ESTIMATION OF RADON-222 CONCENTRATIONS IN A RESIDENTIAL AREA IN BAGHDAD CITY

Dr. Salam J. AlMaliky, . Dept. of Environmental Engineering, Eng. College , AlMustansiriya University.
Dr. Baha` ElDin Ma`rof, Ministry of Sciences and Technology.
Ahmed H.Ali, Dept. of Environmental Engineering, Eng. College , AlMustansiriya University.

ABSTRACT

Airborne radioactive particulates (for both indoor and outdoor air), in Al-Jaderiya region (Baghdad), have been collected to measure the concentration of Radon-222 daughter products of gamma ray emission (^{214}Pb, ^{214}Bi and ^{218}Po) and hence calculate the concentration of Radon-222. 24 samples were analyzed (12 indoor and others outdoor), using gamma ray spectrometric system based on a High purity Germanium detector (HpGe) of (40%) efficiency. The average concentrations of Radon-222, were found to be (93.7 Bq/m^3) and (18.9 Bq/m^3), in indoor and outdoor air respectively. The comparison of these concentrations with some internationally typical values has showed that the concentrations of Radon-222 are higher in outdoor air of the area of study compared with many regions in USA and other countries. On the contrary, the concentrations of Radon-222 in indoor air of the area of study are less than those in many European countries.

KEYWORDS

Natural radioactivity, Radon-222, indoor air, outdoor air, Spectrometric System.

خلاصة

تم جمع نماذج الهواء للدقائق المشعة العالقة في ألجو (الداخلي و الخارجي) في منطقة الجادرية (بغداد) لغرض قياس تراكيز نواتج انحلال الرادون−222 الباعثة لأشعة جاما (ألرصاص−214، ألبزموث− 214 و البولونيوم− 218) و من ثم حساب تركيز الرادون− 222. تم تحليل (24) نموذجا، (12 منها للهواء الداخلي و البقية للهواء الخارجي)، باستخدام منظومة تحليل أطياف جاما عالية النقاوة مستندة على عداد جرمانيوم نقي ذي كفاءة(40%). اظهرت النتائج ان معدل تراكيز الرادون−222 في الهواء الداخلي و الخارجي هي (93.7 بكريل/م^3) و (18.9 بكريل/م^3) على التوالي. ان مقارنة تلك النتائج مع مثيلاتها على المستوى العالمي تظهر ان تراكيز الرادون−222 في الهواء الخارجي لمنطقة الدراسة اعلى من قيمها في عدد من مناطق الولايات المتحدة الامريكية و دول اخرى. على العكس من ذلك، فقد كانت تراكيز الرادون−222 في الهواء الداخلي اقل من قيمها في العديد من الدول الاوربية .

كلمات دالة

الاشعاع الطبيعي، غاز الرادون−222، هواء داخلي، هواء خارجي، منظومة تحليل اطياف.

INTRODUCTION

Periodical monitoring of Radon-222 concentration had been emphasized by many international studies. They proved that the inhalation of short-lived decay products of Radon-222 accounts for about one half of the effective dose equivalent from all natural source of radiation and may sometimes lead to a high enough dose to cause cancer for human (Kulwant et.al, 2006).

The recent pooled analysis of key European studies estimated that the risk of lung cancer increases by 16% per 100 $Bq.m^{-3}$ increases in radon concentration. The dose–response relation seems to be linear without evidence of a threshold, meaning that the lung cancer risk increases proportionally with increasing radon exposure. Furthermore, the new results show that if a threshold exists, it should not be higher than 150 $Bq.m^{-3}$.

Recent studies showed that background levels of radon in outdoor air of most American cities are generally quite low, about 0.1 to 15 $Bq.m^{-3}$ (Krewski et.al, 2005), while, as regard to the indoor air, these studies have assessed that the Radon-222 annual mean levels in dwellings of 11 European countries is above 400 $Bq.m^{-3}$ for existing dwellings and above 200 $Bq.m^{-3}$ for future dwellings (Ernesto et. al, 2008). Also, EPA recommends homes be fixed if the radon level is 148 $Bq.m^{-3}$ or more.

GAMMA SPECTROMETRIC ANALYSIS OF ^{214}Pb AND ^{214}Bi

The activity concentrations of ^{214}Pb and ^{214}Bi in the samples of a Gamma spectrometric system may be calculated according to the following equation (Walsh et. al, 1983):

$$A_{Ei} = \frac{N_{Ei}}{\varepsilon \times t \times \gamma_d \times V_s} \quad (1)$$

The parameters E, ε_E and γ_d that are needed for Eq. (1) are listed in **Table 1**. Also, Concentration of ^{218}Po is calculated from the following relationship (UNSCEAR, 1977):

$$C_{Po\text{-}218} \approx 1.55\, C_{Pb\text{-}214} \quad (2)$$

Table 1 Parameters of gamma energy, detection efficiency and percent yield of Radon daughters (Walsh et. al, 1983)

Nuclide	E (keV)	ε_E	γ_d
^{214}Pb	351.9	0.04739	37.1
^{214}Bi	609.3	0.02253	46.1

CALCULATION OF RADON CONCENTRATION IN INDOOR AND OUTDOOR AIR

The concentration of Radon-222 in indoor and outdoor air may be calculated from the following equations (Stephen, 2008):

$$X_{Eq} = 0.106X_1 + 0.514X_2 + 0.380X_3 \quad (3)$$

$$X_{Rn} = \frac{X_{Eq}}{F} \tag{4}$$

The X_{Eq} to determine Radon gas concentration is 0.4 for indoor exposure and 0.8 for outdoor exposure (Ali, 2002).

The measured Radon-222 (in Bq/m^3) can be converted to Working Levels (WL)[1] by the use of the relationship (Stephen, 2008) :

$$WL = \frac{X_{Rn} \times F}{3700} \tag{5}$$

AIR SAMPLING PROGRAM:

Twenty four samples (outdoor and indoor air), were taken in different locations in Al-Jaderiya region (inside the complex of The Ministry of Science and Technology-Baghdad/ Iraq). Twelve samples were collected for indoor air from basement, ground, and the first floor. Other samples were collected for outdoor air from different locations outside the buildings. The duration for each sample was 1-2 hrs.

These samples were analyzed with a gamma spectrometric system as shown in **Fig.**1.

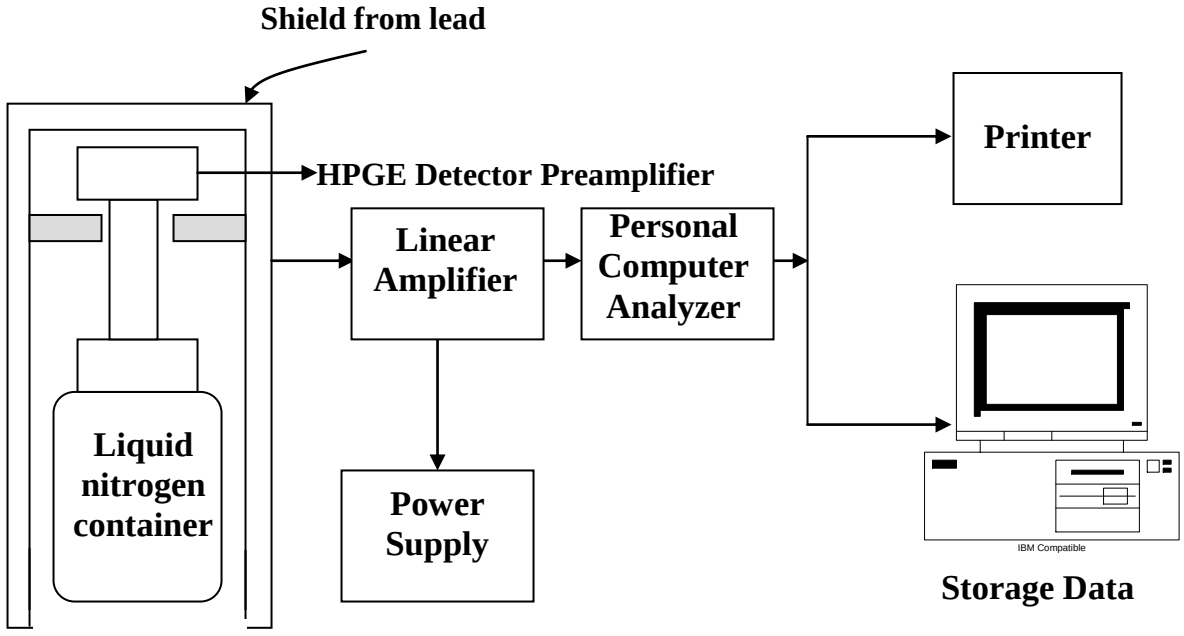

Fig.1 Gamma ray spectrometric system.

[1] WL is a measure of the concentration of potential alpha particles per liter of air

RESULTS AND DISCUSSION

Estimation of Radon-222 Concentrations in Outdoor Air

The activity concentration of ^{214}Pb and ^{214}Bi in outdoor air, measured by gamma spectrometric system are used as an input for eq.(2) to determine ^{218}Po concentration in outdoor air (**Table 2**).

Table 2. Measured concentrations of ^{214}Pb and ^{214}Bi and calculated 218Po concentrations in outdoor air.

Sample No.	Radon Decay Products Concentrations (Bq/m^3)		Calculated ^{218}Po concentrations (Bq/m^3)
	^{214}Pb	^{214}Bi	
1	8.5	20.6	13.2
2	7.8	16.1	12.1
3	10.8	23.8	16.7
4	16.3	16.3	25.3
5	15.6	24.9	24.2
6	10.0	16.7	15.5
7	8.2	15.7	12.7
8	12.7	20.6	19.6
9	12.3	21.9	17.5
10	10.5	16.8	16.3
11	13.4	22.6	20.7
12	9.7	20.0	15.0

Radon-222 concentrations in outdoor air were calculated according to eq. (3) and (4), and listed in **Table 3**. These concentrations were converted to WL using eq. (5).

The concentrations of Radon-222 in outdoor air are ranged from 14.3- 25.1 Bq/m^3 and the average concentration is 18.9 ± 3.3 Bq/m^3.

ESTIMATION OF RADON-222 CONCENTRATIONS IN INDOOR AIR

The activity concentration of ^{214}Pb and ^{214}Bi in indoor air, measured by gamma spectrometric system are used as an input for eq.(2) to determine ^{218}Po concentration in indoor air (**Table 4**).

Table 3. Calculated concentrations of Radon-222 in outdoor air.

Sample No.	Radon-222 Concentration		
	Bq/m^3	pCi/l	WL
1	16.9	0.46	0.004
2	14.3	0.38	0.003
3	20.5	0.55	0.004
4	21.6	0.58	0.006
5	25.1	0.68	0.005
6	16.4	0.44	0.004
7	14.4	0.39	0.003
8	20.5	0.55	0.004
9	20.6	0.56	0.004
10	16.8	0.45	0.004
11	22.1	0.60	0.005
12	17.7	0.48	0.004
Average concentrations	18.9 ± 3.3	0.51 ± 0.009	0.004 ± 0.0008

Table 4. measured concentrations of ^{214}Pb and ^{214}Bi, and calculated ^{218}Po concentrations in indoor air

Sample No.	Location	Radon-222 Decay Products Concentrations (Bq/m^3)		Calculated ^{218}Po concentrations (Bq/m^3)
		^{214}Pb	^{214}Bi	
1	Cellar	45.7	57.8	70.8
2	Cellar	40.3	56.4	62.5
3	Cellar	42.6	61.4	66.6
4	Ground floor	23.3	36.2	36.1
5	Ground floor	36.7	49.2	56.9
6	Ground floor	27.1	41.9	42.6
7	Ground floor	39.1	60.6	60.6
8	Ground floor	35.3	54.8	52.9

9	First floor	20.7	28.4	32.1
10	First floor	18.6	26.2	28.8
11	First floor	19.0	24.0	29.5
12	First floor	20.2	29.7	31.3

The concentrations of Radon-222 in indoor air were calculated according to eq. (3) and (4), and listed in **Table 5**. These concentrations were converted to WL using eq. (5).

The average concentration of Radon-222 in indoor air is 93.7 ± 30.7 Bq/m^3 (2.5 ± 0.8 pCi/l). The maximum concentration was noticed in the cellar (132.4 Bq/m^3). This can be justified because it is closer to the soil than other floors and as soil is the larger source of Radon-222 that comes from decay of Radium in soil. In addition, the ventilation rate in the cellar is less than that in upper floors (Muirhead, 2002); while the minimum concentration was observed in the first floor (55 Bq/m^3).

Table 5. Calculated Radon-222 concentrations in indoor air.

Sample No.	Location	Radon-222 Concentration		
		Bq/m^3	pCi/l	WL
1	Cellar	132.4	3.6	0.014
2	Cellar	121.9	3.3	0.013
3	Cellar	130.6	3.5	0.014
4	Ground floor	73.9	1.9	0.008
5	Ground floor	108.9	2.9	0.012
6	Ground floor	85.9	2.3	0.009
7	Ground floor	123.8	3.3	0.014
8	Ground floor	111.4	3.0	0.012
9	First floor	62.1	1.6	0.007
10	First floor	56.4	1.5	0.006
11	First floor	55.0	1.5	0.006
12	First floor	62.5	1.7	0.007
Average concentration		93.7 ± 30.7	2.5 ± 0.8	0.010 ± 0.003

CONCLUSIONS

- The concentration of Radon-222 in area of study is within the internationally acceptable limits.
- The concentrations of outdoor Radon-222 in study area are higher than those reported for many regions in USA and other countries. This may need more studies so as to point out the causes for such high levels. On the contrary, the concentrations of indoor Radon-222 in study area are less than those reported for many regions in USA and other countries.
- The minimum concentration occurs in the first floor which proofs that Radon-222 concentration decreases with altitude from the ground surface.
- The ratio between indoor and outdoor Radon-222 concentration (average) as calculated in this study is about (5). This proofs that the sources of Radon-222 in indoor air are more than those in outdoor air and that indoor air is in a confined space and that the outdoor

concentration is affected by atmospheric stability, which is a function of incoming solar radiation and of surface wind speed.

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NOTATIONS

γ_d : Percent yield (number of gammas per disintegration for a transition at energy E).

ε_E : The detection efficiency of energy E.

Vs : The volume of sample (m^3).

A_{Ei}: The specific activity (Bq/m^3).

F: the equilibrium factor.

N_{Ei}: The net peak area of a peak at energy E.

t :the counting live time.

X_1, X_2 and X_3: the activity concentration of Po-218, Pb-214 and Bi-214, respectively.

X_{Eq}: the Equilibrium Equivalent Concentration (EEC) of Radon daughter products.

X_{Rn}: Radon-222 gas concentration.

UNSCEAR: United Nation Scientific Committee on the Effects of Atomic Radiation