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Indoor Radon Concentration in Some Schools in Kaya, Burkina Faso

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Abstract: The determination of indoor radon concentrations in residential buildings, schools and workplaces is an important public health concern. The purpose of this research was to measure the concentration of radon gas in the school in the city of Kaya and to evaluate the effective dose in the lungs and the risk of cancer. This study used Corentium's AIR THINGS digital radon detector to determine the radon concentration in sixteen (16) schools. The digital radon detector air Things of Corentium was placed in each office for a minimum period of one week and the concentration values were recorded every 24 hours. The values recorded in each school were the short-term average and the long-term average during seven days of measurement. The highest short-term average concentration was 82.11 Bq/m3, and was calculated in School 10 (Lycée Provincial Moussa Kargougou). The maximum radon concentration value measured in the short term in school 10 was 298 Bq/m3. The maximum long-term radon concentration value measured in the school 10 was 63.00 Bq/m3 and below the limit of 100 Bq/m3 recommended by the WHO. The average concentration of radon gas in schools in the city of Kaya was 11.19 ± 5.97 Bq/m3. This concentration was well below the limit recommended by the WHO.

Keywords: *radon, concentration, school, absorbed dose, effective dose*

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1. Introduction

Radon is an odourless, tasteless and colorless radioactive gas. It comes from natural Uranium found in the ground and in materials such as bricks and concrete. Epidemiological studies in Europe, North America and Asia have shown that lung cancer can be linked to indoor radon exposure, even at relatively low radon levels commonly found in residential buildings [1,2,3]. Radon is considered the second leading cause of lung cancer in smokers, after tobacco and the leading cause of lung cancer in non-smokers in the general population. There is no known threshold concentration below which exposure to radon presents no risk. The dose relationship linked to radon and lung cancer is linear [1,4,5].

Loffredo et al, [6] showed in their study that the concentration of radon gas in kindergartens and primary schools in southern Italy was between 11 and 1416 Bq/m^3, with a geometric mean of 77 Bq/m^3 and a geometric standard deviation of 2. Radon concentrations ranged from 17 to 868 Bq.m^{-3}, with a geometric mean of 117 Bq.m^{-3} and a geometric standard deviation of 1.78 in Bulgarian schools [7]. Radon concentrations were between 60 and 250 Bq.m^{-3} with a most probable value of 135 Bq.m^{-3} in 512 schools in 8 of the 13 regions of Greece [8]. Radon concentration levels in elementary schools in Tunis, capital of Tunisia, ranged from 6 to 169 Bq.m^{-3} with an average value of 26.9 Bq.m^{-3}. The annual effective dose in elementary schools in Tunis ranged between 0.025 and 0.715 mSv.y^{-1} for teachers while for students the range was 0.019 to 0.525 mSv.y^{-1} [9].

Preliminary studies on the concentration in places of residence in a few districts of the Ouagadougou city and in university residences have revealed very varied and high concentrations by location [10,11].

The need therefore to assess radon concentrations in order to better protect against risks; both in residences and in the workplace is therefore not to be neglected. It is in this sense that the general objective of our study is: Evaluation of the concentration of radon gas and the health risk in schools in the city of KAYA, Burkina Faso.

Figure 1. Geographical location of the schools concerned by this study

2. Materials and Methods

2.1. Presentation of the Study Area

The study was conducted in the city of Kaya. The city of Kaya, capital of the North-central region is located 100 km from Ouagadougou, the political capital of Burkina Faso. It is located between 13°5' North Latitude and 1°05' West Longitude, and covers an area of 922 Km^2. The urban commune of Kaya has seven (7) sectors. Each sector of the commune of Kaya is made up of several districts. To carry out radon gas concentration measurements in schools in the town of Kaya, at least three schools were chosen in each sector. This study concerned five (5) of the seven (7) sectors of the city of Kaya. It concerned 16 schools.

Figure 1 presents the geographical location of the different schools where the measurements were carried out in the town of Kaya.

2.2. Materials

2.2.1. CORENTIUM AIR THINGS Digital Radon Detector

AIRTHINGS CORENTIUM Home is the radon monitor suitable for family homes, public buildings and workplaces. A simple and fast instrument that can be used by everyone. Operating on batteries, AIRTHINGS CORENTIUM Home can easily be moved through the building, thus allowing to obtain a complete overview of the distribution of radon in the dwelling.

The AIRTHINGS CORENTIUM Home radon monitor samples indoor air through a passive diffusion chamber and uses alpha spectrometry to accurately calculate radon concentration. The detection is done using silicon photodiodes both to count and to measure the energy of the alpha particles resulting from the chain of decomposition of the radon gas. The instrument is not sensitive to variations in temperature and humidity, to aerosols and to electromagnetic fields. It is guaranteed for one year and requires no maintenance or calibration for a lifespan of 10 years.

It is one of the three (3) best detectors for its very high precision and also in relation to its price. It is a very interesting device to know the state of indoor pollution. CORENTIUM AIR THINGS radon sensors are designed for indoor use only. The CORENTIUM AIR THINGS detector is easy to handle and move.

The CORENTIUM AIR THINGS digital radon detector is our choice for measuring radon concentration in residential buildings in the city of Kaya.

The CORENTIUM AIR THINGS Digital Radon Detector gives two values on each reading. These values are also the short-term average and the long-term average.

Figure 2 below shows the image of the radon measuring device, the CORENTIUM AIR THINGS detector.

Figure 2. Front and back view of the CORENTIUM AIR THINGS digital radon detector

2.2.2. Measurement Methods

For concentration measurements, the device was placed in each school in a classroom for a minimum period of one week. Concentration values were taken every 24 hours for a week. The values recorded were the short-term average and the long-term average. The CORENTIUM AIR THINGS digital radon detector gives two values for each reading, which were: the short-term average and the long-term average. The "long-term average" value displayed by AIR THINGS by CORENTIUM designates the average radon concentration for a continuous measurement, for a maximum period of one year (recalculated once a day). The "short-term average" value represents the average of the radon concentration of the last 24 hours ("1 day", recalculated every hour) and the average concentration of the last week ("7 days", recalculated once a hour). In general, the long-term average concentration is used to identify the health risks posed by radon. Short-term average concentration averages are often used to identify the effects of actions taken to reduce radon levels (eg changing ventilation). Short-term concentration averages can also be used to obtain a general but relevant estimate of concentration levels, in cases where long-term measurement is not possible [10].

2.3. Dose Estimate

From a radiological point of view, radon is a major cause of the dose absorbed by the population [12] and this cause increases in places with reduced ventilation such as classrooms. Therefore, estimating the health risk associated with the inhalation of radon gas and its progeny by students and teachers in primary and secondary school classrooms is important since among younger people, cancer rates of lungs are significantly higher in places where the radon concentration is high.

2.3.1. Annual Absorbed Dose

The formula used to calculate the annual absorbed dose is given as follows:

$$D\,(\text{mSv y}^{-1}) = C_{Rn}\,(\text{Bq m}^{-3}) \times F \times O \times T\,(\text{h y}^{-1}) \times D\,(\text{nSv par (Bq h m}^{-3})) \quad (1)$$

Where C_{Rn} is the indoor radon concentration, T is the exposure time in one year, F is the equilibrium factor, O is the occupancy factor and D is the dose conversion factor. The dose conversion factor is 9 nSv per (Bq h m^{-3}). This value is based on a dosimetric model for an adult male with a respiration rate of 0.6m^3/h; inside an aerosol with an average diameter of 100-150 nm. O is estimated that people spend 80% of their time indoors, F is 0.4 and T = 24 hours x 365 days = 8760 h y^{-1} [13-18].

2.3.2. Effective Dose to the Lung (mSv)

The annual effective dose to the lung (E_T) is determined from the annual absorbed dose (D), the radiation weighting factor (W_R) which has a value of 20 for alpha particles and the tissue weighting factor (W_T) which is 0.12 for the lung [19]. The formula used to calculate the effective dose to the lung is given as follows [13,10] [14,15,20]

$$E_T\,(\text{mSv}) = D.\,W_R.\,W_T. \quad (2)$$

2.4. Radon Health Risk

2.4.1. Radon Exposure

The formula used to calculate the radon exposure (RE) is given as follows:

$$RE\,(\text{WLM par an}) = C_{Rn}.O.F.\,C_{WL}.\,T\,/T_W. \quad (3)$$

C_{WL} is Conversion of radon concentration to working level, which has a value of 2.7×10^{-4}. T is the number of hours in a year. T_w is the number of working hours in a month. The working level is equivalent to a radon activity concentration of 12,000 Bq/m^3 and 1 WLM roughly corresponds to exposure for one year to an atmosphere where the radon activity would be 230 Bq/m^3.

2.4.2. Lifetime Cancer Risk

The formula used to calculate lifetime cancer risk (CR) is given as follows:

$$CR = RE.T.\,F_R \quad (4)$$

T is the average life expectancy which is 61.9 in Burkina in 2019. F_R is the risk coefficient of exposure to 222Rn gas in equilibrium with its progeny (5×10^{-4} by WLM).

2.4.3. Number of Lung Cancer Cases Per Year and Per Million People

The formula used to calculate the number of lung cancer cases per year per million people (NLCC) is given as follows [15]:

$$NLCC = E_T.(18.10^{-6}\,\text{mSv}^{-1}.\text{year}) \quad (5)$$

3. Results and Discussion

3.1. Radon Concentration in Some Schools in Kaya

Table 1 presents the short-term average concentration, the maximum value, the minimum value and the standard deviation of radon concentration in 16 educational institutions in the city of Kaya.

Table 1. Short-term radon concentration in school of KAYA

Situation of the School		Short-term concentration of Radon			
		Average	Max.	Min.	Standard deviation
Sector 1	School 1	5.11	14.00	1.00	4.76
	School 2	22.22	35.00	1.00	11.78
	School 3	9.00	15.00	1.00	4.88
Sector 3	School 4	3.33	6.00	0.00	2.36
	School 5	9.56	21.00	1.00	6.36
	School 6	5.56	12.00	1.00	4.18
Sector 4	School 7	9.89	20.00	3.00	5.88
	School 8	13.89	24.00	1.00	8.67
	School 9	17.33	28.00	1.00	9.09
Sector 5	School 10	82.11	298.00	2.00	107.98
	School 11	4.56	10.00	0.00	3.61
Sector 6	School 12	8.89	18.00	0.00	6.41
	School 13	6.33	14.00	1.00	4.81
	School 14	9.56	14.00	3.00	3.78
	School 15	12.44	25.00	1.00	7.85
	School 16	14.67	25.00	1.00	7.76

The short-term average concentrations in the sixteen (16) schools in the commune of Kaya were below the limit of 100 Bq/m^3 recommended by the WHO. The highest average concentration was 82.11 Bq/m^3, and was calculated in school 10 (Lycée Provincial Moussa Kargougou). The maximum radon concentration value measured in school 10 was 298 Bq/m^3 and very close to the upper limit of 300 Bq/m^3 recommended by the WHO. What shows that the daily concentrations in the short term can be high and expose the students in a spontaneous way.

Table 2 illustrates the long-term average concentration, maximum value, minimum value and standard deviation of radon concentration in 16 educational institutions in the city of Kaya.

Table 2. Long-term radon concentration in educational establishments

Situation of School		Long-term concentration of Radon			
		Average	Max.	Min.	Standard Deviation
Sector 1	School 1	11.44	21.00	9.00	4.02
	School 2	19.11	23.00	15.00	3.00
	School 3	9.11	10.00	7.00	1.07
Sector 3	School 4	2.78	4.00	2.00	0.76
	School 5	9.78	14.00	8.00	2.21
	School 6	8.00	16.00	2.00	5.18
Sector 4	School 7	10.67	13.00	8.00	1.77
	School 8	12.00	14.00	7.00	2.21
	School 9	12.78	16.00	6.00	3.24
Sector 5	School 10	29.11	63.00	0.00	20.58
	School 11	5.78	7.00	4.00	0.95
Sector 6	School 12	10.56	15.00	8.00	2.36
	School 13	8.89	11.00	7.00	1.57
	School 14	6.22	8.00	2.00	2.43
	School 15	10.67	13.00	6.00	2.75
	School 16	12.11	15.00	9.00	2.14

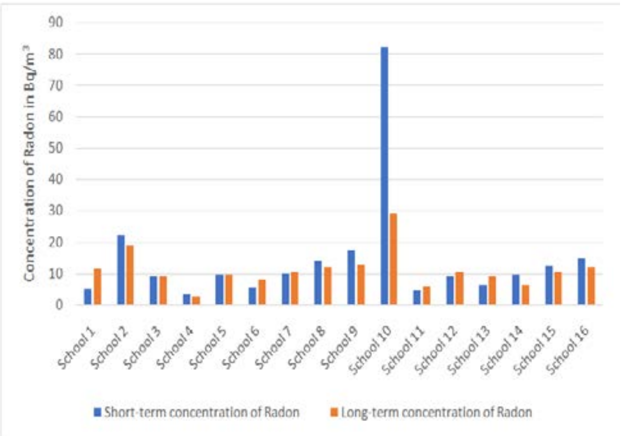

Figure 3. Radon concentration in School in KAYA city

The long-term average concentrations in the sixteen (16) schools in the commune of Kaya were below the limit of 100 Bq/m^3 recommended by the WHO [21]. The highest average concentration was 29.11 Bq/m^3, and was calculated in school 10 (Lycée Provincial Moussa Kargougou). The maximum radon concentration value measured in the school 10 was 63.00 Bq/m^3 and below the limit of 100 Bq/m^3 recommended by the WHO. The low concentrations of radon gas measured in the schools of the commune of Kaya can be explained by the fact that the classrooms are constantly aired and ventilated because of the heat.

Figure 3 presents the histogram of the average long-term and short-term radon gas concentration values in the 16 schools studied in Kaya.

The maximum values of the long-term and short-term radon gas concentrations were observed at school 10. The long-term average concentration was higher than the short-term one in schools 1, 3, 5, 6, 7, 11, 12, and 13. The lowest long-term and short-term concentrations were observed in school 4.

3.2. Absorbed Dose and Effective Dose in Schools

Table 3 illustrates the calculated values of absorbed doses and effective doses in the short and long term in 16 schools in Kaya. The averages of these doses, their maximum and minimum values are also presented in this table.

- Absorbed dose in the short term: The annual short-term absorbed dose varies from 0.014 mSv per year to 0.337 mSv per year. The average annual dose was calculated at 0.060 mSv per year. This level is lower than the normal background level which is 1.1 mSv as quoted by UNSCEAR 2000. None of the schools presented a dose higher than the normal background level. Only School 10 recorded the highest absorbed dose.
- Long-term absorbed dose: The long-term annual absorbed dose is between 0.011 mSv per year and 0.119 mSv per year. The average annual dose was calculated at 0.046 mSv per year. This level is lower than the normal background level which is 1.1 mSv as quoted by UNSCEAR 2000. None of the schools presented a dose higher than the normal background level. The highest absorbed dose is held by school 10.
- Short-term effective dose: The effective dose of radon in the different schools varies from 0.033 mSv per year to 0.808 mSv per year with an average dose equivalent of 0.144 mSv per year. No school has an effective dose equivalent above the recommended limit. At school 10, the effective dose equivalent was 0.808 mSv and is around 1 mSv.
- Long-term effective dose: The effective dose of radon in the different schools was between 0.027 mSv per year and 0.286 mSv per year with an average dose equivalent of 0.110 mSv per year. No school has an effective dose equivalent above the recommended limit.

3.3. Risk of Lung Cancer

Table 4 presents the estimated radon exposure rates in WLM per year, the risk of lung cancer and the number of cancer cases per million (NCCP).

The exposure rate varies from 1.38×10^{-02} to 9.24×10^{-02} with an average of 8.09×10^{-03}; School 10 has the highest rate of 9.24×10^{-02}. The lung cancer risk rate varies between 1.99×10^{-04} and 6.52×10^{-04} with an average of 2.51×10^{-04}. School 10 has the highest lung cancer risk rate. The NCCP rate ranges from 1.02×10^{-06} to 5.16×10^{-06} with an average of 1.98×10^{-06}.

Table 3. Absorbed dose and Effective dose in the short and long term

Situation of school		Short term Absorbed dose of radon (mSv)	Long term Absorbed dose of radon (mSv)	Short term effective dose in the lungs (mSv)	Long term effective dose in the lungs (mSv)
Sector 1	School 1	0.021	0.047	0.050	0,113
	School 2	0.091	0.078	0.219	0,188
	School 3	0.037	0.037	0.089	0,090
Sector 3	School 4	0.014	0.011	0.033	0,027
	School 5	0.039	0.040	0.094	0,096
	School 6	0.023	0.033	0.055	0,079
Sector 4	School 7	0.041	0.044	0.097	0,105
	School 8	0.057	0.049	0.137	0,118
	School 9	0.071	0.052	0.171	0,126
Sector 5	School 10	0.337	0.119	0.808	0,286
	School 11	0.019	0.024	0.045	0,057
Sector 6	School 12	0.036	0.043	0.087	0,104
	School 13	0.026	0.036	0.062	0,087
	School 14	0.039	0.026	0.094	0,061
	School 15	0.051	0.044	0.122	0,105
	School 16	0.060	0.050	0.144	0,119
Average concentration		0,060	0.046	0.144	0.110
Minimum		0,014	0.011	0.033	0.027
Maximum		0,337	0.119	0.808	0.286

Table 4. Relative risk of lung cancer in KAYA educational institutions

Situation of school		Radon exposure (WLM per year)($x10^{-03}$)	Cancer Risk ($x10^{-04}$)	NLCC ($x10^{-06}$)
Sector 1	School 1	8.28	2.56	2,03
	School 2	13.8	4.28	3,38
	School 3	6.59	2.04	1,61
Sector 3	School 4	2.01	0.622	0,492
	School 5	7.07	2.19	1,73
	School 6	5.79	1.79	1,42
Sector 4	School 7	7.72	2.39	1,89
	School 8	8.68	2.69	2,13
	School 9	9.24	2.86	2,26
Sector 5	School 10	21.1	6.52	5,16
	School 11	4.18	1.29	1,02
Sector 6	School 12	7.64	2.36	1,87
	School 13	6.43	1.99	1,57
	School 14	4.50	1.39	1,10
	School 15	7.72	2.39	1,89
	School 16	8.76	2.71	2,14
Average		8.09	2.51	1.98

Table 5. ndoor Radon Levels in Schools for some country

Localisation	Average concentration in school (Bq/m^3)	Reference
This Study	11.19 ± 5.97	
Ota (Nigeria)	18.8	[22]
Oke-Ogun (Nigeria)	45±27	[23]
Al-Samawa City (Iraq)	17.13±1.67	[24]
Palestine	40.42± 2.49	[25]
Kuwait	17	[26]
Bulgarian	148±40	[7]
Italy	100	[27]
Spain	130	[28]

3.4. Comparison with Other Similar Studies

Table 5 presents the concentrations of radon gas in schools in some studies carried out in some countries. A comparison is made between the average concentration of radon gas in schools in the city of Kaya and that obtained in other studies carried out in certain countries.

The average concentration of radon gas in schools in the city of Kaya was 11.19 ± 5.97 Bq/m^3. This concentration was well below the limit recommended by the WHO. The average concentration of radon gas obtained in schools in the city of Kaya is lower than that obtained by Ademola et al. [22] and Obed et al. [23] in Nigeria. Radon gas concentrations in schools in Iraq, Palestine, Kuwait, Bulgaria, Italy and Spain are all higher than in schools in the city of Kaya. This study shows that exposure to radon gas in schools in the city of Kaya is very low.

4. Conclusion

Indoor radon concentrations have been measured in sixteen school of the district of Kaya, Burkina Faso. These concentrations measured in the schools of Kaya were lower than the limit recommended by WHO. This study shows that, no school presents a long-term and short-term effective dose above the recommended limit. The long-term and short-term absorbed doses were below the recommended limit. The average number of cancer cases per million people was two (2).

References

[1] WHO, 2009. WHO handbook on Indoor radon – A public health perspective. World Health Organization, Switzerland.

[2] Tracy, B. L., Krewski, D., Chen, J., Ziekinski, J. M., Brand, K. P., Meyerhof, D. 2006. Assessment and management of residential radon health risks: A report from the Health Canada Radon Workshop. J. Toxicol. Environ. Health A 69: 735–758.

[3] Sousa S.I.V., P.T.B.S. Branco, R.A.O. Nunes, M.C.M. Alvim-Ferraz, F.G. Martins, 2015. “Radon Levels in Nurseries and Primary Schools in Bragança district – Preliminary Assessment”, Journal of Toxicology and Environmental Health - Part A: Current Issues, 78, 805-813, 2015.

[4] USEPA, 2010. U.S. Environmental Protection Agency, www.epa.gov/radon, accessed in March 2014.

[5] Zielinski, J. M., Carr, Z., Krewski, D., Repacholi, M. 2006. World Health Organization’s international radon project. J. Toxicol. Environ. Health A 69: 759–769.

[6] Loffredo Filomena, Irene Opoku-Ntim , Giovanni Meo and Maria Quarto, Indoor Radon Monitoring in Kindergarten and Primary Schoolsin South Italy. Atmosphere 2022, 13, 478.

[7] Ivanova Kremena, Nina Chobanova, Bistra Kunovska, Jana Djounova, Zdenka Stojanovska, 2022. Exposure Due to Indoor Radon in Bulgarian Schools. Aerosol and Air Quality Research | https://aaqr.org, DATA REPORT.

[8] Clouvas, A., Xanthos, S., Takoudis, G. (2011). Indoor radon levels in Greek Schools. J. Environ. Radioact. 102, 881–885.

[9] Labidi S., D. Al-Azmi, H. Mahjoubi, R. Ben Salah, 2010. Radon in elementary schools in Tunisia. RADIOPROTECTION– VOL. 45 – N° 2 (2010), pages 209 to 217.

[10] Bambara Telado Luc. Kabore Karim. Derra Moumouni. Beogo Cedric. Ousmane Ibrahim Cisse. Francois Zougmore. 2021. «Assessment of Indoor Radon Concentration in Residential Buildings at Ouagadougou and Estimation of the Annual Effective Dose». RadiationScience and Technology.Publ. June 15 2021. Vol. 7. no No. 2. p. 41-46. 2021.

[11] Bambara Telado Luc, Doumounia Ali, Kohio Nièssan, Ouédraogo Soumaila and François Zougmoré, 2022. Radon level in Burkina Faso student residence and estimation of the annual effective dose. Asian Journal of Scientific Research, 15: 31-38.

[12] UNSCEAR 2000 Report to the General Assembly. with Scientific Annexes.«SOURCES AND EFFECTS OF IONIZING RADIATION». VOLUME I. ANNEXE B. UNITED NATIONS PUBLICATION. New York. Sales No. E.00.IX.3. ISBN 92-1-142238-8 x .2000.

[13] Norafatin Khalid, Amran Ab. Majid, Redzuwan Yahaya, et al., «Radiological risk of building materials using homemade airtight radon chamber», Cite AIP Conf. Proc. 1584 207 2014, févr. 2015, [En ligne].

[14] Hüseyin Ali YALIM. Ayla GÜMÜŞ. Rıdvan ÜNAL. 2018. Determination of Indoor Radon Concentration and Effective Dose Equivalent at Workplaces of Afyonkarahisar Province. Süleyman Demirel Üniversitesi Fen Edebiyat Fakültesi Fen Dergisi Süleyman Demirel University Faculty of Arts and Sciences Journal of Science 2018. 13 (2): 29-35.

[15] Hashim Abdalsattar Kareem and Sara Salih Nayi, 2019. Assessment of Internal Exposure to Radon in Schools in Karbala, Iraq. Journal of Radiation and Nuclear Applications, J. Rad. Nucl. Appl. 4, No. 1, 25-34 (2019).

[16] Akeel T. Al-Kazwini. Mohannad M. Al-Arnaout. and Tiba R. Abdulkareem. 2020. Radon-222 Exposure and Dose Concentration Levels in Jordanian Dwellings. Hindawi Journal of Environmental and Public Health Volume 2020. Article ID 6668488. 7 pages.

[17] Yarahmadi Maryam. Abbas Shahsavani. Mohammad Hassan Mahmoudian. Narges Shamsedini. Noushin Rastkari. Majid Kermani. 2016. Estimation of the residential radon levels and the annual effective dose in dwellings of Shiraz. Iran. in 2015. Electronic Physician (ISSN: 2008-5842). June 2016. Volume: 8. Issue: 6. Pages: 2497-2505.

[18] Mirsina Mousavi Aghdam. Stefania DaPelo. Valentina Dentoni. Viviana Fanti. Alessandra Bernardini. Paolo Randaccio. Daniele Chiriu. 2019. Measurements of Indoor Radon Levels and Gamma Dose Rates. Proceedings of the 5th World Congress on New Technologies (NewTech'19) Lisbon. Portugal – August. 2019 Paper No. ICEPR 149.

[19] International Commission on Radiological Protection (ICRP) (1991) 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60.

[20] Amin S. A.. S. D. Alalgawi and H. M. Hashimn. 2015.Indoor radon concentrations and effective dose estimation in AlKarkh side of Baghdad dwellings. IJST (2015) 39A4: 491- 495. Iranian Journal of Science & Technology http://ijsts.shirazu.ac.ir.

[21] Canadian Nuclear Safety Commission (CNSC). 2011. Radon and Health. Minister of Public Works and Government Services Canada 2011 Catalogue number CC172-67/2011 PDF ISBN 978-1-100- 17765-6 Published by the Canadian Nuclear Safety Commission (CNSC) Catalogue number: INFO-0813.

[22] Ademola Augustin Kolapo, Oluwasayo Peter Abodunrin, Moronfolu O. Olaoye, Mariam A. Oladapo and Isreal Ayo, 2015.Measurement of indoor radon in a university environment in Nigeria using Solid State Nuclear Track Detector (CR-39), Nuclear and Radiation Physics, Elixir Nuclear & Radiation Phys. 81 (2015) 31911-31914, Available online at www.elixirpublishers.com (Elixir International Journal).Oke-Ogun region, Nigeria. Journal of Environmental Radioactivity 102:1012-1017, 2011.

[23] Obed, R.I, Ademola, A.K, Vascotto, M and Giannini, G., Radon measurements by nuclear track detectors in secondary schools in Oke-Ogun region, Nigeria. Journal of Environmental Radioactivity, Volume 102, Issue 11, November 2011, Pages 1012-1017.

[24] Al Zabadi H., K. Mallah, G. Saffarini, 2015. Indoor exposure assessment of radon in the elementary schools, Palestine. Volume 13, No 3, International Journal of Radiation Research, July 2015, Int. J. Radiat. Res., July 2015; 13(3): 221-228.

[25] Kadhim Abdul Amir, Ahmed Mesehour Ali, and Ali Abid Abojassim, 2020. Measuring of Airborne Radon concentration inside some Schools of Al-Samawa City, Iraq. AIP Conference Proceedings 2290, 050003 (2020).

[26] Maged, A. F., 2005. Radon concentrations in elementary schools in Kuwait. Health Phys. 90, 258e262, 2006.Italy 100

[27] Giovani, C., Cappelletto, C., Garavaglia, M., Villalta, R., Radon concentration survey in schools of Friuli-Venezia Giulia region, north east Italy. In: Proceedings of Seventh International Symposium "Natural Radiation Environment (NRE VII). Rodi (GR), pp. 20e24, pp. 985e996, 2002.

[28] Hernández, F., Gonzalez-Manrique, S., Karlsson, L., Hernández-Armas, J., Aparicio, A., Counting radon tracks in Makrofol detectors with the "image reduction and analysis facility" (IRAF) software package. Radiat. Meas. 42, 496e504, 2007.