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# Measurement of Indoor Radon Concentration in Various Dwellings of Baghdad Iraq

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**Abstract** In this study, indoor radon concentration ($C_{Rn}$) were measured by solid state nuclear track detectors in bare mode using CR-39 inside fifteen dwelling at different locations in Baghdad governorate for a period two months. The Potential Alpha Energy concentration (PAEC) in Working Level (WL) of radon daughters, exposure to radon progeny (EP) in (WLM $Y^{-1}$), the annual effective dose (mSv/y) and the lung cancer cases per year per million person (CPPP) have been studied. The results show that the radon concentration ranged from 83.4 Bq/$m^3$ in Topchi to 238.8 Bq/$m^3$ in Baya with average 116.78 Bq/$m^3$, Potential Alpha Energy concentration values of radon daughters varies from (0.009 to 0.026) WL with an average value of 0.02WL, the annual effective dose rate from 2.10 to 6.02 mSv/y with average 2.95 mSv/y, exposure to radon progeny from 3.71 to 10.62 WLM $Y^{-1}$ with average 5.2WLM$Y^{-1}$ and the lung cancer per year per million person from 0.88 to 4.46 with average 1.7. The indoor radon concentration was in agreement to radon concentration levels (200 Bq/$m^3$) recommended by the International Commission on Radiological Protection (ICRP).

***Keywords:*** *radon concentration, CR-39, annual effective dose, exposure to radon progeny, lung cancer per year per million person*

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## 1. Introduction

Radon ($^{222}Rn$) is a radioactive gas released during the decay of the Uranium–238 ($^{238}U$) natural series, found in varying amounts in rocks and soils. $^{222}Rn$ is odourless, invisible, and without taste, therefore cannot be detected with the human senses.

$^{222}Rn$ decays directly into Polonium–218 ($^{218}Po$) which following a chain of $\beta^-$ and $\alpha$ decays is transformed into Polonium–214 ($^{214}Po$). Both polonium radioisotopes emit alpha particles, which are highly effective in damaging lung tissues. These alpha emitting $^{222}Rn$ decay products have been implicated in a causal relationship with lung cancer in humans. So, breathing high concentrations of radon can cause lung cancer [1].

Radon is a radioactive gas that emanates from rocks and soils and tends to concentrate in enclosed spaces like underground mines or houses. Soil gas infiltration is recognized as the most important source of residential radon. Other sources, including building materials and water extracted from wells, are of less importance in most circumstances. Radon is a major contributor to the ionizing radiation dose received by the general population.

Radon is an alpha-emitting radioactive gas. It is a daughter product of $^{226}Ra$ and decay with a half-life of 3.82 days emitting alpha particles of energy 5.49 Mev. The radioactive daughter product of radon via $^{218}Po$ and $^{214}Po$ emit alpha particles. These daughter products are solid and have a tendency to attach themselves to aerosols in ambient air. When we breathe or inhale radon and its daughter product along with the normal air, most of the radon is exhaled, its daughter products get logged to the inner walls and membranes of our respiratory system and continue causing constant damage due to their alpha activity [2].

Indoor radon exposure has become a problem all over the world due to the fact that it accounts for approximately 60% of the total natural background radiation [3].

Radon concentration measurements are nowadays routinely performed and different laboratories around the world have developed several types of radon radiation detectors [4].

Addressing radon is important both in construction of new buildings (prevention) and in existing buildings (mitigation or remediation). The primary radon prevention and mitigation strategies focus on sealing radon entry routes and on reversing the air pressure differences between the indoor occupied space and the outdoor soil through different soil depressurization techniques. In many cases, a combination of strategies provides the highest reduction of radon concentrations.

Radon is now recognized as the second most important cause of lung cancer after smoking in the general population. When radon gas is inhaled densely ionizing alpha particles emitted by deposited decay products of radon can interact with biological tissue in the lungs leading to DNA damage. Cancer is generally thought to require the occurrence of at least proliferation of intermediate cells that have sustained degree of DNA damage which can greatly increase the pool of cells available for the development of cancer [5].

The European Commission recommendation on the protection of the public against indoor exposure to radon (90/143/Euratom) sets reference levels above which remedial action should be taken. These levels correspond to an annual average indoor radon gas concentration of 400 Bq/m3 for existing buildings and an annual average radon gas concentration of 200 Bq/$m^3$ for future constructions [6].

Research has concluded that lung cancer risk increases linearly with long term radon exposure, with no evidence for a threshold below which there is no cancer risk. The increase in risk is statistically significant for annual average indoor radon concentrations even below the recommended level of 200 Bq/$m^3$ [7].

The present study aimed to determine the radon concentrations, radon exhalation rate, the alpha potential energy, the absorption effective dose exposure and the lung cancer cases per year per million person in selected region in Baghdad city. These evaluations can help in stabling a reference level of activity concentrations from which any further increase in those levels for any reason could be detected.

## 2. Site Description

Baghdad governorate is the capital of Iraq and located on a vast plain bisected by the river Tigris. The Tigris splits Baghdad in half, with the eastern half being called Al-Risafa and the Western half known as Al-Karkh as shown in Figure 1.

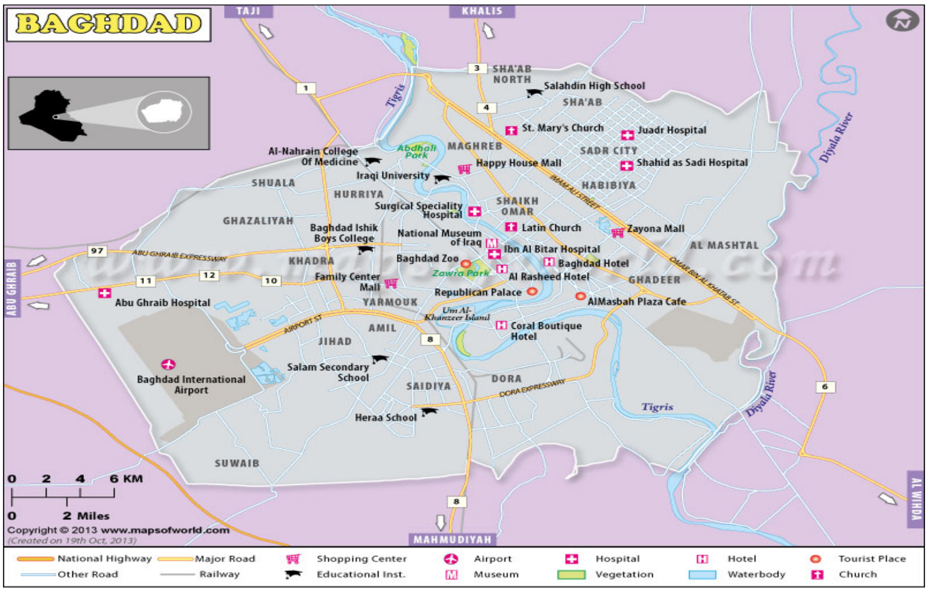


**Figure 1.** Sketch map shows locations of study samples in Baghdad governorate

The land on which the city built is almost entirely flat and low-lying, being of alluvial origin due to the periodic large floods which have occurred by the river, with location of latitude 31.30º- 33.10º N, and longitude 44.32º- 44.10º E. It is located about 32 m above the sea level, with a total area of nearly 4555 $km^2$ [8].

Table 1, shows the symbol and location name of the different studied sites in Baghdad governorate.

**Table 1: Symbols, locations name and kinds of the building materials in Baghdad governorate**

| Symbol | Location | Details for buildings | | |
|---|---|---|---|---|
| | | House type | Site Detector | Building materials |
| 1 | Tunnel Police | modern | Kitchen | Ceramics, Alabaster, secondary roof, Burke Cement, Plaster |
| 2 | America | Old | Kitchen | Ceramics, Kashi, Bricke, concrete, Plaster |
| 3 | Jadiriya _ College of Agriculture | modern | Faculty of Agriculture | Ceramics, secondary roof, Cement, Plaster |
| 4 | Palestine Street | modern | Living room | Ceramics, Bricke, Cement, Plaster |
| 5 | Adamiyah | modern | Living room | Ceramics, Bricke, Cement, Plaster, Alabaster |
| 6 | Dora | Old | Kitchen | Ceramics, Block, Cement, Plaster, Kashi |
| 7 | Bayaa | modern | Bedroom | Alabaster, Tabouk, Cement, Plaster |
| 8 | University district | Old | Living room | Ceramics, Kashi, Cement, Plaster |
| 9 | Amil district | modern | Bedroom | Ceramics, Kashi, Plaster and Bricke |
| 10 | Suleikh | Old | Living room | Ceramics, Kashi, Bricke |
| 11 | Khadraa | Old | Bedroom | Ceramics, Kashi, Bricks, Cement, Plaster |
| 12 | Diyala Bridge | Old | Kitchen | Kashi, Block, Cement, Plaster |
| 13 | Yarmouk | Modern | Kitchen | Ceramics, Block, Cement, Plaster, Bricke, Alabaster |
| 14 | Saidiya | Modem | Living room | Ceramics, Kashi, Plaster |
| 15 | Topji | Old | Kitchen | Cement, Kashi |

## 3. Materials and Methods

A passive method using CR-39 track detectors based on SSNTD technique, was employed for the assessment of radon concentration and radon exhalation rate of some regions in Baghdad city. Detectors (CR-39) of thickness (250 μm) and size 1x1 $cm^2$ were exposed to the indoor environment of a dwelling for a known period of time of the order of two months (February to April, 2015), in bare mode, during which time the alphas originating from $^{222}Rn$ and its progeny would leave tracks on it.

Altogether 15 dwellings in Baghdad governorate were selected for the radon study. The choice of the houses was random. The majority of the houses were concrete with plastered walls with proper ventilation system. The detectors were placing at a height of about 2 m from the ground and at least 1 m away from the ceiling and the walls so that direct alpha particles from the building materials of the dwelling do not reach the detectors. Detectors were placed in different rooms of the ground floor of the dwelling.

The exposed detectors were collected and etched using of 6.25 mol/l NaOH at 60±1°C for 5 h, the detectors then washed by distilled water. The counting of alpha tracks was done using a binocular optical research microscope with a magnification of 400x.

## 4. Calculation

The average radon concentration ($C_{Rn}$) in terms of Bq/$m^3$ was determined using equation [9,10]

$$C_{Rn}\left(Bq.m^{-3}\right)=\rho/K.t \qquad (1)$$

Where, ρ is the track density (track /$mm^2$), K is the calibration factor which was found experimentally to be equal to 11.81(track.$mm^{-2}$/ Bq.d.$m^{-3}$) as shown in Figure 2, and t is the exposure time which is equal to 60 days.

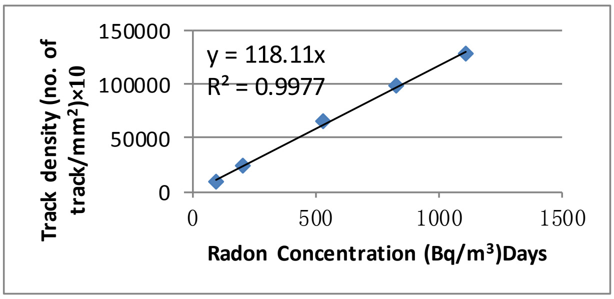


**Figure 2.** The relation of radon concentration and track density in standard samples [11]

The Potential Alpha Energy concentration (PAEC) in terms of (WL) units was obtained using the relation [12,13]:

$$PAEC\left(WL\right)=F.C_{Rn}/3700 \qquad (2)$$

Where, F is the equilibrium factor between radon and its progeny and it is equal to 0.4 as suggested by (UNSCEAR, 2000) [14].

Exposure to radon progeny (EP) is then related to the average radon concentration $C_{Rn}$ was calculate using equation [15]:

$$EP\left(WLMY^{-1}\right)=n.8760.F.C_{Rn}/170\times3700 \qquad (3)$$

Where, $C_{Rn}$ is radon concentration in Bq.$m^{-3}$, n is the fraction of time spent indoors which is equal to 0.8, 8760 is the number of hours per year, 170 is the number of hours per working month and F is the equilibrium factor for radon is equal to 0.4.

In order to estimate the annual effective dose rate received by the population, one has to take into account the conversion co-efficient from the absorbed dose and the indoor occupancy factor. According to the UNSCEAR (2000) report, the committee proposed 9.0 x $10^{-6}$ mSv/h per Bq/$m^3$ to be used as a conversion factor, 0.4 for the equilibrium factor of Rn-222 indoors and 0.8 for the indoor occupancy factor [13].

The annual effective dose equivalent (AEDE) in terms of (mSv/y) units was obtained using the relation [16,17]:

$$AEDE\left(mSv/y\right)=C_{Rn}.F.H.T.D \qquad (4)$$

where, H is the occupancy factor which is equal to (0.8), (T) is the time in hours in a year, (T=8760 h/y), and (D) is the dose conversion factor which is equal to [9×$10^{-6}$ (m Sv) / (Bq.h.$m^{-3}$)].

The lung cancer cases per year per million person (CPPP), was obtained using the relation [18,19]:

$$\left(CPPP\right)=AED\times\left(18\times10^{-6}mSv^{-1}.y\right) \qquad (5)$$

## 5. Results and Discussions

Table 2 presents the measurements for indoor radon concentrations in $Bqm^{-3}$,PAEC values of radon daughters in WL units, annual effective dose in mSv.$y^{-1}$ and exposure to radon progeny in (WLM $Y^{-1}$) to the occupant of the dwellings of Baghdad governorate.

The indoor radon concentrations varies from (83.4 to 238.8 Bq/$m^3$) Bq/$m^3$, with an average value of 116.78 $Bqm^{-3}$ as shown in Figure 3, the highest concentration was found in AL Bayaa, (bedroom, Alabaster, Tabouk, Cement, Plaster), and the lowest concentration in Al Topji, (Kitchen, Ceramics, Block, Cement, Plaster, Alabaster). The results of indoor radon concentrations in Baghdad governorate were less than the lower limit of the recommended range (200- 300 Bq/$m^3$) [20]. Potential Alpha Energy concentration values of radon daughters varies from (0.009 to 0.026) WL with an average value of 0.02WL, as shown in Figure 4. All results of the potential alpha energy concentration (PAE) in indoors dwellings in Baghdad governorate were lower than the recommended value of (53.33mWL) reported by the (UNSCEAR, 1993) [21]. The annual effective dose (AEDE) received by the residents varies from (2.10 to 6.02mSv/y with an average 2.95 mSv/y as shown in Figure 5. The Exposure to radon progeny varies from (10.62 to 3.71) WLM $Y^{-1}$ with an average 5.2 WLM $Y^{-1}$. The highest risk of a fatal lung cancer lung cancer per year per million person was found in Al Bayaa region.

The results indicate that radon concentrations in some compartments like bedroom in all apartments we investigated were significantly higher than the radon concentrations measured in the kitchens rooms. Although kitchens and bedrooms are constructed mainly from the same skeletal building materials (Tabouk- Cement - Plaster), the finishing materials used in such compartments, largely differ from that used in other locations within the same apartment. Ceramic, in particular is used extensively to replace the traditional painting materials, commonly used in living room and bedrooms.

**Table 2. Indoor radon concentration ($C_{Rn}$), Potential Alpha Energy Concentration (PAE), Annual Effective Dose Equivalent (AEDE), Exposure to radon progeny (EP) and lung cancer cases per year per million person (CPPP)**

| Locations | $C_{Rn}$ ($Bq/m^3$) | PAE (WL) | AEDE mSv/y)( | EP (WLM $Y^{-1}$) | Estimate of risk of a fatal lung cancer /$10^6$ |
|---|---|---|---|---|---|
| Tunnel Police | 129.0 | 0.014 | 3.25 | 5.74 | 1.37 |
| Ameria | 151.9 | 0.016 | 3.83 | 6.76 | 1.62 |
| Jadiriya _ College of Agriculture | 93.5 | 0.010 | 2.36 | 4.16 | 0.99 |
| Palestine Street | 86.5 | 0.009 | 2.18 | 3.85 | 0.92 |
| Adamiyah | 114.2 | 0.012 | 2.88 | 5.08 | 1.21 |
| Dora | 118.5 | 0.128 | 2.99 | 5.27 | 1.26 |
| Bayaa | 238.8 | 0.026 | 6.02 | 10.62 | 4.46 |
| University district | 108.9 | 0.012 | 2.75 | 4.84 | 1.15 |
| Amil district | 106.2 | 0.011 | 2.68 | 4.73 | 1.13 |
| Suleikh | 108.3 | 0.011 | 2.73 | 4.82 | 1.15 |
| Khadraa | 108.2 | 0.011 | 2.73 | 4.82 | 1.15 |
| Diyala Bridge | 107.1 | 0.012 | 2.70 | 4.77 | 1.13 |
| Yarmouk | 113.7 | 0.012 | 2.87 | 5.06 | 1.21 |
| Saidiya | 83.5 | 0.0089 | 2.11 | 3.72 | 0.88 |
| Topji | 83.4 | 0.009 | 2.10 | 3.71 | 0.88 |
| Average | 116.78 | 0.02 | 2.95 | 5.2 | 1.7 |

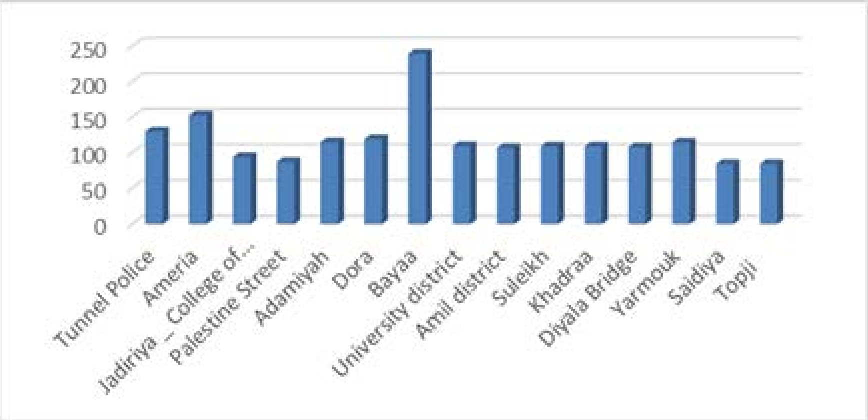


**Figure 3.** The histogram of radon concentration $C_{Rn}$ ($Bq/m^3$) in Baghdad Governorate

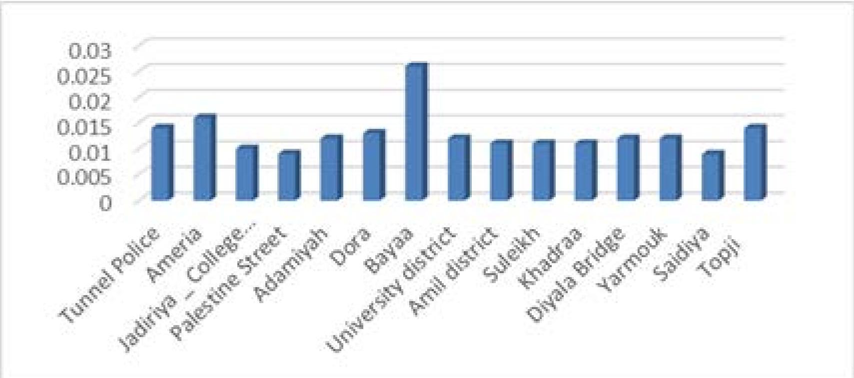


**Figure 4.** The histogram of Potential Alpha Energy Concentration (PAEC) (WL)

Previous reports have indicated that ceramic is a potential source of radon, from where radon is mainly emerging from the decay of thorium and uranium in these materials [12]. Another factor explaining the high levels of radon and exhalation rates in these compartments, are the boor ventilation status due to the relatively narrow openings. Using natural gas in houses and supplying kitchens with water are considered as a potential source for indoor radon.

Increasing the ventilation rate of the building or the use of air conditioning are effective ways of lowering radon levels in indoor air. Other mitigation measures include sealing cracks in floors and walls, under-floor sumps and extraction methods. Prevention of radon exposure in new buildings can be implemented through appropriate provisions during the construction phase [22].

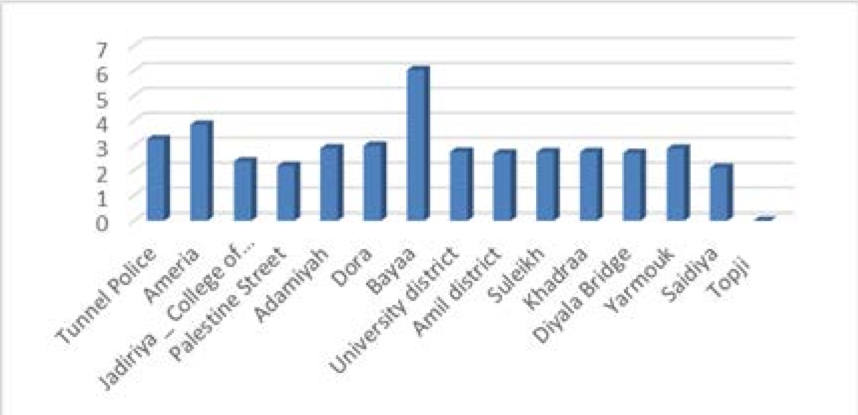


**Figure 5.** The histogram of the Annual Effective Dose Equivalent (AEDE) (mSv/y)

## 6. Conclusion

This work reports that the indoor radon concentration in bedrooms and kitchens have relatively higher than other compartments (living room) of the same dwelling. It is suggested that improvement of ventilation in such compartments is easily possible by simply reducing radon content of their ambient air. High values of radon activity in other rooms in some dwellings may be due to ventilation conditions or the type of building materials. The observed level of the indoor radon concentration in Baghdad governorate is within the permissible level of the recommended range (200- 300 $Bq/m^3$) (ICRP, 2010).

Occupants of these dwellings are therefore, relatively safe. Proper regulatory standards like natural and forced ventilation should be implemented to make the dwellings more clean and safe. There is no significant threat to the human beings due to the presence of natural radon in the dwellings.

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## References

[1] Henshaw, D.L., Eatough, J.P. and Richardson R.B., Radon as a causative factor in induction of myeloid leukemia and other cancers, The Lancet 335, pp.1008-1012, 1990.

[2] Khan, M., Tariq, M., and Rawat, R., Preliminary measurements of radon radiations in Bare Mode in Rampur district of Western U.P. India. IOSR Journal of Applied Physics, 1(4), pp. 4, 2012.

[3] United Nations Scientific Committee on the Effects of Atomic Radiation, Sources and effects of ionizing radiation. Report to the general assembly, 1, 1993, Annex B.UNSCEAR.

[4] Nidal, Dwaikat, Ghassan, Safarini, Mousa, El-hasan, and Toshiyuki, Iida, CR-39 detector compared with Kodalphafilm type (LR-115) in terms of radon concentration. Nuclear Instruments and Methods in Physics Research Section A, 574, pp. 289, 2007.

[5] EPA, 2003. "Assessment of risks from radon in homes". (http:/ / www. epa. gov/ radon/ pdfs/ 402-r-03-003. pdf). Office of radiation and indoor air, US environmental protection agency.

[6] Commission recommendation on the protection of the public against indoor exposure to radon (90/143/Euroatom). OJ L 80, 27.3.1990, pp. 26-8.

[7] Darby S, Hill D, Auvinen A, Barros-Dios JM, Baysson H., Bochicchio F, Deo H, Falk R, Forastiere F, Hakama M, Heid I, Kreienbrock L, Kreuzer M, Lagarde F,Mäkeläinen I, Muirhead C, Oberaigner W, Pershagen G, Ruano-Ravina A, Ruosteenoja E, Rosario AS, Tirmarche M, Tomásek L, Whitley E, Wichmann HE, Doll R. Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies. BMJ 330:223, 2005.

[8] Ali M. O., "Study of pollution by heavy elements in some parts of Baghdad" Journal of Baghdad Science, Vol.7, No.1.2, pp.955-962, 2010.

[9] Fazal R., Jamil K., Zakaullah M. , Abu-Jarad F., Mujahid S.A., Experimental and Monte Carlo simulation studies of open cylindrical radon monitoring device using CR-39 detector. Journal of Environmental Radioactivity, Vol.65, pp.243-254, 2003.

[10] Rafat M., Amin M., Eissa F., "Radon level and radon effective dose rate determination using SSNTDs in scanner cave, Eastern desert of Egypt" Environ Monit Assess, Vol.143, pp.59-65, 2008.

[11] Ammar A. B., Jaafar M.S., Nada F. T., Iskandar S.M., Ammir H. A. and Zakariya A. H., Indoor Radon Concentration Measurement in Selected Factories in Northern and Central Iraq, J. of Envir.and Earth. Sci., Vol. 3, No.3, pp.105-112, 2013.

[12] Ismail A. H., Jaafar M. S., " Indoor Radon concentration and its Health Risks in Selected Locations in Iraqi Kurdistan using CR-39 NTDs" Bioinformatics and Biomedical Engineering (iCBBE) , 4th international Conference in Cheng du ,18-20 June, 2010.

[13] Kansal S., Mehra R., Singh N.,P. " Life time fatality risk assessment due to variation of indoor radon concentration in dwellings in western Haryana, India" Applied Radiation and Isotopes, Vol.70, pp.1110-1112, 2012.

[14] UNSCEAR, 2000. "Effects of atomic radiation to the general assembly, in united nations scientific committee on the effect of atomic radiation". United Nations: New York.

[15] Jyoti Sharma, A. K. Mahur, Rupesh Kumar, Rati Varshney, R. G. Sonkawade, R. Swarup1, Hargyan Singh and Rajendra Prasad, Comparative study of indoor radon, thoron with radon exhalation rate in soil samples in some historical places at Jaipur, Rajasthan,

India, Advances in Applied Science Research, 3 (2):1085-1091, 2012.

[16] Mowlavi A.M., Fornasier M.R., Binesh A. and de Denaro M." Indoor radon measurement and effective dose assessment of 150 apartments in Mashhad, Iran" Environ Monit Assess, Vol.184, pp.1085-1088, 2012.

[17] Abu Murad, K. M., Al-Omari R. A., "Indoor radon levels in Irbid and health risks from internal doses. Radiation Measurements", Vol.43, pp.S389-S391, (2008).

[18] Mansour H.H., "Measurement of indoor radon level in Erbil capital by using solid state nuclear track detectors" Radiation measurement Vol.40, pp. 544-547, 2005.

[19] Abdullah A.A., "Internal and external radiation exposure evaluation amongst selected workers and locations in Iraq" Ph.D. Thesis, University Sains Malaysia, Malaysia 2013.

[20] ICRP, Lung Cancer Risk from Radon and Progeny and Statement on Radon. ICRP Publication 115, Ann. ICRP 40, 1, 2010.

[21] UNSCEAR, "Genetic and somatic effects of ionizing radiation", United Nations, 1993.

[22] Christine B., Karen V., Bhikha T., Stephen C., Saviour F., Dorianne G., Malta Medical Journal, Vol. 25, 04, pp. 33-39, 2013.