

Assessment of Indoor Radon Doses Received by the Students and Staff in Schools in some Towns in Sudan

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Abstract: An indoor radon survey has been carried out in 82 schools situated in four towns in the Sudan, namely: Omdurman, Madeni, Sinnar, and Al Hosh, by using CR-39 solid-state nuclear track detectors SSNTDs. A total of 388 detectors were installed in the selected schools, 349 were collected and 39 were lost. The detectors were placed in the indoor environment of the selected schools for a period of 120 days. The main objective of this study was to assess the health hazard due to the indoor radon inside these schools. The radon concentration levels varied from 26 to 124 Bq.m⁻³, with an average value of 59 ± 7 Bq.m⁻³. Present indoor radon concentration values for the selected schools are far below than the radon action level (200- 600) Bq.m⁻³ as recommended by ICRP, higher than the worldwide, population weighted, average radon of 40 Bq.m⁻³ as reported by UNSCEAR. The mean annual radon effective dose equivalent was estimated to be 0.56 ± 0.09 mSv.y⁻¹, which is lower than the action level recommended by the ICRP of 3–10 mSv.y⁻¹, than the “normal” background level of 1.1 mSv.y⁻¹; as quoted by UNSCEAR.

Keywords: CR-39, effective dose, schools, radon concentration, health hazard.

1. Introduction

Radon (²²²Rn) is a radioactive noble gas, arising from the natural decay chain of uranium (²³⁸U). Uranium occurs in trace amounts throughout the earth's crust with varying concentrations. The contribution to the mean effective dose equivalent from inhalation of ²²²Rn and its short-lived decay products (²¹⁸Po, ²¹⁴Pb, ²¹⁴Bi and ²¹⁴Po) has been estimated to be about 50% of the total effective dose equivalent from all natural radiation sources [1].

When radon gas is inhaled, densely ionizing alpha particles emitted by deposited short-lived decay products of radon (²¹⁸Po and ²¹⁴Po) can interact with biological tissue in the lungs leading to DNA damage. Cancer is generally thought to require the occurrence of at least one mutation, and proliferation of intermediate cells that have sustained some degree of DNA damage can greatly increase the pool of cells available for the development of cancer. Since even a single alpha particle can cause major genetic damage to a cell, it is possible that radon-related DNA damage can occur at any level of exposure. Therefore, it is unlikely that there is a threshold concentration below which radon does not have the potential to cause lung cancer, and considered the second leading cause of lung cancers after tobacco [2].

Many worldwide epidemiological studies have been conducted in recent decades in order to confirm the association of the number of lung cancer cases with chronic exposure to indoor radon. As a result of these studies, summarized in the leading international organization elaborations, it is now one of the best-documented associations [2]-[6].

In the United States of America, reports recorded for radon alone to be responsible for approximately 15,000 – 20,000-lung cancer deaths per year [7]. The risk is reported to be proportional to the radon level down to EPA's action level of 0.148Bq/L and probably even below this level [7], [8]. The International Commission on Radiological Protection (ICRP) recommended radon concentration of (200-600) Bq.m⁻³ for dwellings[9], the recommendations emphasized the importance of controlling radon exposure in dwellings and work places arising from existing exposure situations [10]. Most of our time is spent indoors; therefore, the measurement and evaluation of radon concentrations and effective dose in buildings are important [11]-[17].

The concentration of radon in indoor air varies significantly from season to season and from house to house with respect to the surrounding environment [18]-[22]. The main natural sources of indoor radon are soil [23]-[25], building materials (sand, rocks, cement, etc.) [26], water sources [27]-[28], natural energy sources like (gas, coal, etc.) [29], all of which contain traces of U-238.

The most important source for indoor radon concentration in low-rise constructions is the subjacent earth. About 56% of the radon entry into the house is due to radon transport by advection and diffusion from soil to earth [30]. About 21% is due to the diffusion from the building materials and 20% is due to infiltration from the outdoor air [30].

Solid-state nuclear track detectors have been widely used for passive measurements of indoor radon and their alpha emitting decay products. The use of CR-39 plastic track detector in air volume of cups has become the most reliable procedure for time integrated, long measurements of radon

and their daughters activity concentration under different environmental condition [31]-[33].

The aim of this study was to determine the radon levels, by using CR-39 solid state nuclear track detectors SSNTDs in the schools of four towns in Sudan namely: Sinnar town which located in Sinnar state, Medani and El Hosh towns that located in Gezira state, this state is lies between the Blue Nile and the White Nile rivers, while Omdurman town is located in Khartoum state, the locations of these towns are shown in (Figure1).



Figure 1. The map showing the towns in which the schools are located in Sudan.

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2. Materials and Methods

A total of 388 dosimeters were installed in class rooms/offices of each selected school in each town. The dosimeters were exposed to indoor radon. Almost 90% of the installed detectors were recovered, while 10% were lost due to mishandling by the school’s staff.

All the selected schools were built from mud, red bricks, sand, and cement. Some schools were partially ventilated, whereas others were well ventilated.

A correct calibration procedure is paramount for a good accuracy of results. Hence, precalibrated passive dosimeters containing solid-state nuclear track detectors using allyl diglycol carbonate of super grade quality (CR-39 SSNTD, Pershore Moulding, Ltd., U.K.) were used to study radon-222 concentrations. These passive dosimeters used here are similar to those we have used in previous studies [18]-[20],[22]. After three months, the dosimeters were collected and chemically etched using a 30% solution of KOH at a temperature of $(70.0 \pm 0.1) ^\circ\text{C}$ for nine hours. An optical microscope was used to count the number of tracks per cm^2 recorded on each detector used. After correcting for the background, the track density was determined and converted into activity concentration C_{Rn} (in Bq.m^{-3}) using the

following equation [24],[34]:

$$C_{Rn} = \frac{\rho_{Rn}}{K_{Rn}t} \quad (1)$$

Where ρ_{Rn} is, the track density (tracks per cm^2), K_{Rn} is the calibration constant which was previously determined to be $4.824 \times 10^{-3} \text{ tracks cm}^{-2} \text{ h}^{-1}/(\text{Bq.m}^{-3})$ [34], and t is the exposure time.

2.1 Dose Estimation and Lung Cancer Risk

To estimate the radon effective dose rate (ED) expected to be received by the inhabitants of these towns due to indoor radon, the conversion coefficient from the absorbed dose and the indoor occupancy factor has to be taken into account. In the UNSCEAR-2000 report [1], the committee recommended to use 9.0 nSv h^{-1} per Bq.m^{-3} for the conversion factor (D_f) (effective dose received by adults per unit ^{222}Rn activity per unit of air volume), 0.4 for the equilibrium factor of radon indoors (E_f) and 0.8 for the indoor occupancy factor (O_f). We used the following formula to calculate the effective dose rate [1],[34]:

$$\text{Effective Dose (mSv/y)} = C_{Rn} D_f O_f E_f \times 24 \times 365 \times 10^{-6} \quad (2)$$

In the present case, the value of H was found to 0.3. In calculating H, it was assumed that students spend 8 h per day in school and out of these 8 h; they spend 90% time indoors and 10% outdoors.

The relative risk of lung cancer (RRLC) due to indoor exposure to radon was calculated using the equation [18], [19], [34], [35]:

$$\text{RRLC} = \exp(0.00087352 C_{Rn}) \quad (3)$$

3. Results and Discussion

In this study, we present results of the radon concentration levels, effective dose (ED) and relative risk of lung cancer (RRLC) in schools at four towns in Sudan. Table 1. and Figure 2. shows the radon concentration for the schools in the studied towns.

It is clear that, the maximum concentration value appear in school that located in Omdurman town to be 124 Bq.m^{-3} , while the minimum concentration value was recorded in school situated in Medani town to be 26 Bq.m^{-3} .

Many of the measurements were performed in areas with low indoor radon concentrations as we have found in previous surveys that measuring indoor radon concentrations in Sudan. In particular, in schools of Omdurman town some of schools are built from mud material and others with cement and concrete materials, from our survey we noticed that schools of the town are crowded and badly ventilated, in addition to that, the walls and floors of such rooms and offices are not covered with any materials. All these reasons cause the concentration levels to be high $76 \pm 10 \text{ Bq.m}^{-3}$.

This is not a surprising result because radon concentration depends not only on the radon source term but also on the ventilation rate in the building and the exhalation rate of radon from the walls and floors.

The lower concentration values in these schools are found to be consequently: Medani $58 \pm 8 \text{ Bq.m}^{-3}$, Sinnar $55 \pm 6 \text{ Bq.m}^{-3}$ and El Hosh town of $48 \pm 5 \text{ Bq.m}^{-3}$. These results may be due to the fact that, the schools are far apart and the construction materials are mainly red brick and straw materials; these materials usually contain lower amounts of naturally occurring radioactive isotopes when compared to cement and concrete materials [26]. Taken together with relatively good natural ventilation, these facts can explain why the values of Rn concentration in schools of these cities are below the average for the entire study [34].

Comparing our results of this study with national values for radon concentration in dwellings we can find that the concentration values found in Medani is 57 Bq.m^{-3} and in El Hosh of 50 Bq.m^{-3} [34], it is clear that the results of this survey are in the range of these values.

No intervention is required if the radon level is below 74 Bq.m^{-3} , indicating that this level is safe for occupancy [36].

In all probability, the only intervention needed is to improve ventilation since it is well known that increased ventilation rate is an important factor in reducing indoor radon level. [31] We also found that the indoor radon concentrations in moderately ventilated schools were higher in comparison to those in well-ventilated schools.

The recorded values of indoor radon concentration in our study are far below than the radon action level (200- 600) Bq.m^{-3} as recommended by ICRP-1993 [9], lower than the new reference level (100 Bq.m^{-3}) set by WHO.[2] and below the action level (148 Bq.m^{-3}) recommended by Environmental Protection Agency (EPA) [36] Mean value is slightly higher than the world-wide, population weighted, average radon of 40 Bq.m^{-3} as reported by UNSCEAR [1] and well within values reported for various schools in other countries worldwide (Table2).

Table 1: Summary statistic of radon concentrations measurements, effective dose and radon relative lung cancer risk in schools in the studied towns in Sudan

Town	No.	Radon concentration (Bq.m^{-3})			ED (mSv.y^{-1})	RRLC%
		Min	Max	(Mean \pm s.d)		
Omdurman	98	37	124	76 ± 10	0.72 ± 0.09	1.069
Medani	89	26	87	58 ± 8	0.55 ± 0.07	1.052
Sinnar	84	34	88	55 ± 6	0.52 ± 0.06	1.049
Al Hosh	78	37	58	48 ± 5	0.45 ± 0.05	1.043
Overall	349	26	124	59 ± 7	0.56 ± 0.07	1.053

Table 2: Comparison of results with other results in various locations in the world

Country	Mean Conc. (Bq.m^{-3})	DE (mSv.y^{-1})	RRLC %	Reference
Greek	149	-	-	[37]
Italy	209	-	-	[38]
	144	-	-	[39]
	Range of 10 and 108	-	-	[40]
India	52	0.49	-	[41]
Austria	52	-	-	[42]
Croatia	70.6	-	-	[43]
U S A	148	-	-	[44]
Ireland	93	-	-	[45]
Slovenia	168	-	-	[46]
Omdurman	76	0.72	1.069	This study
Medani	58	0.55	1.052	This study
Sinnar	55	0.52	1.049	This study
Al Hosh	48	0.45	1.043	This study

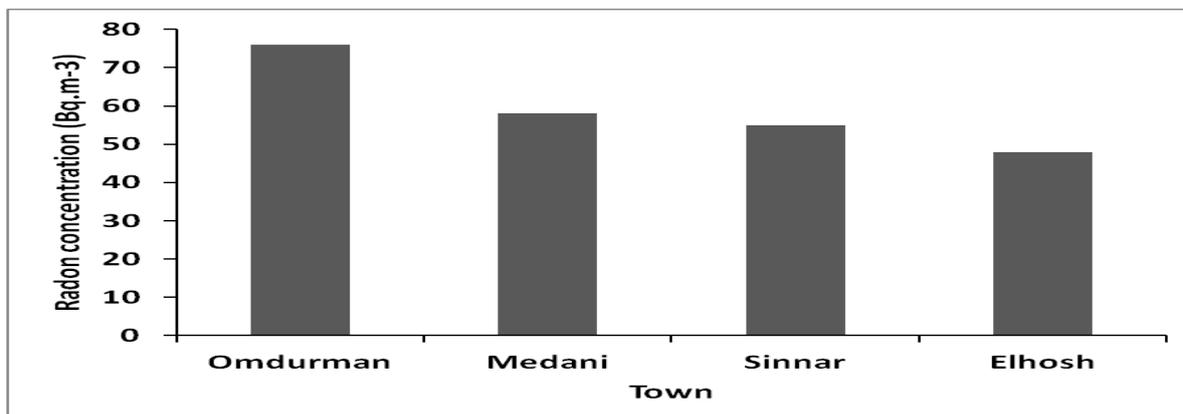


Figure 2: Radon concentration from schools of the studied towns.

Table 2 and Figure. 3 present the frequency distribution of the radon gas concentration (Bq.m⁻³) in the 82 schools.

The frequency distribution of concentration levels in schools showing that only small percentage of houses are slightly above the level requiring intervention; only 4% of these schools had indoor radon concentrations in the range of 120 to 150 Bq.m⁻³. 8% of schools with radon concentrations between 90 to 120 Bq.m⁻³, 22.4% of schools are having concentration values ranging from 60 to 90 Bq.m⁻³. Most 62% of the radon concentrations presented

in Figure 3 were between 30 and 60 Bq.m⁻³, the schools of concentrations lower than 30 Bq.m⁻³ constitutes 3.7%. in comparison of our results, it was found that in Amman schools a percentage of 30–50% were below 100 Bq.m⁻³ [47], while in New York state schools a concentration level of 150 Bq.m⁻³ was exceeded in 47% of the studied schools [48]. In contrast, higher values were reported for Slovenia where in 8% of schools radon concentration was higher than 400 Bq.m⁻³ and in 3%, even higher than 1000 Bq.m⁻³ [46].

Table 3: Frequency distribution of radon concentration levels from the schools of the studied towns in Sudan.

Concentration level in schools (Bq.m ⁻³)	Number of dosimeters	Percentage%
0 – 30	13	3.7
30 – 60	216	61.9
60 – 90	78	22.4
90 – 120	28	8.0
120 – 150	14	4.0

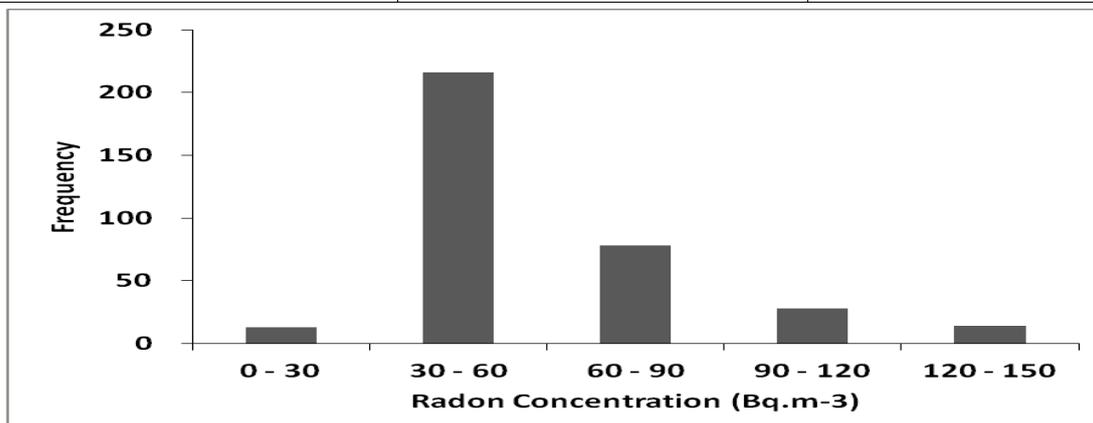


Figure 3: Frequency distribution of the radon gas concentration (Bq.m⁻³) in the 82 schools.

The range of radon effective dose rate from our study, varied from 0.45 ± 0.05 to 0.72 ± 0.09 mSv per year. Only as indication, substituting the measured average radon concentration value of 59 ± 7 Bq.m⁻³ and occupancy factor of 0.3, and a conversion factor of 9 nSv per Bq.h.m⁻³, for the 82 schools, the overall average effective annual dose in the studied schools of the four towns came out to be 0.56 ± 0.07 mSv per year. Despite the fact that the overestimation in the estimated effective dose for teachers (due to the overestimation of the radon concentration) is on the safe

side from the radiation protection point of view, it is so important that we wish not to present in detail values of effective doses.

The mean annual effective doses in schools of the Omdurman, Medani, Sinnar, and El Hosh towns were found to be 0.72 ± 0.09 , 0.55 ± 0.07 , 0.52 ± 0.06 , and 0.45 ± 0.05 mSv per year, respectively.

These values are lower than the “normal” background level of 1.1 mSv per year; as quoted by UNSCEAR-2000 [1], less than even the lower limit of the recommended action level 3–10 mSv per year as reported by the ICRP-1993 [9].

The relative lung cancer risk range from (1.069 to 1.043) with an average of 1.053, which is lower and not constituting any health hazards to the students and staff members of these schools.

4. Conclusion

Radon concentration measurements were performed in 82 schools in four towns of Sudan. The mean value of indoor radon concentration measured at schools of four towns in Sudan was below the action level recommended by ICRP. The ventilation rate in the residential areas and construction materials play a very important role in the controlling of indoor radon concentration. Furthermore, the calculated effective dose for all schools is lower than the average value given by UNSCEAR and below the ICRP action level. Consequently, the relative lung cancer risk for radon exposure is low in these buildings and they can be considered safe when the hazardous health effects of radon are concerned.

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References

- [1] United Nations Scientific Committee on the Effects of Atomic Radiation, "Sources and Effects of Ionizing Radiation", UNSCEAR, Vol. I Annex A: Dose Assessment Methodologies, United Nations, New York, 2000.
- [2] WHO "Handbook on indoor radon, a public health perspective". World Health Organization, Geneva, 2009.
- [3] ICRP "International Commission on Radiological Protection statement on radon". ICRP Ref 00/902/09, www.icrp.org/ICRP Statement on Radon, 2009.
- [4] David G. Hoel "Questions about Radiation and Risk Estimates That Remain after BEIR V. Radiation Research", Vol. 136, No. 1, pp. 137-139, 1993.
- [5] EEA, "Environment and health". European Environmental Agency, Copenhagen, 2005.
- [6] United Nations Scientific Committee on the Effects of Atomic Radiation, "Sources-to-effects assessment for radon in homes and workplaces", UNSCEAR report vol. II annex E, New York, 2006.
- [7] Biological Effects of Ionizing Radiation (BEIR) VI report: "The health effects of exposure to indoor

- radon". The US National Academic Press, Washington, 1999.
- [8] Bochicchio, F., "Radon epidemiology and nuclear track detectors: methods, results and perspectives". Radiat. Meas. 40, pp. 177–190, 2005.
- [9] International Commission on Radiological Protection. "Protection against radon at home and work". ICRP Publication 65, Ann. ICRP 23, 1993.
- [10] International Commission on Radiological Protection "The 2007 recommendations of the International Commission on Radiological Protection". Elsevier, New York, Ann ICRP 37(2–4), ICRP Publication 103, 2007.
- [11] O. M. Mukhtar, Abd Elmoniem A. Elzain, "Radon monitoring at Khartoum using the charcoal technique". Abhath Al-Yrmouk "Basic Sci. &Eng.", 15(2):225–235, 2006 .
- [12] H.H. Mansour, et al., "Measurement of indoor radon levels in Erbil capital by using solid-state nuclear track detectors", Radiation Measurements, 40, 2–6, pp. 544–547, 2005.
- [13] F. Marcinowski, "Nationwide Survey of Residential Radon Levels in the US", Radiat. Prot. Dosim., 45, 1-4, pp. 419-424, 1992
- [14] K. Ulbak, et al., "Results from the Danish Indoor Radiation Survey", Radiat. Prot. Dosimetry, 24, 1-4, pp. 401-405, 1988.
- [15] A. Canoba, et al., "Indoor Radon Measurements and Methodologies in Latin American Countries", Radiat. Meas., 34 , 1-6, pp. 483-486, 2001.
- [16] F. Bochicchio, et al., Annual average and seasonal variations of residential radon concentration for all the Italian Regions, Radiation Measurements, 40, 2–6, p. 686–694, 2005.
- [17] M. Rafique, et al., "Estimation of Annual Effective Radon Doses and Risk of Lung Cancer in the Residents of District Bhimber, Azad Kashmir, Pakistan", Nuclear Technology & Radiation Protection, 26, 3, pp. 218-225, 2011.
- [18] Abd-Elmoniem A. Elzain, et al., "A Survey of Indoor Radon - 222 levels in Kassala town", Gezira j. of eng. & applied sci. 3, 2, pp. 72–100, 2008.
- [19] Abd-Elmoniem A. Elzain, "Indoor Radon-222 Concentration in Some Cities in Kassala State", Eastern Sudan, Proceedings of the 2011 International AARST Symposium, 2, pp.71-84, 2011.
- [20] B. A. Al-Bataina, and Abd-Elmoniem A. Elzain, "Seasonal variation of indoor radon-222 concentration levels in Zarqa City, Jordan". Abhath Al-Yrmouk "Basic Sci. &Eng.", 12, pp.191–202, 2003.
- [21] Hajo Idriss, et al., "Characterization of 222Rn and Meteorological Parameters in Uro House at South Kordofan State", Indoor and Built Environment, DIO: 10.1177/1420326X14528190, 2014.
- [22] Abd-Elmoniem A. Elzain, "Seasonal variation of radon-222 concentration in shops and pharmacies of Alzarqa Town- Jordan", Proceedings of the 2011 International AARST Symposium, 2, pp.38-45, 2011.
- [23] Abd-Elmoniem A. Elzain , et al., "Radium and Radon Exhalation Studies in Some Soil Samples from Singa and Rabak Towns, Sudan using CR-39", International

- Journal of Science and Research (IJSR),3, 11, 632-637, 2014.
- [24] G. Somogyi, et. al., "Measurement of exhalation and diffusion parameters of radon in solids by plastic track detectors", Nucl. Tracks Radiat. Meas. 12, (1-6), pp. 701-704, 1986.
- [25] Abd-Elmoniem A. Elzain, et.al., "Measurements of Radon gas Concentration in a Soil at Some Towns in Kassala State", Gezira j. of eng. & applied Sci., 4, 1, pp .15 – 42, 2009.
- [26] Abd-Elmoniem A. Elzain, "Radon exhalation rates from some building materials used in Sudan", Indoor and Built Environment, DOI: 10.1177/1420326X14537285, 2014.
- [27] Abd-Elmoniem A. Elzain, "Measurement of Radon-222 Concentration Levels in Water Samples in Sudan", Advances in Applied Science Research, 5, 2, pp.229-234, 2014.
- [28] Abd-Elmoniem A. Elzain, "A study on the radon concentrations in drinking water in Kassala State (Eastern Sudan) and the associated health effects". World Applied Sciences Journal, 31, 3, 367-375, 2014.
- [29] A. Banman, D. J. Hervat, and N. Lokobauer, "In: Natural radiation environment (ed.) Vahra K J, Wiley Eastern, New Delhi, pp. 401–415, 1982.
- [30] Sources and Effects of Ionizing Radiation. UNSCEAR, Report to General Assembly, with Scientific Annexes United Nations, New York, 1993.
- [31] S. M. Farid, "Indoor radon in dwellings of Jeddah city, Saudi Arabia and its correlations with the radium and radon", Indoor and Built Environment,(2014), DOI: 10.1177/1420326X14536749
- [32] M. Shakir Khan, et. al., The Study of Indoor Radon in the Urban Dwellings Using Plastic Track Detectors, Environmental Earth Sciences, 63, 2, pp .279-282, 2011.
- [33] S. A. A. Jasem, & H. N. Aood, "Indoor Radon Levels and the Associated Effective Dose Rate Determination at the Shatt – Alarab District in the Basrah Governorate, Iraq", 2, 3, p. 117-122, 2014.
- [34] Abd-Elmoniem A. Elzain " A Study of Indoor Radon Levels and Radon Effective Dose in Dwellings of Some Cities of Gezira State in Sudan". Nuclear Technology and Radiation Protection, DOI:10.2298/NTRP1404307E, 2015.
- [35] J. H . Lubin, and J. D. Boice, "Lung cancer risk from residential radon meta-analysis of eight epidemiology studies". J. Nat. Cancer Institute, 89, 1, pp. 49 -57, 1997.
- [36] U.S. Environmental Protection Agency (US-EPA). Why is radon the public health risk that it is? <http://www.epa.gov/radon/aboutus.html> (accessed 16 April 2014).
- [37] S. Clouvas, G. Xanthos, Takoudis, "Indoor radon levels in Greek schools" , Journal of Environmental Radioactivity, 102, pp. 881-885, 2011.
- [38] Rosabianca Trevisi, Federica Leonardi, Carla Simeoni, Sabrina Tonnarini, Miriam Veschetti, "Indoor radon levels in schools of South-East Italy", Journal of Environmental Radioactivity, 112, pp. 160 – 164, 2012.
- [39] G. Venoso, F. De Cicco, B. Flores, L. Gialanella, M. Piugliese, V. Roca, C. Sabbarese, "Radon concentrations in schools of the Neapolitan area". Radiat. Meas., 44, pp. 127 – 130, 2009.
- [40] A. Malanca, R. Fava, L. Gaidolfi, "Indoor radon levels in kindergartens and play-schools from the province of Parma". J. Environ. Radioact., 40, pp. 1–10, 1997.
- [41] S.U. Rahman, Matiullah, J. Anwar, A. Jabbar and M. Rafique, Indoor Radon Survey in 120 Schools Situated in Four Districts of the Punjab Province – Pakistan, Indoor Built Environ, 19, 2, pp. 214–220, 2010.
- [42] O. Ennemoser, P. Schneider, W. Ambach, P. Brunner, "Increased radon concentrations in classrooms used for pottery workshops". Sci. Total Environ., 116, pp. 291–295, 1992.
- [43] C. J. Planini, T. Šmit, Z. Faj, B. Šuveljak, B. Vuković, V. Radolić, "Radon in schools and dwellings of Osijek", J. Radioanal. Nucl. Chem., 191, pp. 45–51, 1995.
- [44] A.J. Siniscalchi, S.J. Tibbetts, X. Soto, R.C. Beakes, K., Van der Leeden, M.A. Thomas, N.W. McHone, "Implication of temporal variations in radon exposure in schools", Environ. Int. 22 (Suppl. 1), pp. 1015–1024, 1996.
- [45] H. Synnott, O. Hanley, D. Fenton, P.A. Colgan, "Radon in Irish schools: the results of a national survey", J. Radiol. Prot., 26, pp. 85 – 96, 2006.
- [46] C. J. Vaupoti, M. Sikovec, I. Kobal, "Systematic indoor radon and gamma-ray measurements in Slovenian schools", Health Phys., 78, pp. 559 – 562, 2000.
- [47] M. K. Kullab, B. A. Al-Bataina, A. M. Ismail, K. M. Abumurad, A. Ghaith, "Study of radon-222 concentration levels inside kindergartens in Amman". Radiat. Meas., 28, pp. 699–702, 1997.
- [48] Kunz et al., "Soil characterization for indoor radon potential at eighteen schools in New York State", Environ. Int. 22 (Suppl. 1), pp. 557–561, 1996.

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