2002). Many studies have been conducted worldwide to determine its concentration in different environmental media in order to reduce its adverse effects on human beings (Hamzeh *et al*., 2012; Rani *et al*., 2013; Abojassim, 2013; Domenico *et al*., 2014; Abojassim *et al*., 2015). The aim of the present study is to investigate the radon in tap water used for drinking in Baghdad city of Iraq.

Area of study: Baghdad is the capital of the Republic of Iraq, as well as the largest city in Iraq, which has an area of (204.2) km^2, located along the Tigris River, at Latitude (33°20) north, longitude (44°26) east (Wiet, 1971; Stanek, 2012). In the present study (30) regions were chosen as fair distribution. The regions were determined using (GIS) as shown in Fig. 1. Table 1 show the sites studied which it is content of location name, sample code and coordinate of area under study.

MATERIALS AND METHODS

In the present study, radon concentration is measured in 136 tap water samples collected from 34 locations in Baghdad government, Iraq, using RAD-7, an electronic radon detector (Durridge Co., USA). From each location, four water samples were taken and analyzed for radon concentration. The water collected directly from the tap is used by the residents. The water samples were taken in 250-mL vials. In the present research, as a sample was collected, it was analyzed immediately on the entire sampling site. The time difference between taking the sample and analyzing it was few minutes, so no decay of radon in the water occurred. The RAD-7 detector converts alpha radiation directly to an electric signal. RAD-7 has the ability to distinguish between old and new radon (DURRIDGE, 2012). Figure 2 and 3 show the Experimental laboratory and schematic diagram of RAD-7 H_2O respectively. RAD H_2O gives results after a 30-min analysis with a sensitivity that matches or exceeds that of liquid scintillation methods. The RAD H_2O method employs a closed loop aeration scheme, whereby the air volume and water volume are constant and independent of the flow rate. The air recirculates through the water and continuously extracts the radon until the state of equilibrium develops. The RAD H_2O system reaches this state of equilibrium within about 5 min, after which no more radon can be extracted from the water. The extraction efficiency or percentage of radon removed from the water to the air loop is very high about 94%

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Table 1: The studied sites in Baghdad city

No.	Location name	Code sample	Coordinate	
			Longitude (deg)	Latitude (deg)
1	B1	GAZALIYA	44.269 to 44.283 E	33.346 to 33.339 N
2	B2	ZAHRA DISTRICT	44.290 to 44.305 E	33.375 to 33.368 N
3	B3	KADHMIYA	44.334 to 44.341 E	33.382 to 33.375 N
4	B4	WASHASH	44.312 to 44.326 E	33.346 to 33.339 N
5	B5	ADEL DISTRICT	44.276 to 44.290 E	33.339 to 33.332 N
6	B6	JAMIAH DISTRICT	44.295 to 44.315 E	33.325 to 33.318 N
7	B7	HAIFA STREET	44.365 to 44.385 E	33.332 to 33.325 N
8	B8	ALAWI HILLA	44.370 to 44.384 E	33.325 to 33.318 N
9	B9	MANSOUR	44.341 to 44.355 E	33.318 to 33.310 N
10	B10	YARMOUK	44.334 to 44.348 E	33.396 to 33.289 N
11	B11	JIHAD	44.290 to 44.304 E	33.274 to 33.267 N
12	B12	BAAIH	44.314 to 44.341 E	33.267 to 33.260 N
13	B13	SAIDIYA	44.355 to 44.370 E	33.260 to 33.253 N
14	B14	SHORTA DISTRICT	44.305 to 44.312 E	33.246 to 33.238 N
15	B15	AALAM DISTRICT	44.312 to 44.326 E	33.224 to 33.217 N
16	B16	ABUDSHER	44.348 to 44.362 E	33.181 to 33.174 N
17	B17	ASKAN DISTRICT	44.326 to 44.364 E	33.339 to 33.332 N
18	B18	QADISIYAH DISTRICT	44.345 to 44.375 E	33.295 to 33.285 N
19	B19	SAHA DISTRICT	44.391 to 44.398 E	33.418 to 33.222 N
20	B20	TURATH DISTRICT	44.334 to 44.341 E	33.217 to 33.210 N
21	B21	HARTHYA	44.370 to 44.377 E	33.310 to 33.305 N
22	B22	RESALA DISTRICT	44.319 to 44.326 E	33.253 to 33.246 N
23	B23	RAA DISTRICT	44.319 to 44.326 E	33.231 to 33.224 N
24	B24	BAB MOATHAM	44.389 to 44.398 E	33.362 to 33.354 N
25	B25	FUDHAL	44.384 to 44.391 E	33.346 to 33.339 N
26	B26	MSTANSRIA	44.398 to 44.413 E	33.375 to 33.368 N
27	B27	OBEIDI	44.515 to 44.555 E	33.385 to 33.375 N
28	B28	BALADIAT	44.375 to 44.575 E	33.375 to 33.325 N
29	B29	MASHTAL	44.425 to 44.625 E	33.325 to 33.275 N
30	B30	WAZIRIYA	44.325 to 44.425 E	33.370 to 33.350 N
31	B31	ALGADEER	44.463 to 44.478 E	33.318 to 33.311 N
32	B32	KARADA	44.427 to 44.442 E	33.303 to 33.296 N
33	B33	ZAAFRINIA	44.429 to 44.514 E	33.253 to 33.246 N
34	B34	DORAA	44.384 to 44.398 E	33.253 to 33.246 N

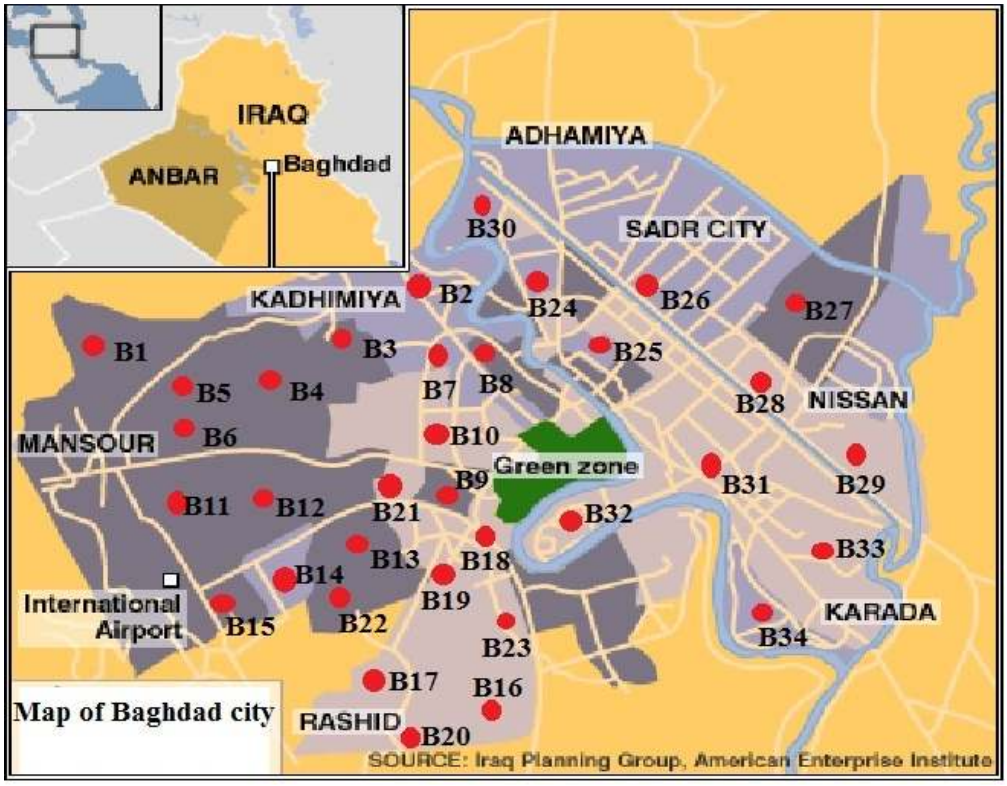

Fig. 1: Map showing the area surveyed during the present investigation

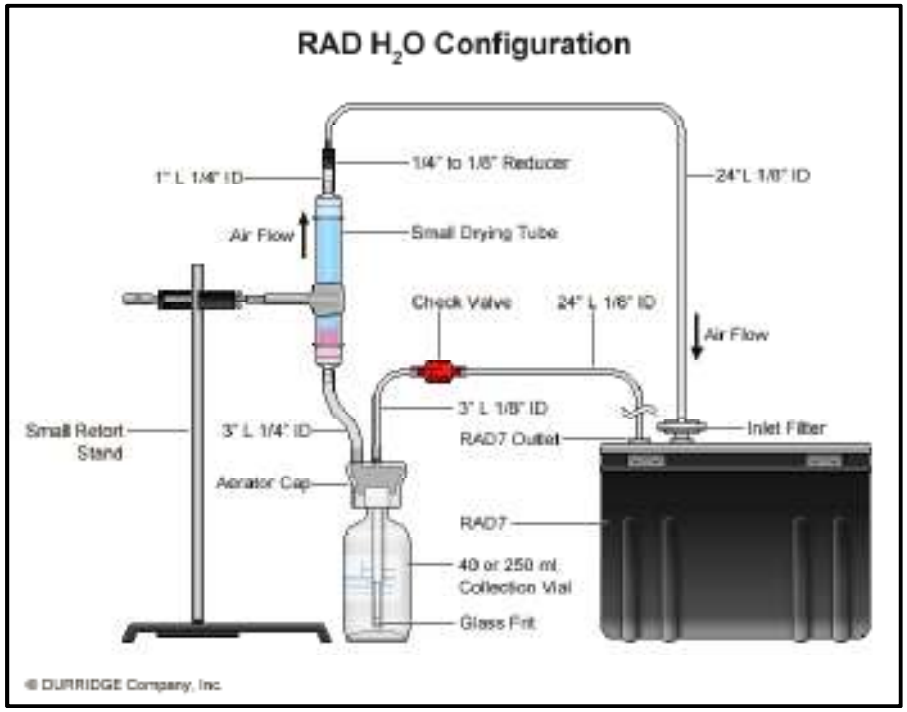

Fig. 2: Experimental laboratory set-up for Radon-in-water activity concentration measurements with Radon-in-air analyzer RAD-7 plus the RADH$_2$O accessory. Courtesy by Durridge, Inc. (DURRIDGE, 2012)

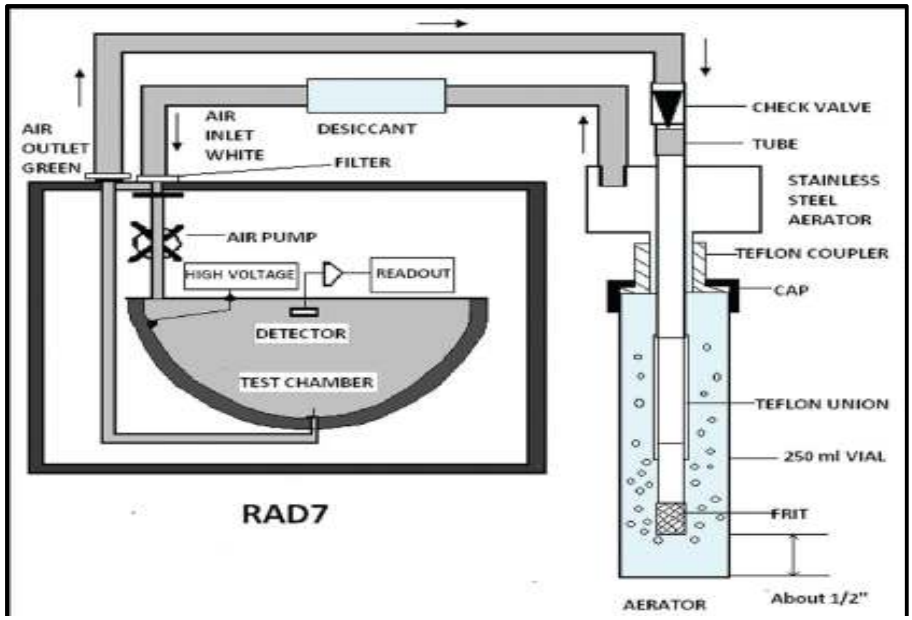

Fig. 3: Schematic diagram of the RAD-7 H$_2$O (DURRIDGE, 2012)

for a 250-mL sample. The exact value of the extraction efficiency depends somewhat on ambient temperature, but it is almost always well above 90%. The RAD-7 detector converts alpha radiation directly to an electric signal.

As per EPA recommendations that all continuous radon monitors be calibrated at least every 6 months in a radon calibration chamber, the instrument was calibrated recently. The spectrum obtained from RAD-7 at the end of a run was carefully observed and there were clearly defined peaks and no noise across the spectrum. The peaks were located in the middle of the windows, which indicate the perfect working order of the instrument and hence reliable and accurate readings.

Radon enters human body through ingestion and through inhalation as radon is released from water into

air. Therefore, radon in water is a source of radiation dose to stomach and lungs:

- For ingestion, the annual effective dose was calculated using the formula (Somlai *et al*., 2007):

$$E = K \times C_{Rn} \times KM \times t \quad (1)$$

where, E is the effective dose from ingestion (Sv), K the ingesting dose conversion factor of ^{222}Rn (2×10^{-8} for children and 1×0^{-8} Sv/Bq for adults (UNSCEAR, 1993). C_{Rn} is the radon concentration in Bq/L, KM is the water consumption (2 L/day), t is the duration of consumption (365 d) (WHO, 2004).

- For inhalation, the parameters used are (UNSCEAR, 1993; WHO, 2004):
  - Ratio of radon in air to radon in tap water supply was in the range of 10^{-4} Bq/m^3
  - Average indoor occupancy time per person was 7000 h/y
  - Equilibrium factor between radon and its progeny was equal to 0.4
  - Dose conversion factor for radon exposure was 9 nSv (Bq h/m^3)$^{-1}$.

The annual effective dose due to inhalation corresponding to the concentration of 1 Bq/L in tap water was 2.5 mSv/y.

RESULTS AND DISCUSSION

The results for radon concentration in tap water samples are shown in Fig. 4. All samples in this study have radon concentrations except samples (B31, B32, B33 and B34) which are not detected by detector; therefore we exclude them from the result. The radon concentration varies from 0.012 Bq/L in sample code B29 (MASHTAL) to 0.283 Bq/L in sample code B2 (ZAHRA DISTRICT) with an average value of 0.111 Bq/L. The results of radon concentrations values in all samples were compared with the World Health Organization (WHO, 2008) (mean the radon concentrations in tap water from surface waters equals 0.4 Bq/L), it was observed that the recorded values were well within the safe limit.

The annual effective dose in the ingestion (stomach) and inhalation (lungs) per person for child and adult of age group were estimated in this research. Table 2 shows the values of the annual effective dose per person caused by different tap water samples in this

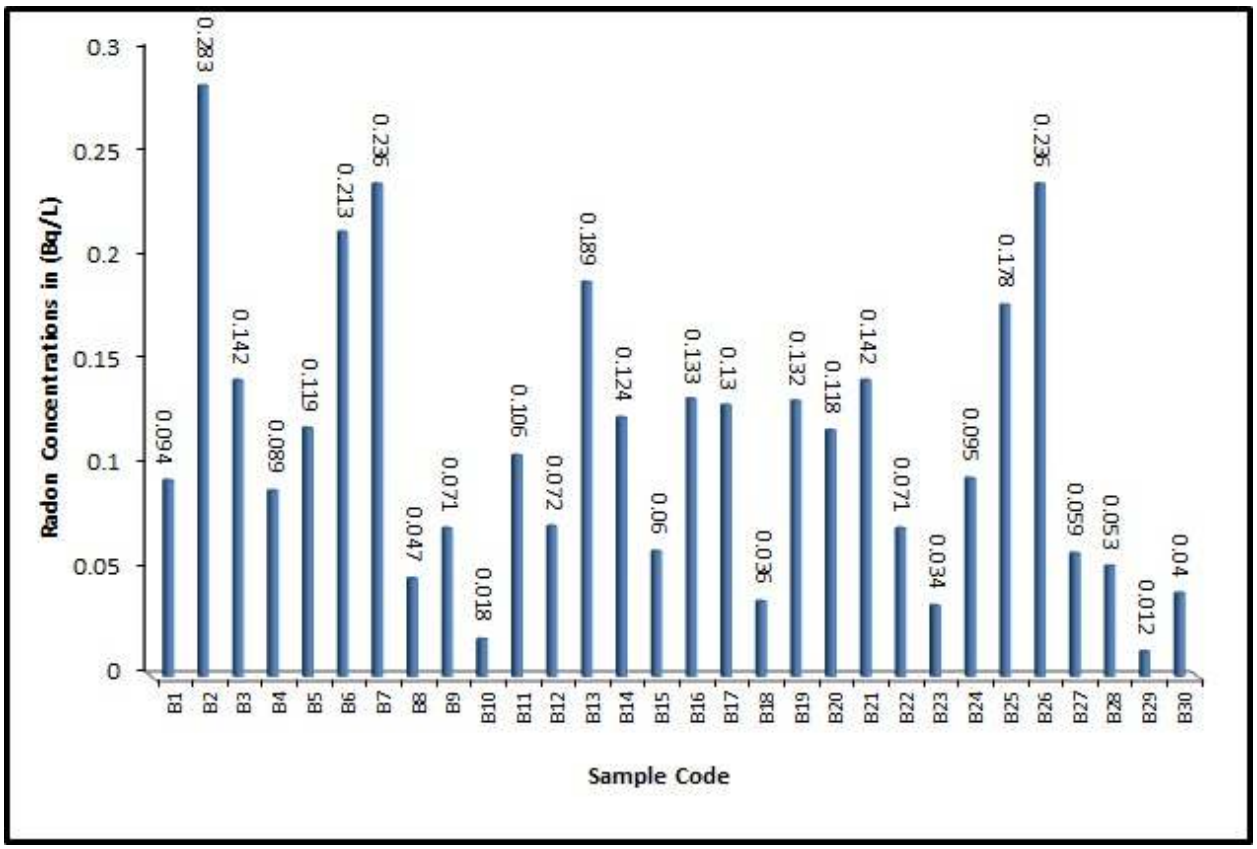

Fig. 4: Results of radon concentrations in tap water samples

Table 2: Results of annual effective dose in tap water samples

		Annual effective dose (μSv/y)					
		Ingestion		Inhalation			
No.	Sample code	Child	Adult	Child	Adult	Total child	Total adult
1	B1	1.3724	0.6862	3.431	1.7155	4.8034	2.4017
2	B2	4.1318	2.0659	10.3295	5.16475	14.4613	7.23065
3	B3	2.0732	1.0366	5.183	2.5915	7.2562	3.6281
4	B4	1.2994	0.6497	3.2485	1.62425	4.5479	2.27395
5	B5	1.7374	0.8687	4.3435	2.17175	6.0809	3.04045
6	B6	3.1098	1.5549	7.7745	3.88725	10.8843	5.44215
7	B7	3.4456	1.7228	8.614	4.307	12.0596	6.0298
8	B8	0.6862	0.3431	1.7155	0.85775	2.4017	1.20085
9	B9	1.0366	0.5183	2.5915	1.29575	3.6281	1.81405
10	B10	0.2628	0.1314	0.657	0.3285	0.9198	0.4599
11	B11	1.5476	0.7738	3.869	1.9345	5.4166	2.7083
12	B12	1.0512	0.5256	2.628	1.314	3.6792	1.8396
13	B13	2.7594	1.3797	6.8985	3.44925	9.6579	4.82895
14	B14	1.8104	0.9052	4.526	2.263	6.3364	3.1682
15	B15	0.876	0.438	2.19	1.095	3.066	1.533
16	B16	1.9418	0.9709	4.8545	2.42725	6.7963	3.39815
17	B17	1.898	0.949	4.745	2.3725	6.643	3.3215
18	B18	0.5256	0.2628	1.314	0.657	1.8396	0.9198
19	B19	1.9272	0.9636	4.818	2.409	6.7452	3.3726
20	B20	1.7228	0.8614	4.307	2.1535	6.0298	3.0149
21	B21	2.0732	1.0366	5.183	2.5915	7.2562	3.6281
22	B22	1.0366	0.5183	2.5915	1.29575	3.6281	1.81405
23	B23	0.4964	0.2482	1.241	0.6205	1.7374	0.8687
24	B24	1.387	0.6935	3.4675	1.73375	4.8545	2.42725
25	B25	2.5988	1.2994	6.497	3.2485	9.0958	4.5479
26	B26	3.4456	1.7228	8.614	4.307	12.0596	6.0298
27	B27	0.8614	0.4307	2.1535	1.07675	3.0149	1.50745
28	B28	0.7738	0.3869	1.9345	0.96725	2.7083	1.35415
29	B29	0.1752	0.0876	0.438	0.219	0.6132	0.3066
30	B30	0.584	0.292	1.46	0.73	2.044	1.022
Average		1.622	0.811	4.054	2.027	5.676	2.838

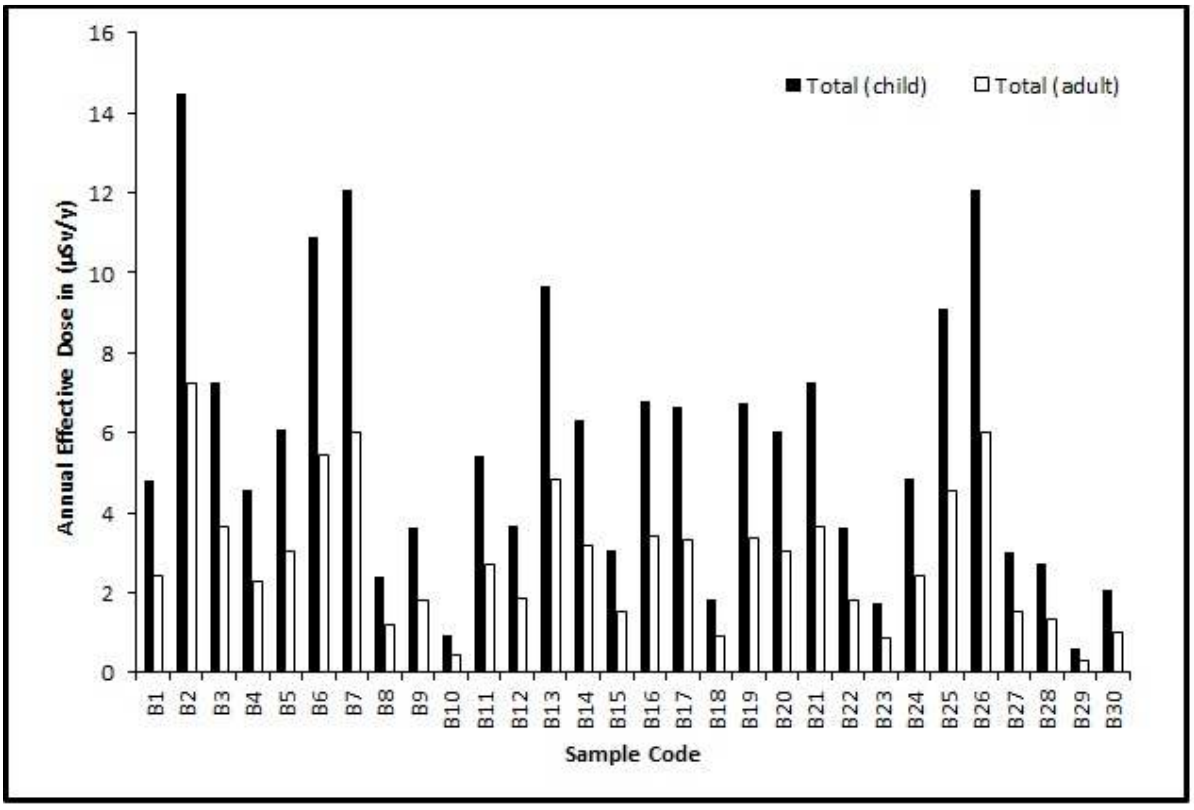

Fig. 5: Relation of total annual effective dose between children and adults

Table 3: Comparison of radon concentrations in tap water samples with previous measurements from different countries

Country	Range of radon concentration (Bq/L)	References
Kenya	0.80-4.70	Otwoma and Mustapha (1998)
Algeria	0.26-2.28	Amrani and Cherouati (1999)
Venezuela	0-2.00	Horvath *et al*. (2000)
Cyprus	0.1-2	Sarrou and Pashalidis (2003)
Brazil	0.39-0.47	Marques *et al*. (2004)
Palestine	0.9 to 1.3	Hamzeh *et al*. (2012)
Iraq (Najaf)	0.0243-0.2255	Ali and Ahmed (2013)
Iraq (Baghdad)	0.012-0.283	Present study

study. The estimated total annual effective dose of children ranged from 0.6132 µSv/y at sample code B29 to 14.4613 µSv/y at sample code B2 with an average (5.676) µSv/y, while for adults the total annual effective dose ranged from 0.3066 at sample code B29 to 7.23065 µSv/y at sample code B2 with an average (2.838) µSv/y. The results of total annual effective dose from all the locations of the studied area is found to be well within the safe limit which it were by World Health Organization (WHO, 2004) and EU Council (European Commission, 1998) recommended a 0.1 mSv/y. Figure 5 shows the relation between total annual effective dose for child and for adult, it was found the total annual effective dose of child larger than of total annual effective dose for adult, this result may be due the ingesting dose conversion factor.

The value of radon concentration obtained in Baghdad water was compared with those reported by other countries. Radon concentration values obtained in the tap water samples in this investigation generally lies well within the range reported by other countries as given in Table 3.

CONCLUSION

In this study may be concluded that, radon concentration in the tap water samples in some location of Baghdad government lays in the range from (0.012) to (0.238) Bq/L with a average of (0.111) Bq/L. The recorded values of radon concentration in tap water are within the safe limits recommended by the WHO. The estimated total annual effective dose for ingestions and inhalations at child and adult from all the locations of the studied area is found to be well within the safe limit (0.1 mSv/y) as recommended by WHO and EU Council. The results show no significant radiological risk for the inhabitants of the studied regions.

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