INTERCOMPARISON OF RADON MEASUREMENT TECHNIQUES

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INTRODUCTION

Direct and continuous measurement of radon is of importance e.g. when estimating the effect of various countermeasures against high radon concentrations and locating the possible radon leakage paths. The need for continuous measurements has increased in Finland after the National Board of Health set the recommended limits (an action level of 800 Bq/m^3 and a planning value of 200 Bq/m^3 for new buildings). According to the latest statistics (2) the 800 Bq/m^3 limit is exceeded in approximately 1.4 % of the dwellings. Up till now, few devices for continuous measurement have been available, and are based on different measuring principles. Different radon and radon daughter measuring techniques have been reviewed by Budnitz (1). However, little attention was given to the continuous measurement. The national laboratories in the European Community carry out intercomparison measurements, but these have been limited for the purpose of quality assurance only. Recently, Shimo et al. (15) presented an intercomparison test. With the two continuous instruments included, they obtained comparable results when using indoor and outdoor air as sampling gas.

The object of the present study is to test continuous radon meters available in Finland (representing different measuring principles) to find out their reliability in different circumstances and their suitability for different tasks. Here, we report the results of laboratory measurements showing the effect of humidity and aerosol concentration on the instruments. Preliminary results of the field tests are also included.

METHODS AND INSTRUMENTS UNDER COMPARISON

The techniques and instruments studied were: a scintillation chamber (SC), a continuous flow ionization chamber (IC), an electrostatic monitor (EM), and a new commercial method based on ion concentration measurement (IM).

Scintillation Chamber (SC): Perhaps the most common method in continuous and sample radon measurement is the Scintillation or Lucas chamber (3,12,13,16). We used a commercial ZnS(Ag) device with a build-in pump. The instrument is fabricated by Pylon Electronic Development Co Ltd, Canada. A continuous 0.4 lpm air flow was maintained through the scintillation cylinder and alpha particles were counted for appropriate time periods. The response time of the instrument is approximately 3 hours because of the daughters attached into the scintillator. The detection level is set by statistical limitations: 40 Bq/m^3 is measured with an accuracy of about 20 % using a 30 min counting interval.

Ionization Chamber (IC) is another one of the traditional widely used methods (5,9,10,11,15) We used two continuous flow (8 lpm, chamber volume 20 l) instruments constructed in the Physics laboratory of Tampere University of Technology. The analoc correction circuit presented by Janka and Lehtimäki (10) gives the instrument a fast response time of 5 min. The sensitivity of the instrument is about 20 Bq/m^3.

Electrostatic Monitor (EM) suitable for continuous measurement was presented by Dalu and Dalu (4) and has since been modified (14,17). We used an instrument made

by Studsvik Energiteknik (Sweden) that is to be commercially distributed by Alnor Co. The instrument is based on radon diffusion through a plastic foam into the measurement chamber where the decay products are collected on the surface of a surface-barrier detector by an electric field. Capable of resolving the energies of RaA and RaC', the instrument has potential for fast response. This is somewhat limited by the diffusion process through the foam: the practical response time is over 30 minutes. A built-in pump is used for flushing the chamber but not used during the counting. By using an external pump and a high efficiency filter it is possible to operate the instrument in a continuous flow mode. This mode was also studied. Statistical limitations set the 20 % accuracy concentration at appr. 100 Bq/m^3 using 30 min intervals and RaA counting.

Ion Concentration Measurement (IM): A new commercial instrument, Ilma-Radon, made by Ilmasti Co, Finland is basically an ion meter. The use of indoor small ion concentration as a measure of the radon concentration is based on the fact that radon with the short lived decay products is the major contributor to the ion formation rate indoors. The main advantage of this type of measurement is the fast response, because the life time of small ions is short and practically no daughters are collected. The ion method has, however, inherent causes of inaccuracy. The indoor ion concentration is dependent on the processes which remove small ions: recombination, attachment to surfaces and aerosol particles as well as electric fields (7,8).

EXPERIMENTAL AND RESULTS

The laboratory tests were done in a 26 m^3 test chamber where different concentrations of radon and other airborne substances could be generated. ^{222}Rn was allowed to diffuse into the test chamber from a 1 mCi $RaCl_2$ salt dilution through an injection needle and a dilution volume. The chamber contained filters to clean the chamber air and a humidifier. Also compressed (and filtered) air supply and an exhaust blower were available.

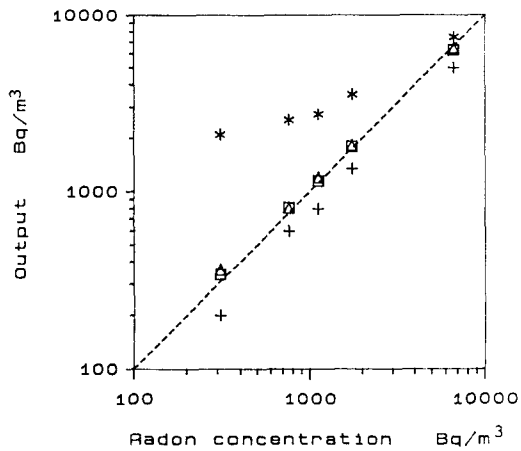

Figure 1. The output of the devices as a function of Rn concentration. △ =SC, □ =IC, + =EM, ⋆ =IM.

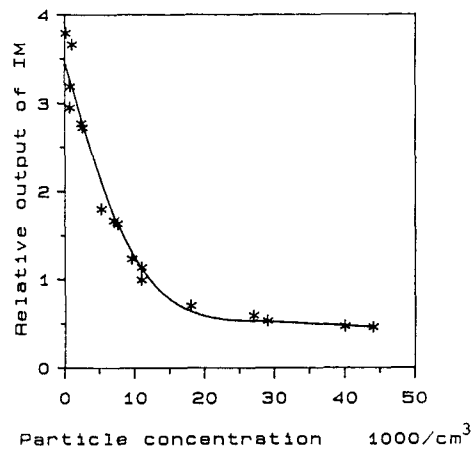

Figure 2. The effect of the aerosol concentration on the IM output.

Calibration: The instruments were calibrated in the facilities of the Finnish Centre for Radiation and Nuclear Safety. Monitors were placed in a 8 m^3 calibration room, where radon was produced by uranium ore. Radon concentration was continuously registered by two Lucas-type detectors, which had been calibrated against standard radon sources. The temperature and the relative humidity remained reasonably constant with values of 25 °C

and 30 % , respectively. The results at five different radon levels are shown in Figure 1: the IC and SC outputs were in good agreement with the radon concentration over the measured range; the EM calibration was too low but linear. The large deviation of the IM output is mainly due to the low aerosol concentration (approximately 250 $1/cm^3$).

Aerosol Concentration: The effect of aerosol concentration on the indicated radon concentration was studied using tobacco smoke. One of the ionization chamber monitors equipped with a HEPA filter served as a concentration reference. The aerosol size distributions and concentrations were measured using a TSI Differential Mobility Particle Sizer. IM was found to be the only instrument affected by the aerosol concentration. Figure 2 shows the relative output of IM as a function of the total number concentration of particles larger than 0.01 μm: the output is approximately inversionally proportional to the aerosol concentration, as would be expected.

Humidity: In order to achieve a low humidity level, compressed air was fed to the chamber. During the test, the humidity was increased stepwise. One of the IC:s was again used as a reference meter taking the sample through a dryer. The temperature in the chamber varied less than 1 °C during the experiment. The relative output of the instruments as a function of R.H. is presented in Figure 3. The most sensitive is EM due to the change in the neutralization of RaA. This has been found to be dependent also on the concentration of various trace gases in the air (e.g. 6). Due to active charcoal filtered air feed, the concentration of these gases in the chamber air was propably lower than in normal indoor air. It is possible that the change in the output is to some extent caused by infiltration of gaseous compounds from the surrounding laboratory during the experiment. The ionization chamber shows a very weak dependency of the same kind. The output of the Scintillation Chamber remained practically unaffected by the changes in humidity. The main reason for the scatter in IM results is probably the changes in the particle size distribution and concentration.

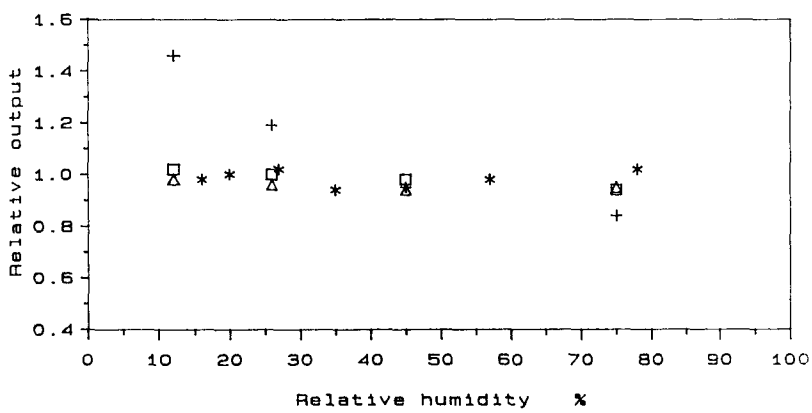

Figure 3. The effect of humidity on the relative output of the instruments. Temperature 25...26 °C. △ =SC, □ =IC, + =EM, ⋆ =IM.

Field Tests: Due to the observed variations of the IM response, the meter was further tested in eleven separate dwellings — ranging from one-storey small houses to four-storey buildings. The results, shown in figure 4, include 4-10 readings in every dwelling. The momentary radon concentration of measurement points were determined by samples of evacuated scintillation chambers. The IM device tended to give high results especially at low radon concentration. Both aerosol generating activities (cooking) and movements near the device were observed to affect the reading.

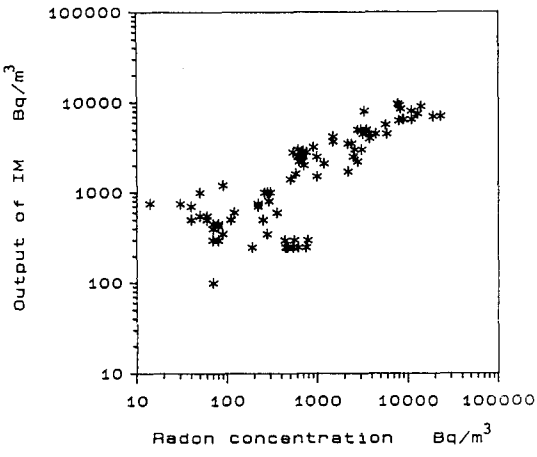

Figure 4. The output of IM as a function of radon concentration. Short time averages in 11 houses.

CONCLUSIONS

In continuous measurement the response of the instrument must be fast enough to be able to follow the concentration variations of interest. IC and IM have response times short enough for practically any application. The use of an external pump and filter gives EM a reasonably fast response, whereas in diffusion mode the response is rather slow. SC is too slow for radon leakage and certain ventilation studies. The most reliable instruments seem to be SC and IC. The IC is somewhat sensitive to changes in the background gamma level, which is not a serious drawback in dwellings. EM is sensitive to the humidity (and the gaseous composition of the air). The dependency of IM output on the aerosol concentration and on electric fields causes the readings to be unreliable, especially in short time measurements. The manufacturer is working on a method to compensate the effect of aerosol particles. The effectivity of this method remains to be studied.

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