

Exploration of radon affected work and living places and methods for the reduction of the radon exposure

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Abstract

High radon concentration in work and living places are caused by a high geological radon potential of the soil, by technological processes, the use of building materials with high uranium, thorium and radium content and the building construction.

Further the influence of the working and living conditions on the dose estimation is very important. Especially the equilibrium factor and the unattached fraction are influenced by the working and living conditions. Further we report on radon risk mapping, the search for radon affected work and living places and the experiences to propose the remedial action or radon protected building construction resulting from the radon risk of the soil. Further the quality control of this remediation or construction process respectively the efficiency of the radon protection will be presented.

But not in all situations are remedial actions possible. Therefore is for exposure reduction a radon personal dosimetry necessary for a limitation and optimization the working or living time under high radon concentration. The personal radon dosimetry on workplaces, for instance water works, mines, show caves and other work places with high radon levels is up to now not sufficient resolved. The possibility to include alert functions, the signalisation of high dose rate and also the time resolute dose determination give new chances for a real online dosimetry in such very dangerous places

Keywords

Radon personal dosimeter, smart card, radon, Thoron, dosimetry, alpha spectrometry, dose assessment, remedial action

1. Introduction

High radon concentration in work and living places are caused by a high geological radon potential of the soil, by technological processes, the use of building materials with high uranium, thorium and radium content and the building construction.

For the identification of radon-affected workplaces the radon risk mapping is very important. Based on this knowledge screening methods like passive radon detectors, personal dose meters and active radon monitors are used for the search of radon affected work and living places.

Further the influence of the working and living conditions on the dose estimation is very important. Especially the equilibrium factor and the unattached fraction are influenced by the working and living conditions. For instance the radon concentration is considerably influenced by the ventilation system. The factor F is influenced by dust producing work processes.

For a better knowledge of the radon dosimetry it is also necessary to measure continuously and separately the unattached fraction of the radon progeny. The dose factors for unattached radon daughters are considerably higher than for radon daughters attached to aerosols.

The information about the active particle size distribution give the chance to calculate the real exposure respectively the ICRP 66 lung model. Therefore dose calculations and assessments of remedial actions based only on radon gas or attached radon daughter concentrations may be misleading. Reducing e.g. the aerosol concentration by aerosol filters, the attached fraction is clearly reduced but the unattached fraction increases, resulting in a dose increase instead of a dose reduction.

The main aim of the radiation protection is the reduction of the exposure to the public.

There are two possibilities to reach this aim:

- The best way is the prevention of the exposure by technical methods to reduce the radon concentration in work and living places for instance by remedial actions or
- The exposure control by personal dosimeters and restrictions for the working time under these unhealthy conditions.

2. Identification of radon affected work places

The region of Dresden/Freital is one of the high radon risk areas in Germany. Indoor radon levels up to

100 kBq/m³ have been found. Using of the radon risk maps of the University Bonn of Germany and also our own risk map in the near region of Dresden/ Freital basing on geological studies and soil gas radon measurement special work and living places were selected and after screening with active radon monitors passive radon devices were installed [1]. After this screening in highly radon affected workplaces were measured the active particle size distribution and in continuous measurements the radon concentration and attached and unattached fraction of the radon progenies.

In the same manner we measured also with partner institutions like the Josef Stefan Institute in Slovenian or the NRPA in Norway the same parameters for the characterization of selected work places.

In a previous paper we have described a radon and radon progeny monitor allowing the simultaneous measurement of radon and radon attached and unattached progeny with three silicon Microsystems detectors [2]. In this system the air passes an aerosol filter registered by the first detector and then flows through the radon-measuring chamber. We now have added a metal screen/detector assembly that can be switched into the airflow in front of the aerosol filter to catch and measure the unattached radon daughters. A microprocessor controls the movement of the two-radon daughter detectors and the screen. The cut-off factor of the screen at airflow of 2.5 l/min and the screen geometry is 5 nm. We are thus able to measure radon progeny and attached progeny separately. The three components are measured quasicontinuously with a temporal resolution of 2 hours. The measuring range is 1 to 10 MBq/m³ at a low detection limit of 0.1 Bq/m³ equivalent radon concentrations. By using silicon Microsystems with alpha detector, ADC, memory and logic's - which are integrated on few chips - the costs for the production of equipment are far lower than if produced by means of assembled individual components [3].

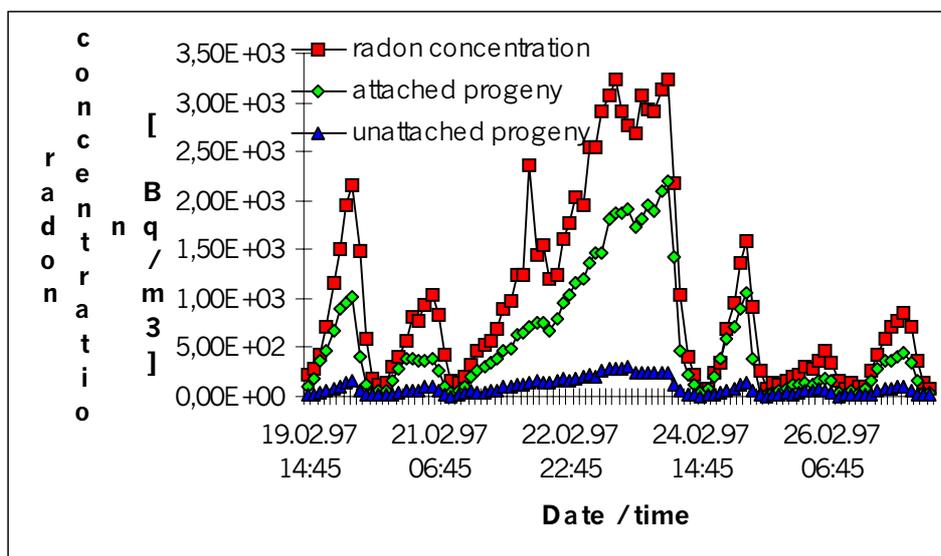


Fig.1 Radon and progeny concentration in a cabinet-maker's shop

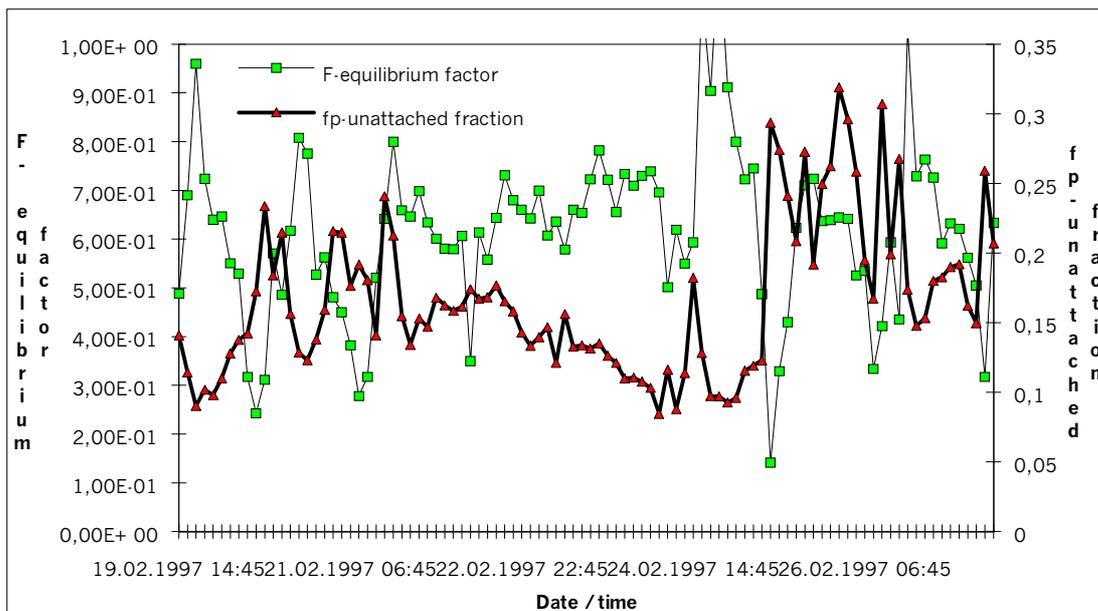


Fig.2 Equilibrium factor F and fp in a cabinet-maker’s shop

Fig. 1 shows a long time measurement of the radon concentration, the attached and the unattached progeny concentration in a cabinet-maker’s shop. The daily variations can be seen clearly. In the morning the ventilation system is switched on and in the evening the ventilation system is switched off. At high ventilation rate the unattached fraction is increased but in the evening - due to the small ventilation rate and the dust producing production processes - the attached fraction is increased. In the dusty production rooms this fact is excellently shown especially during the weekend in Fig. 1. On Monday, early in the morning, the ventilation reduces rapidly the aerosol concentration, and the factor fp increases (Fig. 2). When the production process starts, the dust increases the aerosol concentration as well as the factor F.

Fig. 3 shows a measurement carried out in Dresden (Germany) concerning the equilibrium factor F and fp of the unattached fraction at a work place in a school cellar next to the coal heating system.

The big variation of the fp factor is caused by the change of the ventilation rate and the aerosol concentration in this cellar. The radon and radon progeny concentration is shown in Fig.4. The factor fp ranging up to 0.11 shows that for the dose calculation the unattached fraction is not negligible. A long-term study in this place shows that the average value of the unattached progeny concentration is in the order of 200 Bq/m³ and the attached progeny concentration is of approximately 2,000 Bq/m³. Using the James/Birchell lung model (recommendation of ICRP 66) for the dose calculation, the exposed person (the stoker) accumulates during 2,000 working hours approx. 28mSv/a from the unattached progeny and 32 mSv/a from the attached progeny. In this way we can conclude that the unattached fraction has almost the same dose contribution like the attached fraction at this work place.

Using this new measuring technique it is possible to get more exact information of the real dose at work places or other interest places [4].

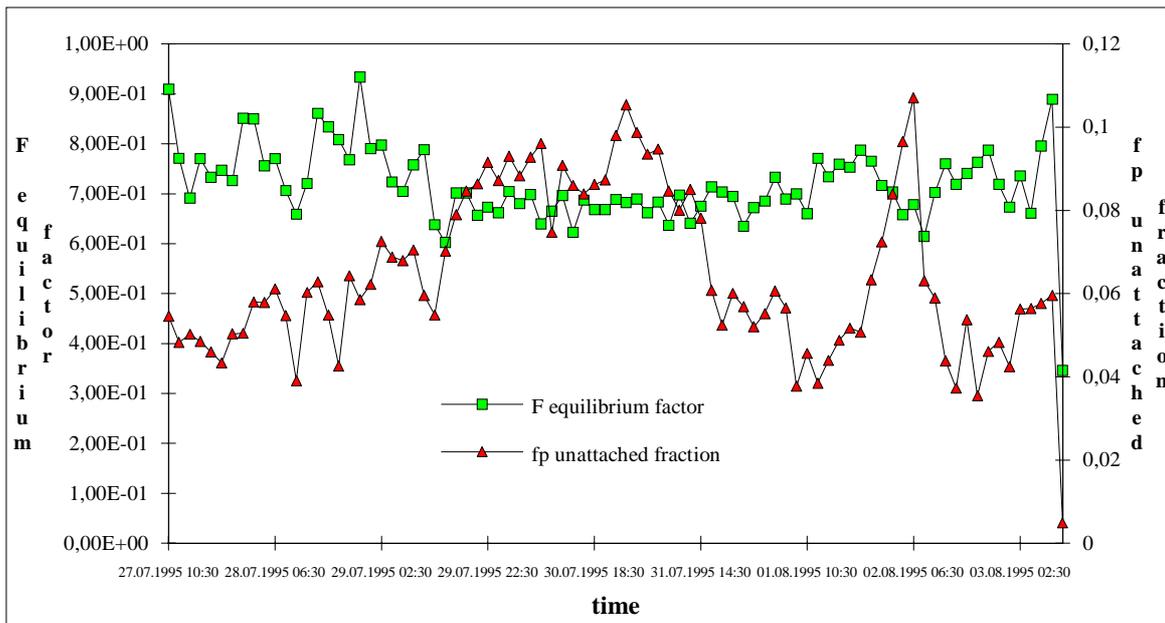


Fig.3 Measurement of the equilibrium factor F and fp in a school cellar in Dresden

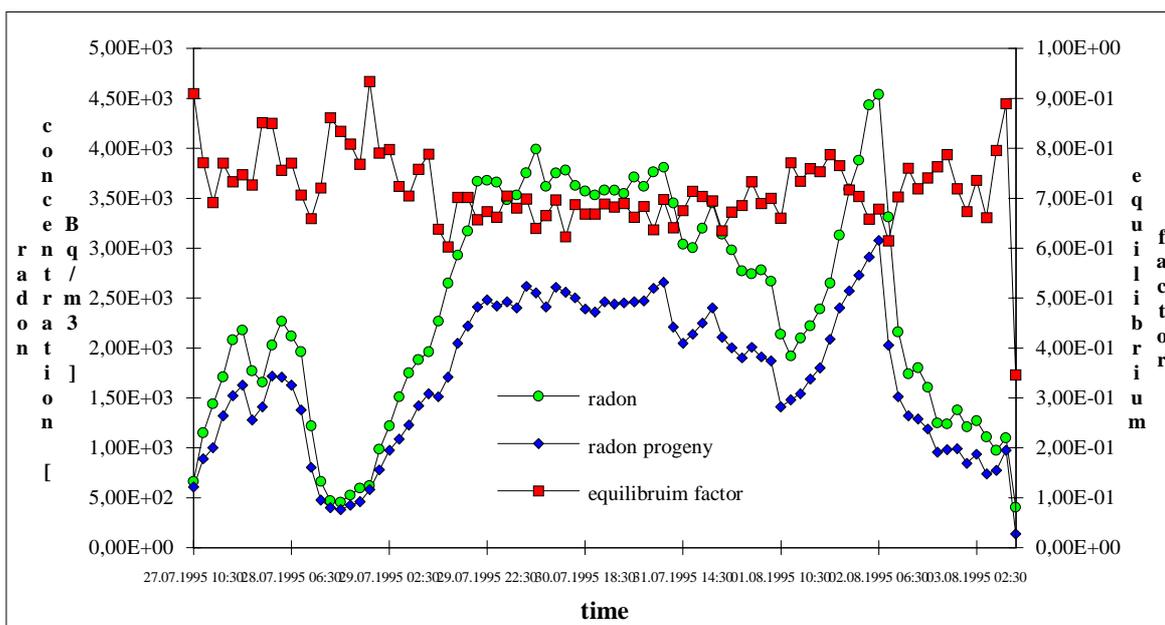


Fig.4 Measurement of radon and progeny concentration in a school cellar in Dresden

Another work place is shown in Fig.5 and 6. In collaboration with Ivan Kobal and Janja Vaupotic from the "Jozef Stefan" Institute in Lubljana (Slovenia), we measured the radon, attached and unattached progeny concentrations in the Postoina show cave in several places. Especially in the place "partizanski rov" we measured a very low factor F in the order of 0.1 (Fig.6). This low factor F is caused by the extremely clean and aerosol-free air and the natural ventilation in this cave. In this case the main contribution for the dose of the tour guides resulted from the unattached progeny with approx. 30 mSv/a during 2,000 working hours.

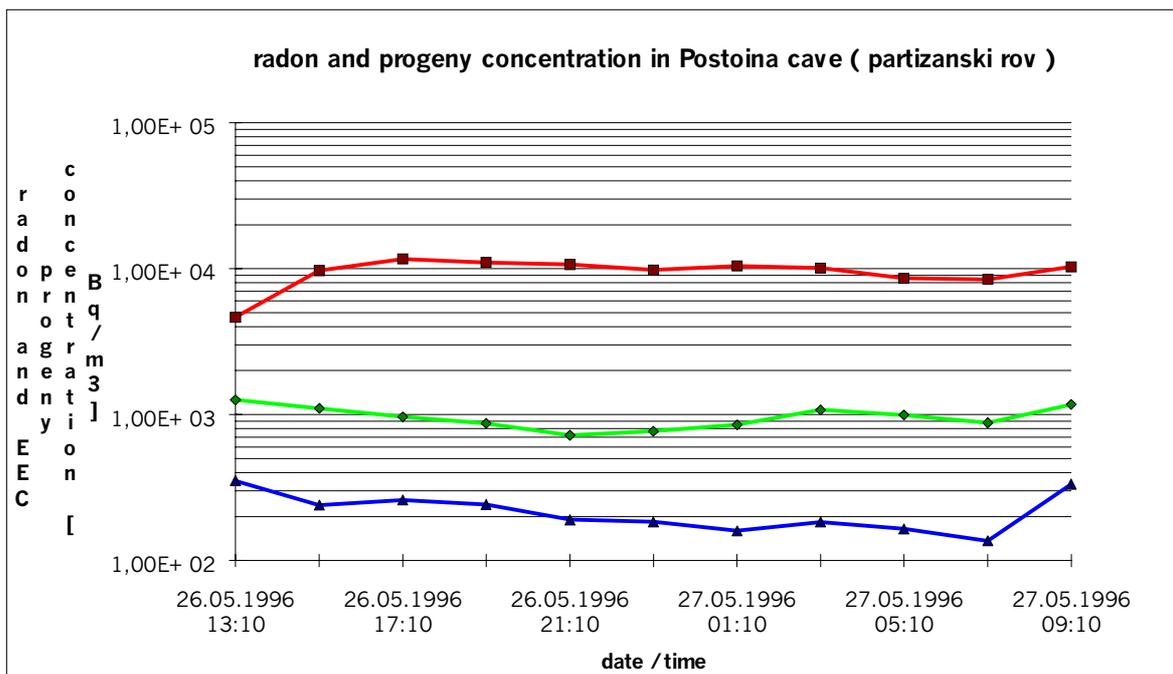


Fig.5 radon and progeny concentration in a show cave

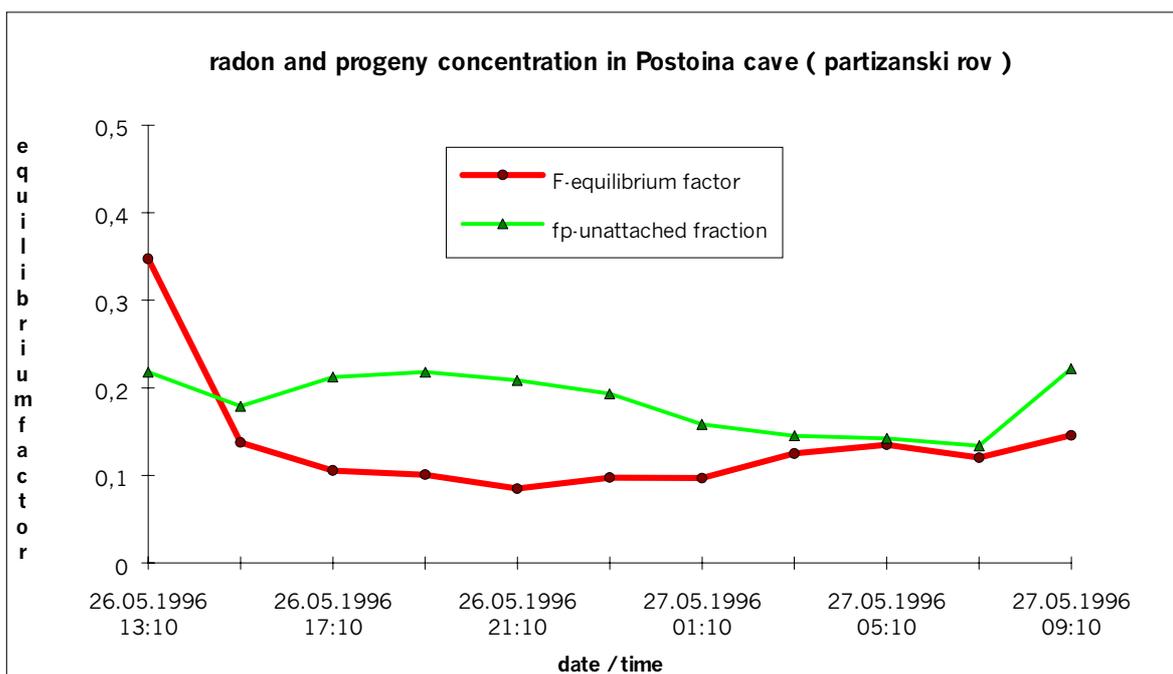


Fig.6 Equilibrium factor F and fp in a show cave

The contribution of the attached fraction is of approximately 15 mSv/a. In this cave the usual working hours for the guides are 10 hours per day and in this way the above-mentioned dose estimation reflects the almost real conditions.

This first study shows that at work places the working conditions have a strong influence on the real dose of the worker due to the radon progeny. We found places with very low

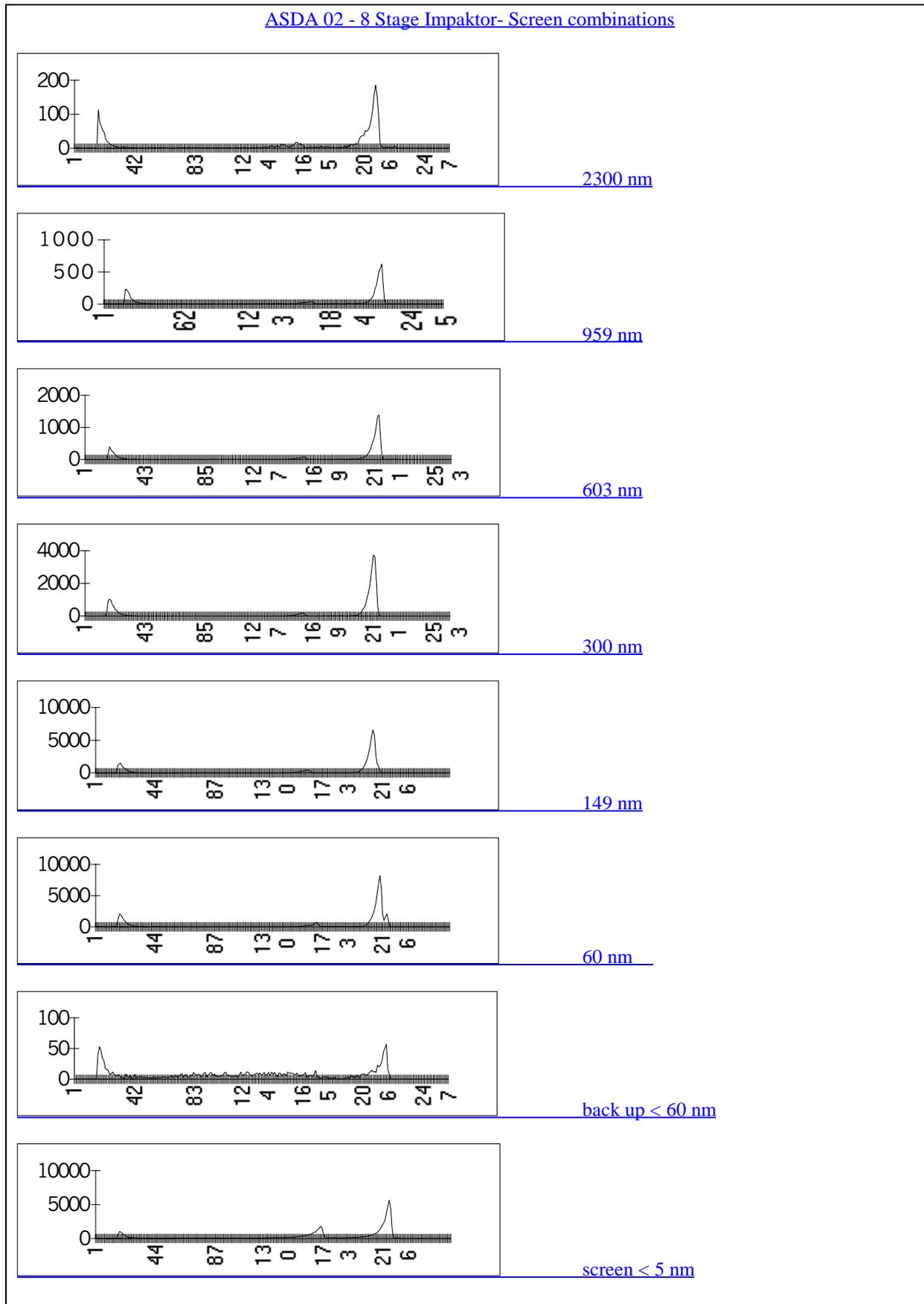


Fig. 7 spectra of the 8 stages of the ASDA 02 measuring system

factors F of approximately 0.1 and dusty places with high factors F of approximately 0.8. The unattached fraction f_p varies considerably from 0.02 in waterworks [6] up to 0.3 in ventilated rooms.

Using the new in cooperation with J. Porstendörfer and A. Reineking from the University Göttingen (Germany) developed active particle size measuring system ASDA 02 we measured in Kinsarvik/Norway together with A. Birovljev from NRPA different houses with high radon concentrations to study the influence of remedial actions of the aerosol size distributions. This work is started and will be finished soon. First results are shown in fig. 7 and Table 1 and 2. The spectra of the 8 stages are shown in Fig.7.

Radon progeny activity

Dp 50 (nm)	Ra A (Bq/m ³)	Ra B (Bq/m ³)	Ra C (Bq/m ³)
Unattached < 5 nm	1474	116	115
Backup-filter	70	29	38
60	871	355	423
149	690	238	304
292	295	99	97
589	84	27	33
1135	42	10	13
2356	52	2,8	4,2
Sum	3578	876,8	1027,2

Table 1 radon progeny activity in a house in Kinsarvik/ Norway before remedial action

Active size distribution for Ra A

Mode	fraction (%)	median value (nm)	Sigma
1	91.3	104.1	2.45
2	10.2	1033.4	4.88

Table 2 Active size distribution for Ra A in the house in Kinsarvik/Norway

Table 1 present the radon progeny activity for Ra A,B and C for the several stages. The radon gas concentration was in the order of 10 kBq/m³.

The main mode of active particle diameter is in the order of 100 nm and strongly influenced by the living conditions. The living room is direct connected to the kitchen.

3. Exposure control by radon personal dosimeter

In most of the work and living places remedial action are useful, but not in all situations is remedial action possible. Therefore is for exposure reduction a radon personal dosimetry necessary for a limitation and optimisation the working or living time under high radon concentration. The personal radon dosimetry on workplaces, for instance water works, mines, show caves and other work places with high radon levels is up to now not sufficient resolved. The uses of passive detectors like nuclear track etch detectors give the dose after the etching and scanning process. This is very late to react in case of very high radon concentrations and to prevent high exposure rates for the workers. It is well known that in some water works, old mines or show caves partially very high radon concentration in the order of 1 MBq/m³ are observed. Therefore it is necessary to develop new fast active devices with low power consumption and very high reliability. The possibility to include alert functions, the signalisation of high dose rate and also the time resolute dose determination give new chances for a

real online dosimetry in such very dangerous places

3.1 Measuring Device, Realisation, Calibration (Methods)

For these conditions we developed a radon personal dosimeter.

To realize a fast, active device with low power consumption and very high reliability for the radon personal dosimetry we integrated a 8 bit spectrometer, a 4cm² silicon detector, the signal processing, AD-conversion, data storage and the transponder or Irda system which provides the data transfer at a cheque card sized PCB. The electronic scheme of the system is shown in fig. 8 The full power consumption of the system is less than 200 μ A, refers to a battery life time of more than 3 month.

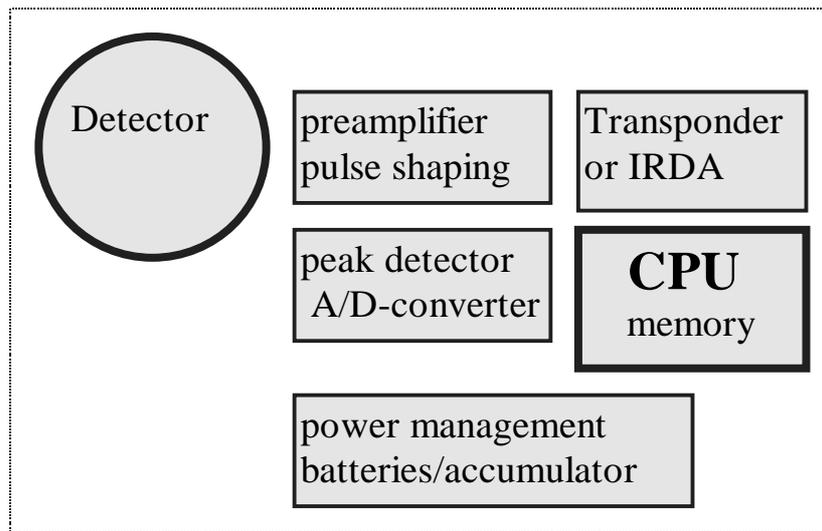


Fig. 8 Electronic scheme of the smart card radon dosimeter

Fig 9 show a spectra of the dosimeter. The radon continuum and the main dominant plate out peaks of the Po-218 and Po-214 are also observed.

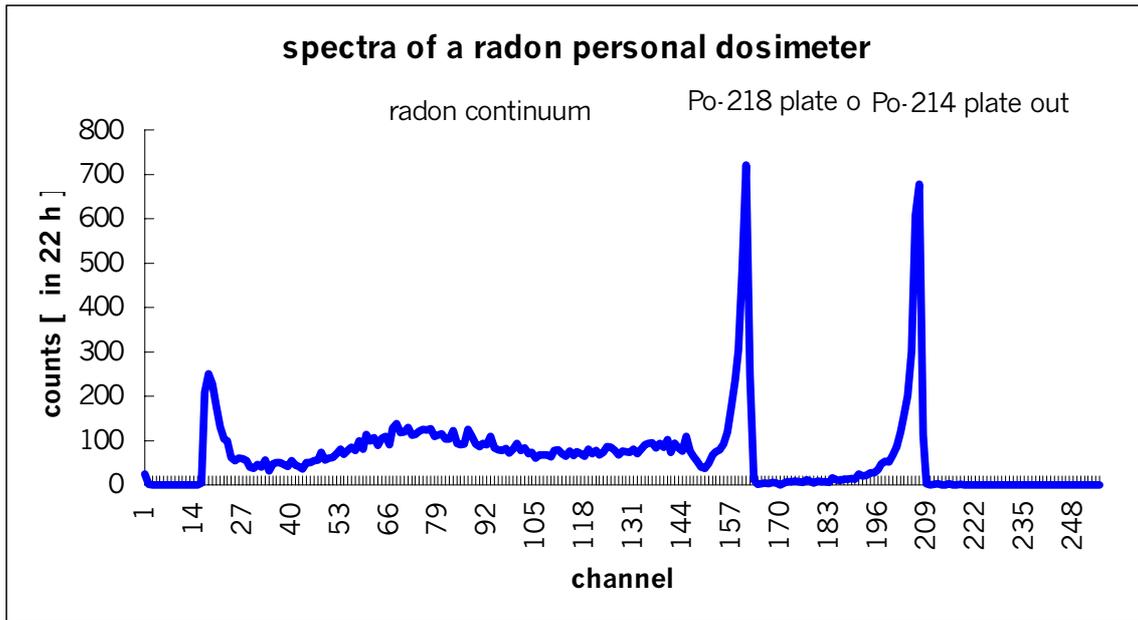


Fig. 9 Calibration spectrum of the Radon personal dosimeter exposed for 24 hours in a radon chamber with a concentration of 1 kBq/m^3

The radon inlet channel is equipped with a $150 \text{ }\mu\text{m}$ gas transfer membrane with a diffusion time of a view seconds. Therefore the system may be used also in environments with fast changing concentrations. The system is also sensitive to analyze Thoron.

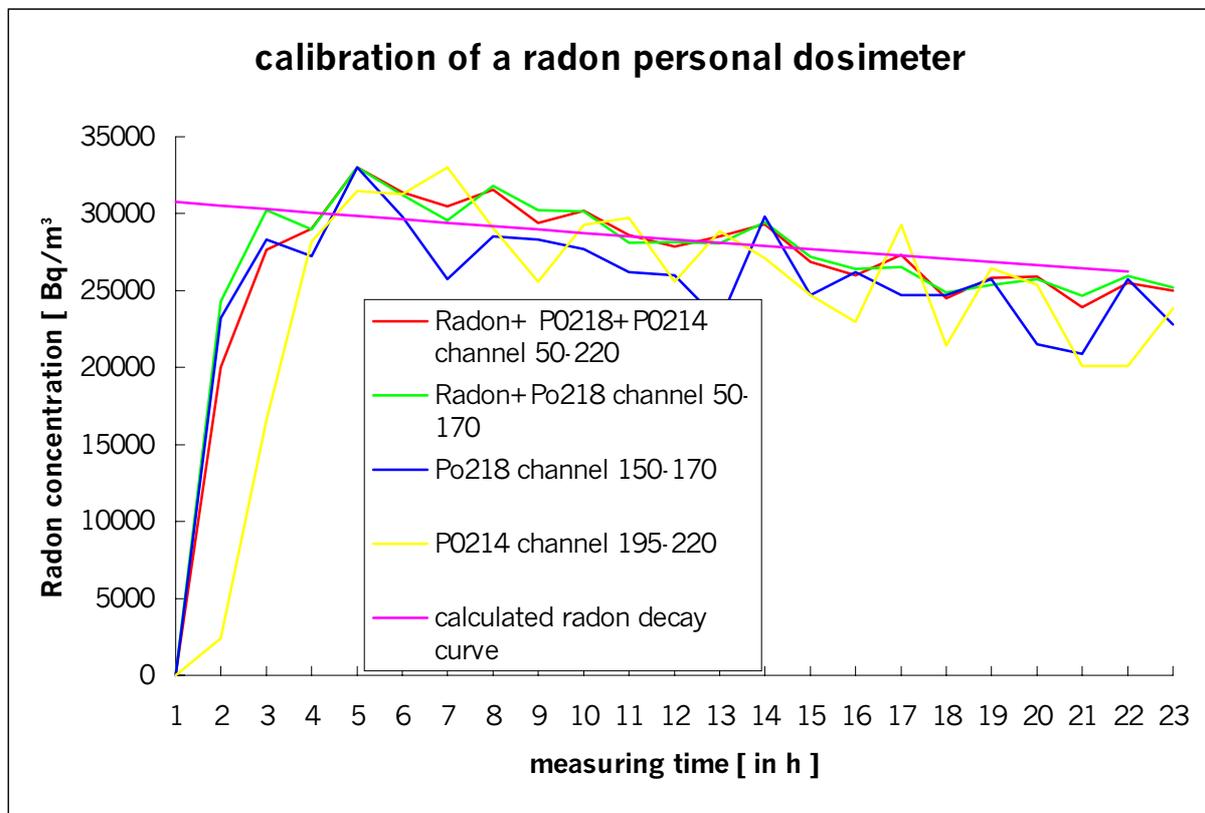


Fig. 10 Calibration data of the dosimeter for the used regions of interest (ROI) with by 30 kBq/m^3 start radon concentration

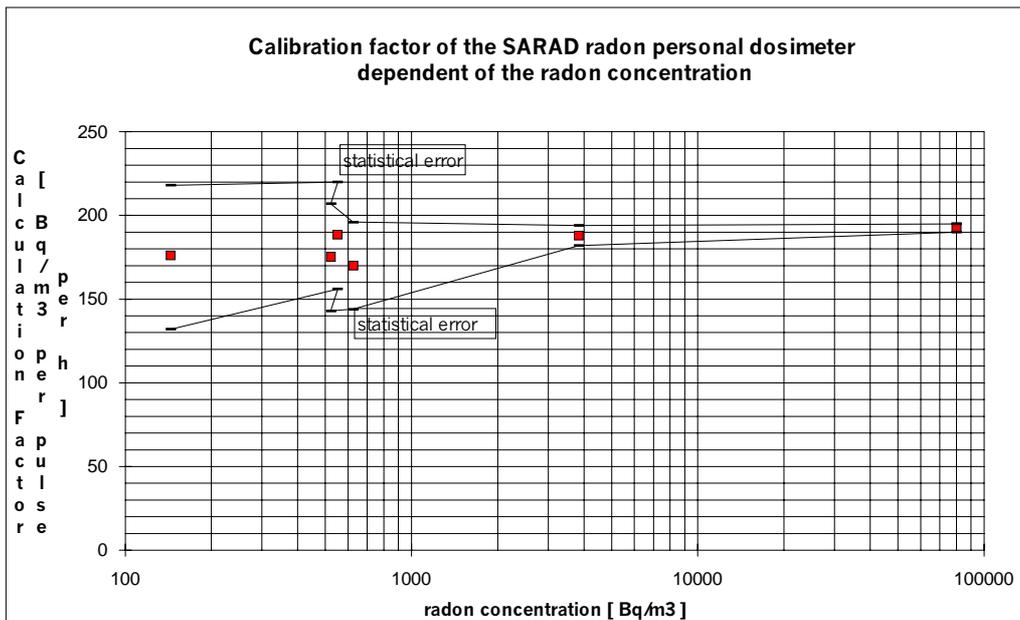


Fig. 11 The calibration factor of the radon personal dosimeter in dependence of the Radon concentration for the ROI 1 window channel 1 to 127

The radon decay curve is good reproduced in a calibration measurement for the 4 region of interest (ROI) stored in the memory of the dosimeter (see fig. 10).

Fig. 11 shows the dependence of the calibration factor versa the radon concentration. This figure shows that the calibration factor is stable over a wide measurement range.

3.2 Experimental results

The Radon dosimeters were tested under different environmental conditions and at several workplaces.

In fig. 12 and 13 the results of a very short measurement in water storage in Geyersgraben/Germany (Erzgebirge) are shown. The measuring time was only 30 min.

Cardcalibrierung				
Nr.	von	bis	Faktor	Resultat
<input checked="" type="checkbox"/> 1	1	60	250	31051.21
<input checked="" type="checkbox"/> 2	1	100	150	19212.94
<input checked="" type="checkbox"/> 3	50	60	1200	30274.93
<input checked="" type="checkbox"/> 4	100	126	2000	0.00

Fig. 12 Results of a radon dosimeter of the 4 ROI in the water storage Geyersgraben/Germany (Erzgebirge)

For data calculation the Po-218 concentration was used. The measured value was 30274 Bq/m3. This value agrees with the calibrated SARAD RM 2000 radon monitor.

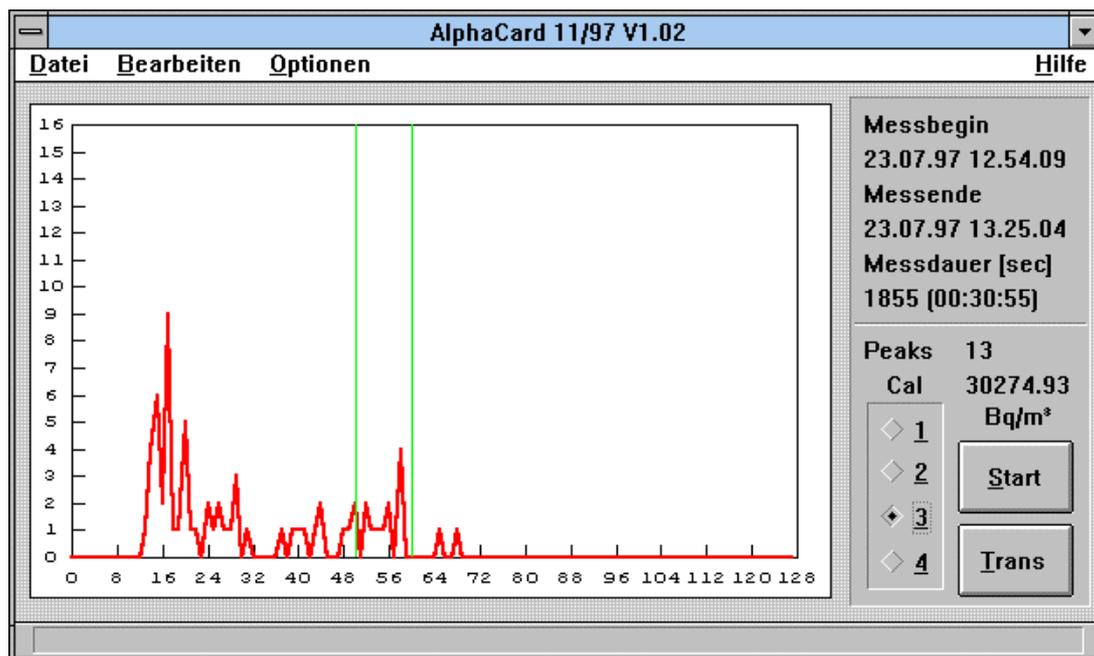


Fig. 13 Radon concentration measurement using the Po-218 (ROI channel 50 to 60) in water storage in Geysersgraben/Germany (Erzgebirge)

Because of the short inhalation time of the workers in this reservoir it is necessary to have a fast response time of the dosimeter to registrant the daily dose exactly. Using this dosimeter system, a new dosimeter concept can be introduced, because direct after the exposure the radon dose is well known and the working plan can be optimized. In several waterworks we measured extremely high Radon concentrations so that it is necessary to limit the working time under such extreme exposures.

An other test cycle was a medium time measurement in a classroom of a school in Freital to screen the Radon concentration for future studies. The measured radon concentration of 580 Bq/m³ shows that the recommendations for workplaces are not exceeded.

Po-218 Po-214

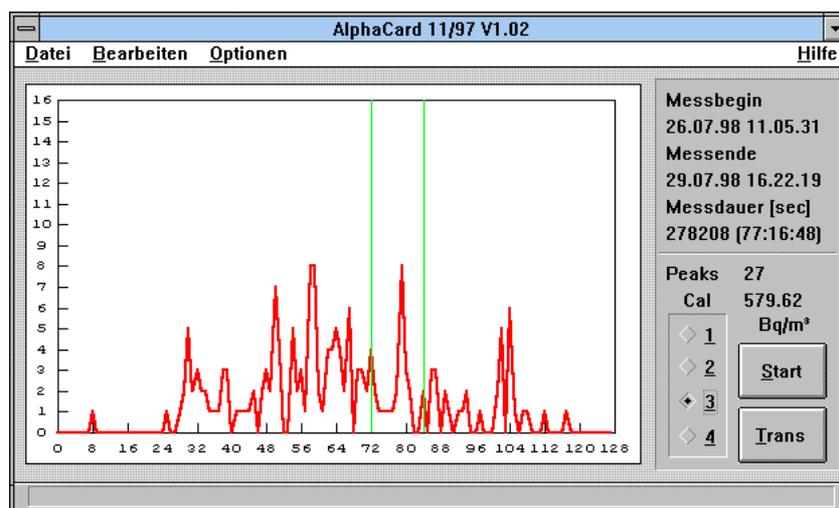


Fig 15 Radon concentration in a classroom of a school in Freital/Germany

4. Remedial action for exposure reduction

The best method for reduction of the exposure is the use of modern technologies of remedial action or new radon protected building technologies.

In new houses the installation of passive driven gas drainage's with double foil systems is a very use full method [1] or radon tight foils in combination with the humidity shield for new houses are installed, but for old houses it is more difficult to find the optimal remedial method.

The region of Dresden/Freital is one of the high radon risk areas in Germany. Indoor radon levels up to 100 kBq/m³ have been found.

For instance in an old house in this region we have equipped the already existing (water) drainage system with an exhaust ventilator, creating a subsoil depressurisation. In the winter bevor the installation of this ventilation the average indoor concentration was around 2 kBq/m³. Figure 16 clearly shows the effect of the ventilation.

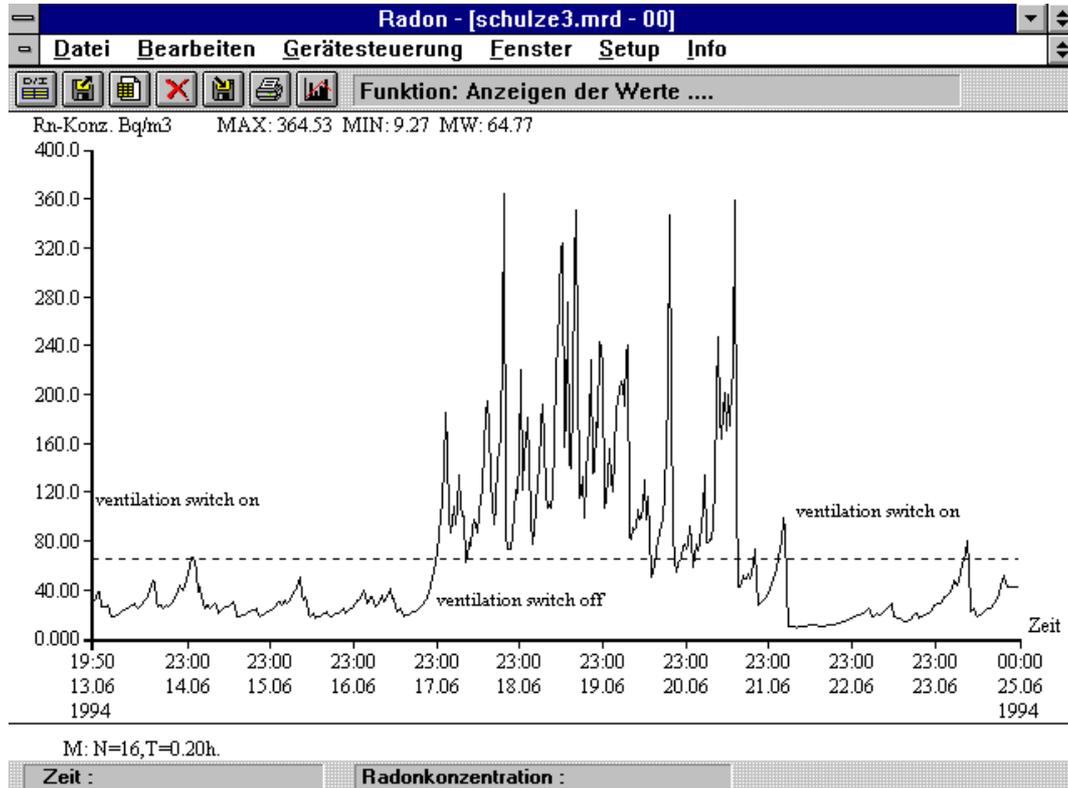


Fig. 16. Effect of a subsoil depressurisation on the indoor radon concentration. A ventilator sucks air from an already existing (water) drainage forming a ring around the house at the basement slab level.

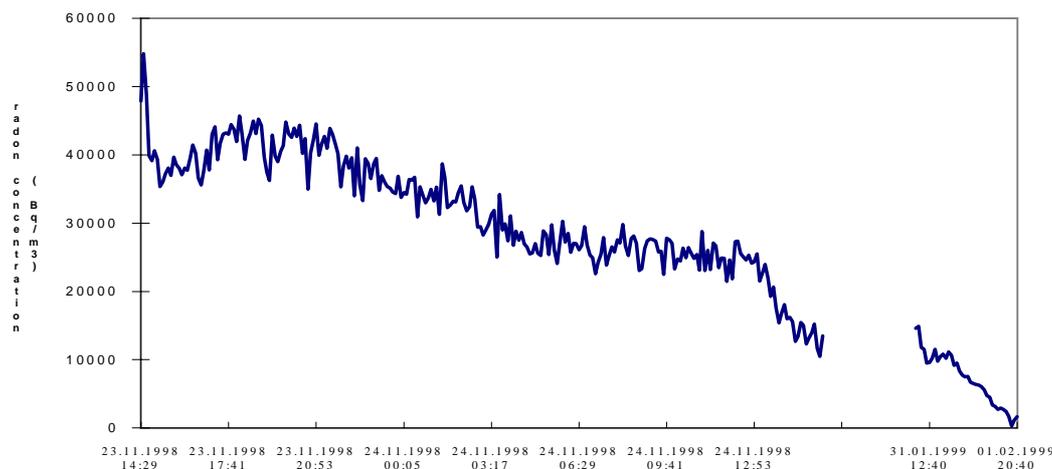


Fig. 17 radon remedial action in a house in Kinsarvik (Norway) using a radon well

The small village Kinsarvik in Norway is an other place there we installed in collaboration with Aleksandar Birovljev from the Norwegian Radiation Protection Authority until now 8 radon wells. So we reduced the indoor radon concentration in some houses from 60 kBq/m³ to 2 kBq/m³. One house is located on

the top of a Moraine and only in wintertime you can measure such high values. In this house more than a factor 10 decreased the radiological risk. Fig 3 shows the efficiency of this radon remedial action. Further is shown that an optimisation of the remedial action has reduced in a third step the radon concentration from 10 to 2 kBq/m³.

5. Conclusion

The reduction of the public exposure is possible by remedial action and personal dosimetry in high radon concentration at work and living places caused by a high geological radon potential of the soil, by technological processes, the use of building materials with high uranium, thorium and radium content and the building construction. Further the influence of the working and living conditions on the dose estimation can be included in radiation protection concept.

The radon risk mapping is one important factor by the search for radon affected work and living places including proposals for remedial actions or radon protected building constructions resulting from the radon risk of the soil. Such methods for remedial actions like active subsoil deprezuration or the installation of gas drainage systems results in high radon reduction factors and lead to a high efficiency in the radiation public exposure decrease.

But not in all situations are remedial actions possible. Therefore is for exposure reduction a radon personal dosimetry necessary for a limitation and optimization the working or living time under high radon concentration. The personal radon dosimetry on workplaces, for instance water works, mines, show caves and other work places with high radon levels is now resolved. The first tests of the newly developed radon personal dosimeter show that the device is easy to handle and works well under different conditions. The calibration is possible in several ROI. This enables also the measurement of Thoron is using a separate Po-216 energy window (ROI). Further studies will be provided to realize the Thoron calibration.

Another project under development is a radon progeny personal dosimeter based at the same electronic concept.

The possibility to include alert functions, the signalisation of high dose rate and also the time resolute dose determination give new chances for a real online dosimetry in such very dangerous places

6. References

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