Proceedings of the 5th World Congress on New Technologies (NewTech'19)
Lisbon, Portugal – August, 2019
Paper No. ICEPR 149
DOI: 10.11159/icepr19.149

Measurements of Indoor Radon Levels and Gamma Dose Rates

Mirsina Mousavi Aghdam[1], Stefania DaPelo[2], Valentina Dentoni[1], Viviana Fanti[3], Alessandra Bernardini[3], Paolo Randaccio[4], Daniele Chiriu[3]
[1]Department of Civil and Environmental Engineering and Architecture
University of Cagliari
mirsina.aghdam@unica.it; vdentoni@unica.it
[2]Department of Geology and Chemical Science
University of Cagliari, Cittadella Universitaria di Monserrato
sdapelo@unica.it,
[3]Department of Physics, University of Cagliari
Cittadella Universitaria di Monserrato and Italian Institute for Nuclear Physics (INFN), Cagliari, Italy
viviana.fanti@ca.infn.it; alessandra.bernardini@dsf.unica.it ; daniele.chiriu@dsf.unica.it
[4]Italian Institute for Nuclear Physics (INFN)
E-laboRad .Srl, Cagliari, Italy
paolo.randaccio@ca.infn.it

Abstract **–** In order to estimate indoor natural radioactivity levels, long and short-term radon tests and ambient gamma dose rate measurements have been performed in several environments of the Faculty of Engineering and in the student canteen of Cagliari University. The measured values were found below the recommended reference levels issued by Directive 2013/59/Euratom. Consistent information about building characteristics, living habits and exposure times were recorded, to be taken into account in the UNSCEAR model. The annual effective dose calculated for each room ranges from 0.004 to 0.628 mSvy^{-1}. The levels of radon concentration measured until now did not exceed the recommended threshold values; additional testing will be performed to ensure full compliance of indoor air quality requirements.

Keywords**:** Long term and short term radon test, Gamma dose rate, Public and work environment, University of Cagliari, Indoor air quality.

1. Introduction

Radon is a gaseous radioactive element which is a product of Uranium decay chain in nature. Inhalation of radon in indoor spaces contributes to about half of the annual dose of ionizing radiation [1]. Long-term exposure to radon and radioactive progenies can increase the risk of lung cancer [2]. The main source of radon gas is the uranium/radium component in the soil beneath the building's foundations. Other sources of radon include the construction material and the radon dissolved in water. The colorless radon gas can penetrate from soil to indoor spaces through cracks in building foundations, cavities, pipelines and through the sewage system. Metrological factors such as wind speed, indoor and outdoor temperature difference, barometric pressure, relative humidity can also influence indoor radon concentration [1 and references therein]. The concentration of radon indoor is in fact, a complex function of different parameters and it can change considerably even during a single day time interval. Therefore, the average value of long term tests (3-12 months) are normally used in radon assessment studies [2]. However, the results of short term tests can be used for initial screening or to perform follow-up test (i.e. a short term test using a Continuous Radon Monitor (CRM)) when the results of long term test exceed the limit values.

Directive 2013/59/Euratom recommends radon concentration level below 300 Bq/m^3 both for homes and workplaces [3]. In this research indoor radon activity concentration and indoor gamma dose rate were measured simultaneously and the effective dose due to exposure to radon and progenies was estimated.

2. Materials and Methods

The study was carried out at the Faculty of Engineering and at the student canteen of Cagliari University. According to the EPA radon testing guidelines, Solid State Nuclear Track Detectors (CR-39) were placed in different environments, mostly in the ground and underground levels (Figure 1). The ambient gamma dose rates were measured simultaneously in the center of the room at one meter above the ground, by using the handheld radiometer MKC-01CA1M. The gamma dose rate measurements were prolonged until the instrument statistic error decreased to 5 percent.

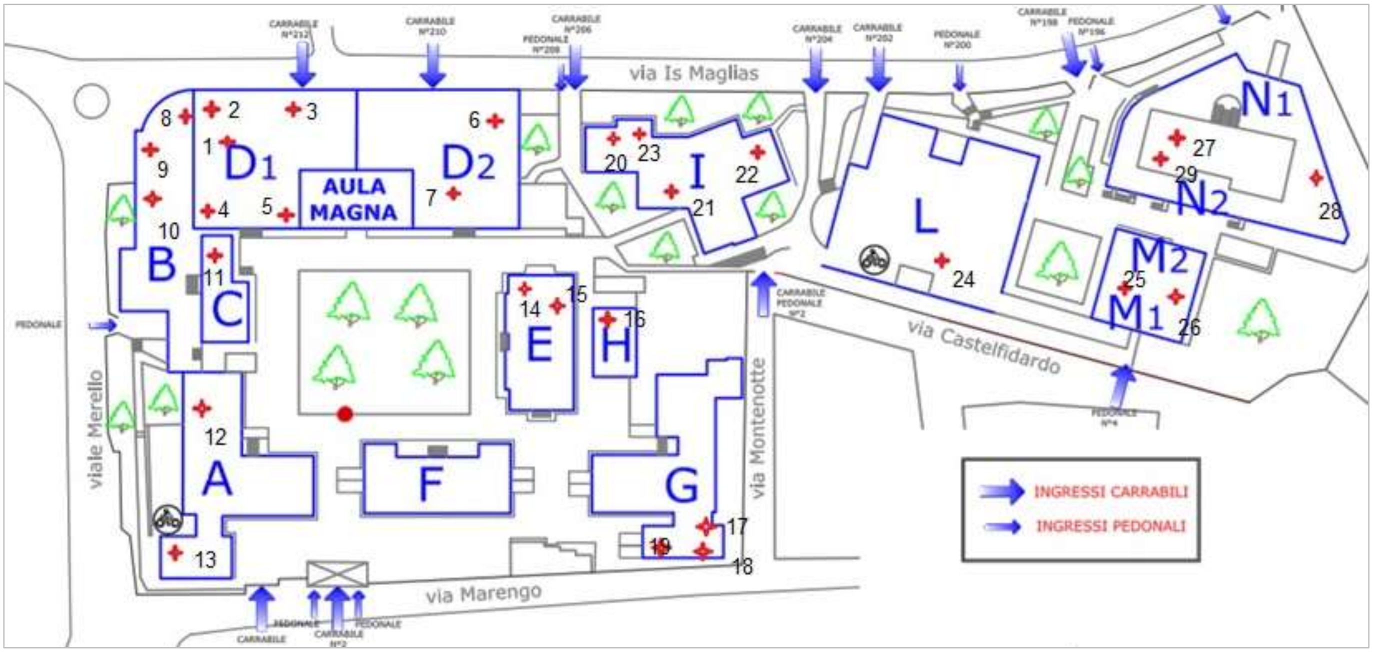

Fig. 1: Location of CR 39 detectors used for assessment of radon levels in different environments of engineering faculty, university of Cagliari, the base map extrapolated from UNICA portal (www.unica.it).

The exposure period of the CR-39 detectors was about 10 months, from March 2018 to January 2019. A questionnaire was prepared for each detector stating the testing information, type of building material, number of inhabitants, the time spent there and the ventilation rate of the room under exam. All the collected detectors were etched for four hours in a 6.25 N NaOH solution with a constant temperature of 90 °C. The detectors were then removed and washed with distilled water. Using an optical microscope attached to a digital video camera, the alpha tracks were scanned. Based on the counted number of alpha tracks and using the calibration factor, the annual average concentration of radon and the standard deviation were calculated for each detector, as reported in Tab.1. According to the Canadian guide for radon measurements in public buildings, a follow-up test was carried out where the annual average concentration was higher than 200 Bq/m^3, by means of a RADEX MR107 radon gas detector (a CRM ion chamber). Finally, the Annual Effective Dose (AED) expressed in mSvy^{-1} was calculated according to the UNSCEAR model with Eq.1 [5]:

$$AED = \mathrm{CRn} \times \mathrm{F} \times \mathrm{D} \times \mathrm{u} \times \mathrm{t} \tag{1}$$

where CRn is the radon concentration (Bq/m^3), F is the equilibrium factor between radon and progenies (0.4 for buildings), D is the dose conversion factor (1.43 Sv/J hm^{-3}), u is the unit factor (5.56 × 10^{-9} J.m^{-3}/Bq.m^{-3}) and t is the exposure time (hour) in a year. The total time spent in a week was recorded for each room, so the time periods in tab.1 were multiplied by 52 and then used for calculation of AED.

3. Results

Indoor radon measurements were carried out in 32 different rooms, the geometric mean, the arithmetic mean, the minimum and maximum value of radon concentration were 57.60, 74.37,12.00 and 291.00 (Bq/m^3), respectively. The highest values were observed in the rooms located at the underground level and where air ventilation was poor. Fig.2 shows the histogram of radon concentrations. As can be seen, all the measured values are below 300 Bq/m^3, which is the recommended level issued by the Euratom Directive. Just in one case, a storage room in the car parking, the value exceeded the level of 200 Bq/m^3 and thus the follow-up measurement was performed. Fig.3 shows the results of the follow-up test carried out for about four days. The average value of radon concentration recorded during the follow-up test was below 200 Bq/m3 (i.e.159 Bq/m^3), so that remediation action is not necessary [4]. Based on radon concentration and the time spent in a room, the annual effective dose due to exposure to radon and progenies were also calculated. As stated in Tab.1 all the calculated values of annual effective dose were below the ICRP recommended level of 1 mSv per year. As observed in the case of the student canteen, the implementation of a proper ventilation system or even taking benefit of the natural air exchange by opening windows and door occasionally can avoid accumulation of radon.

Table 1: Details of measured indoor radon concentrations, gamma dose rates and calculated annual effective dose.

Detector Code	Building Code	Description of Testing Environment	Average C_{Rn} of Building (Bq/m^3)	C_{Rn} (Bq/m^3)	Standard Deviation	Ambient Gamma Dose Rate (µSv/hour)	Type of Building Material	Ventilation Rate (low, medium, high)	Floor	Total time spent in a week (hours)	Calculated Effective Dose (mSv/year)
1	D	Laboratory	48.83	47	±15	0.17	Painted Cement/ Ceramic Tiles	low	-1	15	0.117
2		Workshop		27	±11	0.18	Cement	High	-1	15	0.067
3		Storage room		89	±35	0.21	Painted Cement/Ceramic Tiles	low	-1	2	0.029
4		Classroom		27	±8	0.21	Painted cement /Brick/Linoleum	Medium	Ground	8	0.036
5		Study room		25	±12	0.19	Painted cement /Brick/Linoleum	High	Ground	20	0.083
6		Laboratory		78	±20	0.31	Painted Cement/Ceramic Tiles	Medium	-1	15	0.193
7		Classroom		NA	NA	0.19	Painted cement /Brick/Linoleum	Medium	Ground	NA	NA
8	B	Copy room/Corridor	116.33	123	±20	0.28	Bricks/Cement/Ceramic Tiles	Medium	-1	3	0.061
9		Classroom		108	±28	0.25	Bricks/Cement/Ceramic Tiles	Medium	-1	12	0.214
10		Classroom		118	±37	0.27	Bricks/Cement/Ceramic Tiles	Medium	-1	8	0.156
11	C	Classroom	NA	NA	NA	0.21	Painted Cement/ Ceramic Tiles	Medium	Ground	NA	NA
12	A	Storage room	129.00	68	±20	0.20	Cement/ Ceramic Tiles	low	Ground	10	0.112
13		Workshop		190	±27	0.19	Cement	High	-1	20	0.628
14	E	Corridor	88.5	52	±18	0.24	Painted cement/ Ceramic Tiles	Medium	Ground	30	0.258
15		Corridor		125	±31	0.19	Painted cement/ Ceramic Tiles	low	Ground	25	0.517
16	H	Secretary office	42	42	±9	0.19	Painted Cement/ Ceramic Tiles	Medium	Ground	40	0.278
17	G	Corridor	73.33	42	±16	0.20	Ceramic Tiles	Medium	Ground	16	0.111
18		Corridor		121	±20	0.23	Painted Cement/ Ceramic Tiles	Medium	-1	16	0.320
19		Corridor		57	±19	0.15	Painted Cement/ Ceramic Tiles	High	-1	16	0.151
20	I	Classroom	61	49	±10	0.24	Painted cement/ Ceramic Tiles	Medium	Ground	5	0.041
21		Student office		NA	NA	0.18	Painted cement/ Ceramic Tiles	low	Ground	35	NA
22		Classroom		73	±12	0.18	Painted cement/ Ceramic Tiles	Medium	Ground	8	0.097
23		Classroom		61	±19	0.23	Painted cement/ Ceramic Tiles	Medium	Ground	6	0.061
24	L	Storage room in car parking	291	291	±62	0.27	Cement	low	-1	1	0.048
25	M	Storage room	45	NA	NA	0.18	Cement	low	Ground	NA	NA
26		Laboratory		45	±14	0.24	Ceramic Tiles	High	Ground	35	0.260
27	N	Library	39.67	51	±21	0.16	Painted Cement/Linoleum	Medium	1	25	0.211
28		Basement storage		27	±9	0.11	Cement	High	Ground	1	0.004
29		Computer room		41	±12	0.17	Painted Cement/Linoleum	Medium	1	20	0.136
30	Mensa Via Trentino		15.5	12	±7	0.24	Painted Cement/ Ceramic Tiles	High	Ground	12	0.024
31				19	±8	0.24	Painted Cement/ Ceramic Tiles	High	Ground	12	0.038

NA: Not available because the detector was lost.

As mentioned before, gamma dose rate measurements were also carried out simultaneously. The lowest measured value was 0.11 µSv/hour and the highest 0.31 µSv/hour, while the arithmetic mean was found to be 0.21 ± 0.04 µSv/hour (see also

Fig.2 for the histogram of the measured gamma dose rates). The main source of indoor gamma radiation is the building materials and the materials lining the walls and floors of the rooms [6], however, in this research, no significant difference was found for different types of building material used in the tested environments.

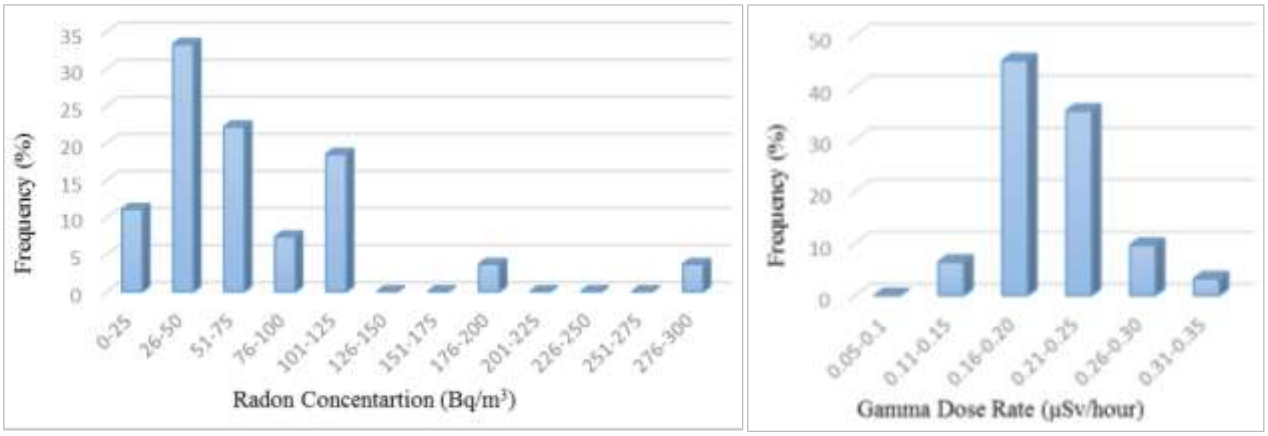

Fig. 2: Frequency distribution of measured indoor radon concentration and gamma dose rate.

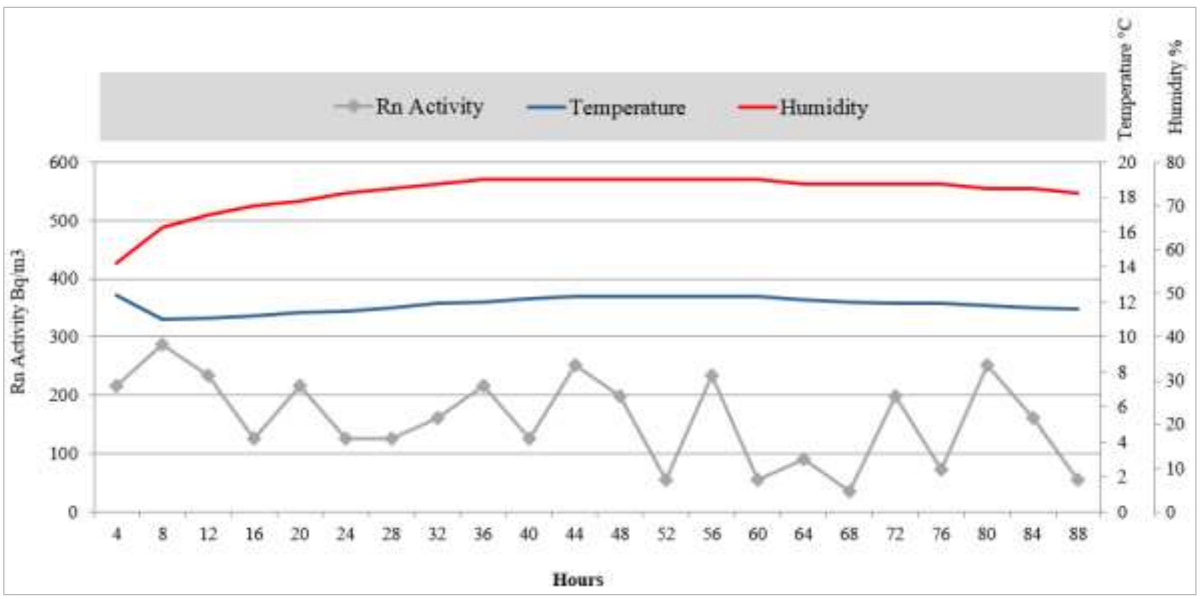

Fig. 3: Results of the follow-up radon test for the storage room in car parking.

4. Conclusion

Long-term exposure to radon can increase the risk of lung cancer. Therefore, public awareness about adverse health effects of radon should be increased and systematic measurement plans should be considered to identify environments where individuals are exposed to elevated radon levels. In this research, indoor radon concentrations and ambient gamma dose rates have been measured simultaneously based on the standard testing procedure. The most important point observed here was that using ventilation systems or even improving natural ventilation can effectively reduce radon levels. This can be an economic and a preliminary solution for increased radon levels, however, for the indoor spaces with significantly high concentration, the implementation of a remediation action is recommended.

References

[1] G. Ciotoli, M. Voltaggio, P. Tuccimei, M. Soligo, A. Pasculli, S.E. Beaubien, S. Bigi, "Geographically weighted regression and geostatistical techniques to construct the geogenic radon potential map of the Lazio region: A methodological proposal for the European Atlas of Natural Radiation," *Journal of Environmental Radioactivity*, vol. 166, no. 2, pp. 355-375, 2017.

[2] H. Zeeb, S. Ferid, *Handbook on Indoor Radon: a Public Health Perspective*. WHO Library, 2009.

[3] European Commission. "Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom," *Off. J. Eur. Commun*, vol. 13, pp. 1-732, 2014.
[4] Health Canada, "Guide for Measurement in Public Buildings (Schools, Hospitals, Care Facilities, Detention centres)," Canadian Minister of Health, 2008.
[5] UNSCEAR (2000) Sources, effects and risk of ionizing radiation. Report to General Assembly with scientific Annexes United Nations.
[6] M. Quarto, M. Pugliese, F. Loffredo, V. Roca. "Indoor radon concentration and gamma dose rate in dwellings of the Province of Naples, South Italy, and estimation of the effective dose to the inhabitants," *Radioprotection*, vol. 51, no. 1, pp. 31-36, 2016.