CONTINUOUS RADON MEASUREMENTS IN SCHOOLS: TIME VARIATIONS AND RELATED PARAMETERS

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INTRODUCTION

Four years ago the Regional Agency for Environmental Protection (ARPA) of Friuli Venezia Giulia region started a very large survey in order to evaluate radon concentration in the schools of the area. Other aims of the study, involving all the 1313 schools and kindergartens of the region, were the reduction of radon exposure of school population when radon indoor concentration resulted too high. In order to study time variations of radon concentrations inside schools and make the best choice for remedial actions in each school, more than 1300 days of continuous measurements were carried out.

In this paper the authors report some of the results of the data collected during four years' work (2001-2004), in different seasons and in different schools usage conditions. Use of schools by students and workers are quite different from use of dwellings by inhabitants: weekends and vacations can introduce significant variations in radon concentration in schools such as air conditioning and heating systems. Natural radon variations (day-night cycles, seasonal and temperature dependent variations etc..) and artificial ones (windows openings, school unused periods, air conditioning or heating systems etc.) were investigated as parameters affecting time dependent radon concentrations.

The knowledge of time variations of radon concentrations allows a lot of considerations about eventually time depending remedial action: it could be possible to improve remedial action when radon concentrations are higher and permit further increase. Moreover radon concentration variations heavily affect the estimation of school population true dose.

Before going up it is important to say that in Friuli Venezia Giulia region soil is the main source of indoor radon concentrations and building material contribution is negligible.

METHODS AND MATERIALS

More than 1300 days of continuous measurements were carried out in more than 40 schools by active instruments. Four active instruments were used: one Pylon AB4; one Pylon AB5 (both consist of a Lucas cell and a photomultiplier); two Rad7 (solid state detectors). Before beginning measurements a laboratory intercomparison among instruments was carried out. Instruments were usually located in the school's room with the highest measured radon concentrations. Active detectors were set to make possible separated evaluation of radon concentration during working (usually Monday - Friday from 7 am to 6 pm) and not working hours. Very often in the other classrooms passive instruments (E-Perm electrects) were located to evaluate differences among different rooms. In each school measurements lasted at least 14 days to include 2 weekends.

RESULTS AND DISCUSSION

a. Day-night cycles

It is well known that indoor radon concentrations are usually higher in winter than in summer and during the night than during the day. These considerations are normally based on results coming from measurements performed in dwellings. The Authors found different results for

radon concentrations continuously measured in schools: in some schools sometimes maximum radon concentrations are usually measured during the night, in other schools the maximum is reached during the day. Figure 1 and Figure 2 show respectively the first and the second mentioned case measured in two schools distant 2 km each other. Measurements periods, usage of the schools (kindergarten) as well as building structure (same project and realization) are the same. The figures clearly show that these trends are typical for each school and, when present, day maximum radon concentration is not an occasional event.

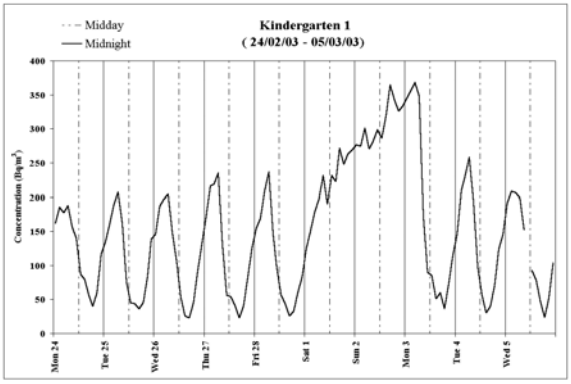

Figure 1. Continuous radon concentration measurements in a kindergarten of Friuli Venezia Giulia region. Maximum radon concentration at 6.00 a.m.

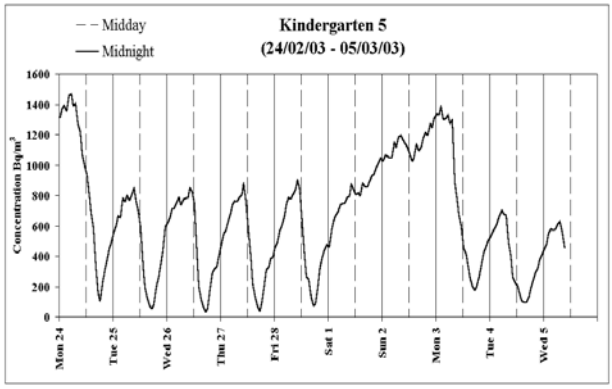

Figure 2. Continuous radon concentration measurements in a kindergarten of Friuli Venezia Giulia region. Maximum radon concentration at 11.00 a.m.

b. School week cycles

Indoor radon concentration trends in working places are usually of two types: one trend is typical of working days and the other characterizes holidays. When the building is closed because of holiday it is expected an accumulation in radon concentrations that sudden falls the morning of the first working day. Some authors (Malisan *et al*., 1994) found this typical trend also for kindergartens. Figure 3 reports one of this expected trend. Figure 4 reports radon concentrations measured in another school (2 km apart from the previous) in the same period: in this case maximum radon concentration is usually in the afternoon and radon concentration accumulation doesn't exist.

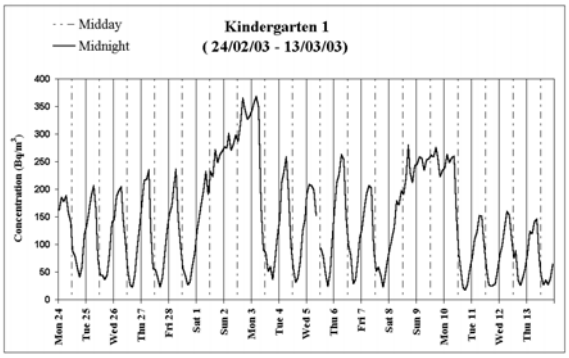

Figure 3. 18 days continuous radon concentration measurements in the same kindergarten of figure 1.

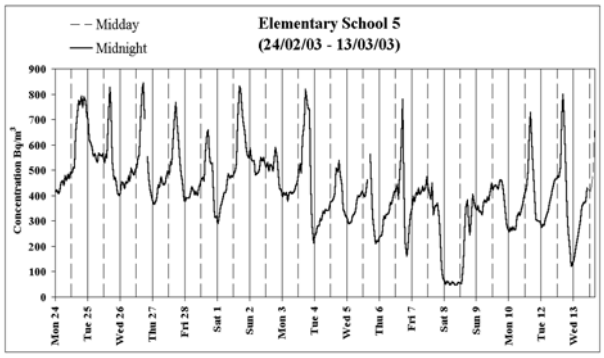

Figure 4. 18 days continuous radon concentration measurements in an elementary school of Friuli Venezia Giulia region. Maximum radon concentration at 4.00 p.m.

c. Radioprotection considerations

Sometimes radioprotection considerations (i.e. radon concentration reference level choice for dwellings or working places) are based on the hypothesis that night radon concentrations are higher than day radon concentrations. In this case radon concentrations during working period should be lower than during not working period and effective doses evaluated on the basis of average radon concentration should be an overestimation of the true doses. Another overestimation might derive from radon concentration accumulation during holidays.

Moreover radon concentration ratio between working and not working hours not always is lower than 1.0 as it is shown in table I reporting the mentioned ratio for radon concentrations measured in 8 kindergartens, elementary and middle schools located in the same area.

On the basis of the considerations reported in the previous paragraph also the possible dose overestimation deriving from using year average radon concentrations (including holidays period) is not so sure.

Table I. Mean values and standard deviations of radon concentrations during continuous measurement periods; mean values and standard deviations of working hours concentrations and concentration ratios between working and not working hour in each school.

Schools	**Average radon concentration (Bq/m^3)**	**Average radon concentration during working hours (Bq/m^3)**	**Ratio working/not working hours**
Kindergarten 2	1537 ± 1205	806 ± 401	0.42
Kindergarten 8	279 ± 150	141 ± 69	0.40
Kindergarten 5	670 ± 362	465 ± 329	0.60
Elementary school 7	568 ± 288	371 ± 198	0.55
Middle school 2	423 ± 217	459 ± 174	1.13
Elementary school 2	139 ± 85	188 ± 97	1.74
Elementary school 5	431 ± 144	470 ± 176	1.15
Kindergarten 1	119 ± 79	52 ± 36	0.33

d. Continuous measurements and remedial actions

Figure 5 shows a typical use of continuous measurements: to check the effectiveness of radon remedial actions (remediation on and off comparison). In the figure it is possible to follow the radon concentration variations depending on the time of switching on remedial action.

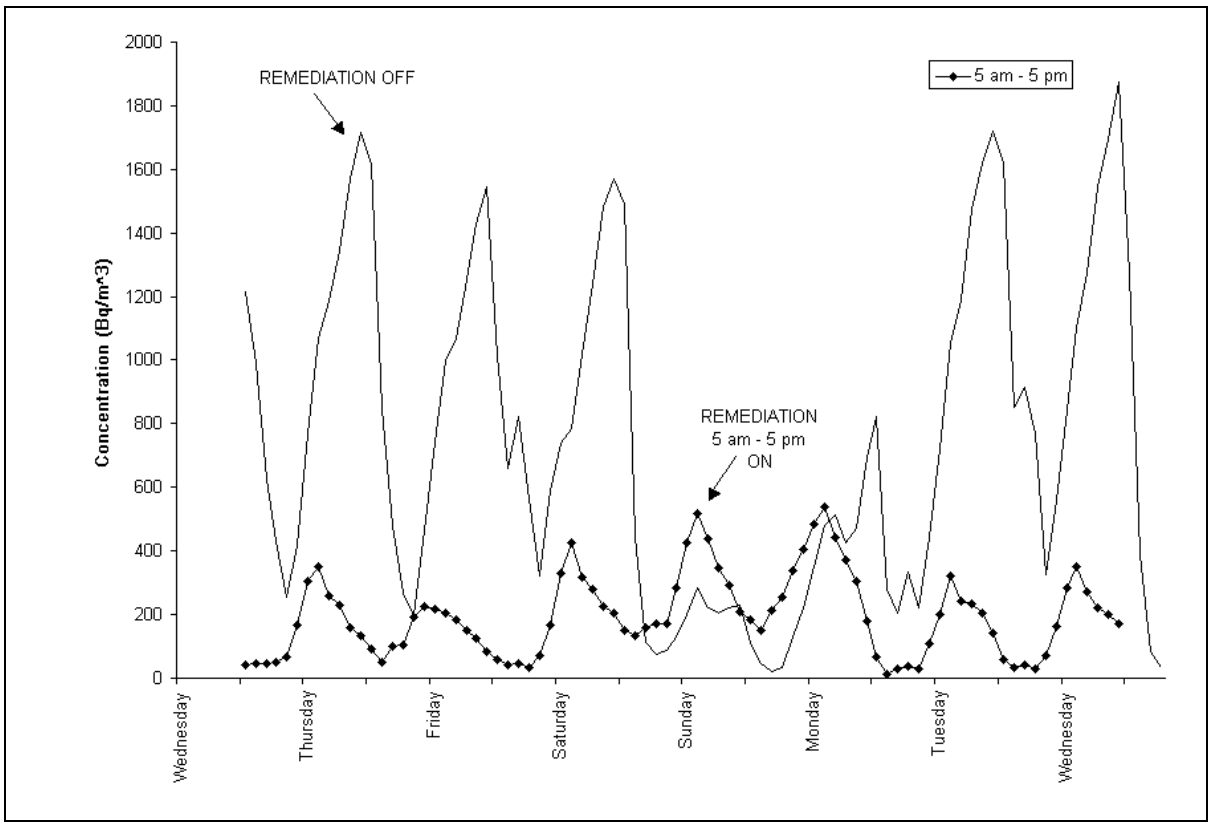

Figure 5. Two weeks radon concentration continuous measurements: remedial action off or on. The remedial action consists in a depressurization of the crawlspace of the building with fans working from 5 am to 5 pm.

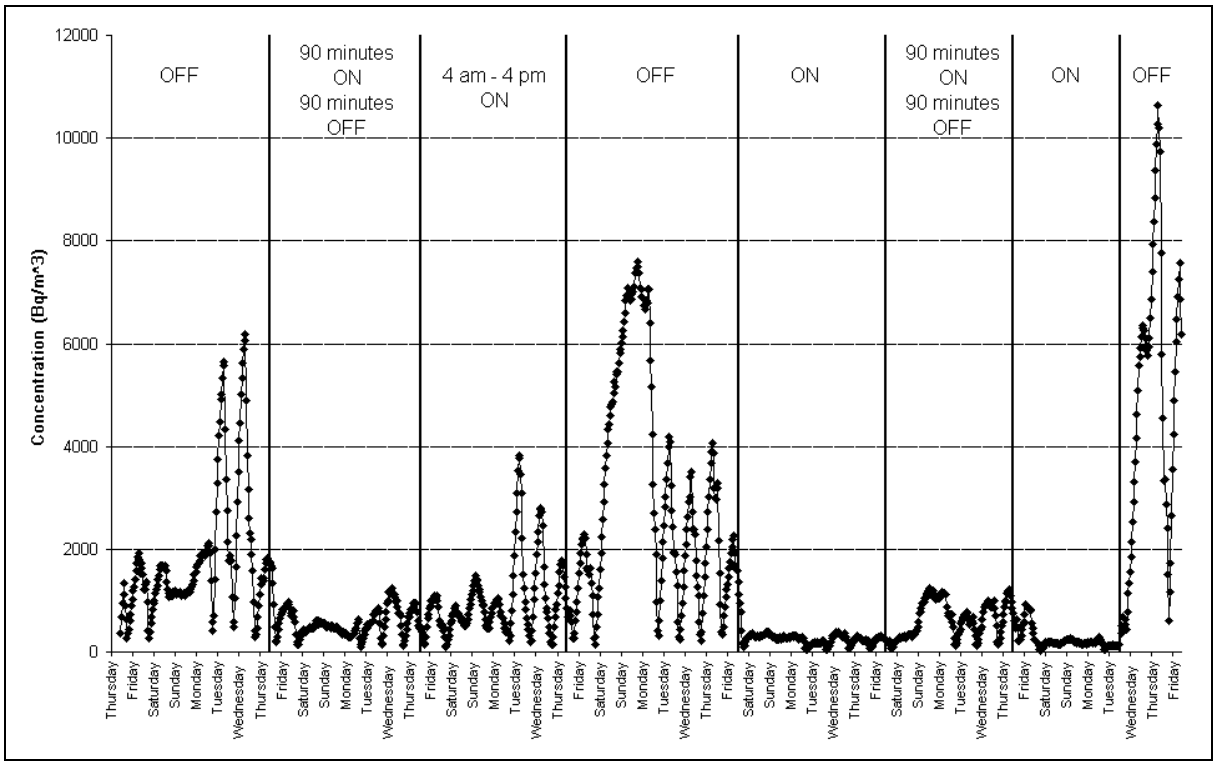

Figure 6. Radon concentration continuous measurements during different fan working periods used to reduce indoor radon concentration.

Furthermore optimization of active remedial action – timing working fan periods – is possible after a study period of radon time variations in the building. Fans should preferably work when radon concentrations are the highest to prevent radon concentration increasing. Figure 6 shows an example of radon concentration continuous measurements during different working periods of the fans used to reduce indoor radon. According to figure 6, whenever it is possible to choose timing working periods for fans, it might be convenient to start remedial action for one continuous week working period before timing the fans. In this way the low radon concentrations induced by continuous work of the fans can be more easily kept steady.

e. *Time variations and related parameters*

A lot of artificial and natural parameters can affect indoor radon concentrations such as starting heating systems, openings doors and windows, outside pressure, temperature, wind etc. In the follows some examples of relation between different parameters and indoor radon concentrations are reported.

Figure 7 shows an interesting effect of the characteristic Trieste strong wind – called "bora"- measured during continuous measurements performed to check the effectiveness of a remedial action applied to a school. Two facts are very clear: remedial action effectiveness is low and "bora" effectiveness is very high, more than the remediation.

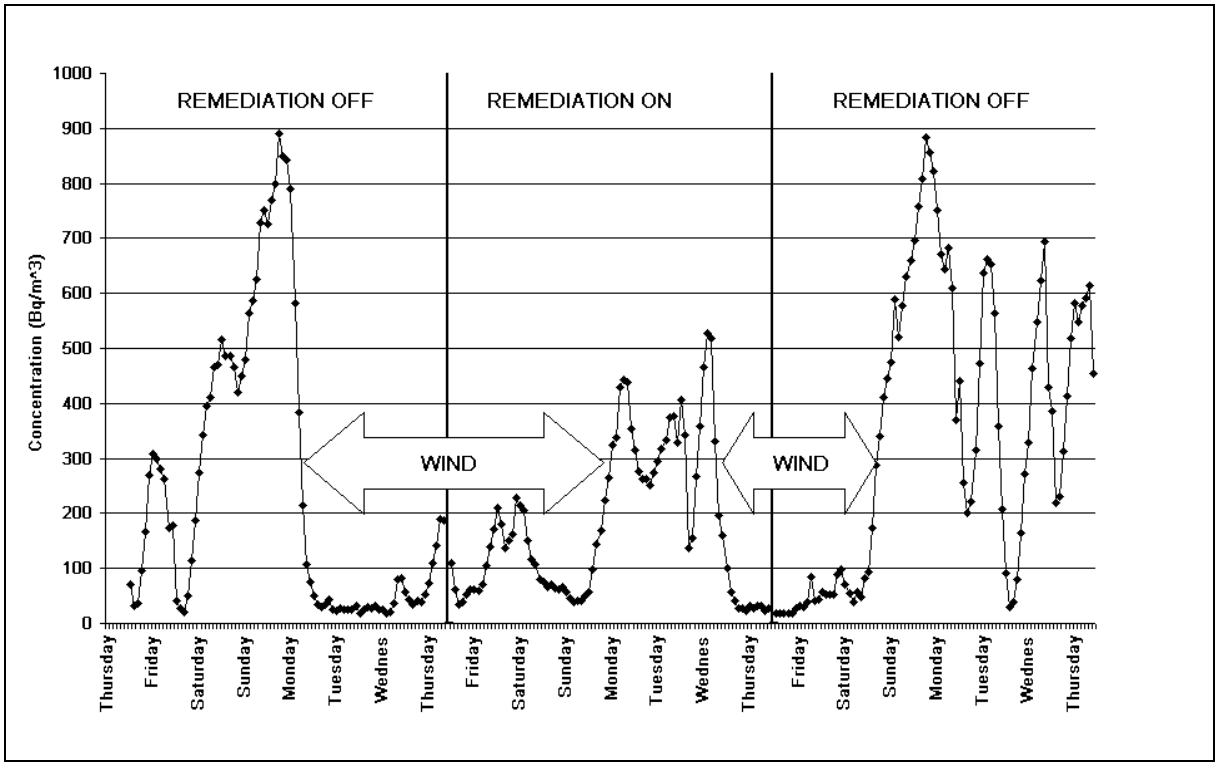

Figure 7. Three weeks radon concentration continuous measurements: during the first and third week, the remedial action was off, during the second week, the remedial action was on.

Figure 8 shows a good direct correlation between indoor radon concentrations and outside temperature but figure 9 shows an equally good inverse correlation between the same two

parameters. Same features can be easily shown with continuous radon concentrations and outside pressure. Of course further investigations in this field are necessary.

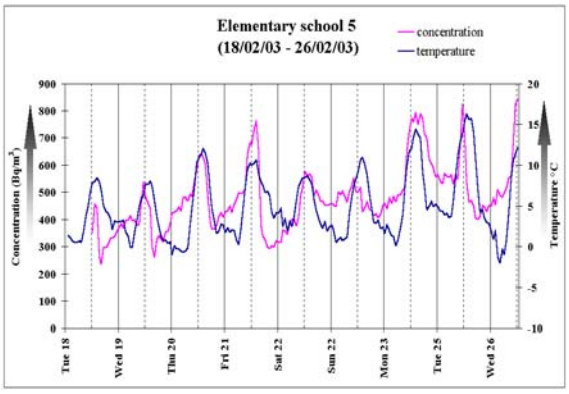

Figure 8. Continuous measurements of radon concentrations and contemporary outside temperature in an elementary school of Friuli Venezia Giulia region.

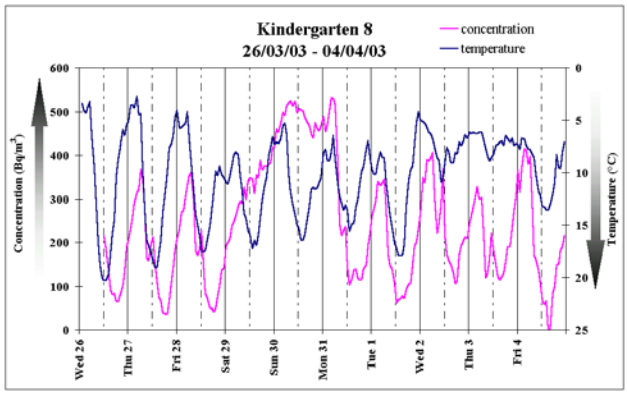

Figure 9. Continuous measurements of radon concentrations and contemporary outside temperature in a kindergarten of Friuli Venezia Giulia region.

CONCLUSIONS

The Authors remark here some of the previous considerations that highlight how it can be useful to perform continuous measurements to solve questions related to radon concentrations:

- same radon concentration average values can come from very different radon indoor time variations;
- radon trend knowledge can be necessary to estimate true effective doses;
- radon remedial actions can be improved and optimized by observation based on continuous measurement;
- continuous measurements could be very useful in understanding radon coming up from soil depending on artificial and natural eventually related parameters.

REFERENCES

1. Malisan M.R., Padovani R., 1994 *Assessment of Radon Exposure in kindergartens in North-East Italy*. Radiation Protection Dosimetry, Vol. 56 (1-4), pp. 293 – 297.