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THE FILTERING EFFECT OF BUILDINGS ON AIRBORNE PARTICULATE MATTER

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THE FILTERING EFFECT OF BUILDINGS ON AIRBORNE PARTICULATE MATTER

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ABSTRACT

Within the radioecological programme of the Nordic Liaison Committee for Atomic energy (NKA) the possible consequences of a major reactor accident are one of its main research branches. The study of the filtering effect of buildings on airborne particulate matter has been one part of this branch. The absorbed dose to a person from a passing radioactive cloud will be lower if he has been indoors and not outdoors during the cloud passage. The aim of this study has been to find filtering factors for typical Finnish and Norwegian houses to use in model work.

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INTRODUCTION

Within the radioecological programme of the Nordic Liaison Committee for Atomic Energy (NKA) the possible consequences of a major reactor accident are one of its main research branches. The study of the filtering effect of buildings on airborne particulate matter is one part of this branch. The absorbed dose to a person from a passing radioactive cloud will be lower if he has been indoors and not outdoors during the cloud passage. The aim of the NKA study is to find filtering (or transfer) factors for typical Nordic houses to use in model work.

The results of Danish investigations by the Risø National Laboratory have already been published (1,2,3,4). The results of a Finnish study by the Finnish Centre for Radiation and Nuclear Safety and a Norwegian study by the Institute for Energy Technology are presented in this paper. The naturally occuring radioactive nuclide ^{7}Be has been used as a tracer in these two studies.

The nuclide ^{7}Be is mainly created in the upper layers of the earth's atmosphere by spallation processes induced by the cosmic radiation. A small amount of ^{7}Be is also created at ground level, and hence also indoors. But for all practical purposes one can consider this nuclide being of purely outdoor origin, as its half life is very long compared to the time for air exchanges in houses. German studies (5,6) indicate that the outdoor variations of the ^{7}Be concentration at ground level are slow compared to the air exchange in houses, and therefore such variations should not significantly influence the results of our study.

The Danish investigations have shown that ^{106}Ru particles of size 0.05 - 0.2 µm behave in the same way used as a tracer as do the ^{7}Be particles (2). The ruthenium activity originated from Chinese atmospheric nuclear weapons tests. It is therefore reason to believe that the ^{7}Be is attached to airborne particulate matter of a size distribution similar to radioactive fallout particles far away from the detonation area. The particles created and released because of a hypothetic reactor core meltdown are assumed to have about the same size distribution as the ^{7}Be and ^{106}Ru particles at a certain distance from the nuclear plant (2). The filtering factors found based on ^{7}Be measurements might therefore also be applicable to a radioactive cloud from such an accident.

Studies of the filtering effects of buildings have also been reported by American (7,8) and Swiss (9) investigators.

EXPERIMENTAL

The Finnish study includes four flats in typical Finnish apartment buildings built between 1968 and 1972. The Norwegian study includes one house, a wooden villa built in 1954. This one is typical of those being built during the first 10-15 years after 1945. Because of the sampling conditions no people might live in the dwellings during the air sampling. It has therefore been very difficult to find flats or houses that could be studied.

The collection of particulate matter on filters was done simultaneously outside and inside the buildings. The ^{7}Be content of the filters should therefore give an information of the filtering effect of the house. In both studies the amount of ^{7}Be on the filters was determined by Ge(Li) gamma spectrometry.

The indoor deposition of ^{7}Be has been measured in the Norwegian house, but not in the Finnish flats. According to Danish results it is of no practical significance (1,3). The deposition of ^{7}Be has been found to be about 0.004 cm/s (3).

a) The Finnish study

For the sampling two portable air pumps were used. They were of type RADeCO, model H-809 C and their air flow meters had been carefully calibrated. After the calibration the samplers were checked during two 96 hours parallel runs. When double glass fibre filters of type Whatman *GF/A* (*diam.* 10.5 *cm*) were used, the air flow varied between 60 and 70 litres per minute for the outdoor sampler and from 79 to 83 litres per minute for the indoor sampler.

The air flow rate was read once a day and the capacity ratio between the two pumps was found to be 1.028.

The investigations of the flats were performed during the summer 1982. For each of the four flats the experimental work was done as described below.

One sampler was placed outside the flat on a balcony, the other in the living room. All windows, external doors and ventilation ducts were closed during the sampling, so according to the Finnish building directions the air exchange rate was about 0.2 times per hour for each flat. This value has however not been checked experimentally. The air leaving the pump was led to the bathroom, the door to which was closed. All the other doors in the flat were kept open. The collection time was 96 hours for each sampling. The filters were not changed during this sampling period.

If the air exchange rate is 0.2 per hour, about 30 m^3 of outdoor air will enter the flat every hour. The pump rate of max. 5.5 m^3/hr should not therefore change the indoor ^{7}Be concentration significantly. After sampling the two filters from each pump were compressed to a circular disc, of which geometry the counting efficiency of the detector was known.

The weather during the first collection period was sunny with slight wind. The mean outdoor temperature during the period was 19.6 ^{0}C. The three days in the beginning of the second collection were also sunny with slight wind but the last day was rainy wih a rainfall of 10 mm. The mean temperature of the second period was 17.7 ^{0}C. The third collection period was sunny or slightly cloudy with a mean temperature of 17.4 ^{0}C. The wind was slight. The weather of the last period was mostly cloudy, except the last day. Rainfall during that period was 10 mm and the mean temperature was 10.2 ^{0}C.

b) The Norwegian study

The Norwegian investigations were similar to the Finnish, but two series of four different samplings each were done in the same house. The first series of air sampling was done during the autumn 1982, the second during the early summer 1984.

Two identical pumps of type Gascoignes of which the air flow rate had been carefully calibrated, were running simultaneously during the sampling. The collection time was 72 hours for each sampling. Each pump was equipped with one single glass fibre filter of type Whatman GF/A (diam. 9 cm). The capacity of the pumps was 315 litres per minute, the ratio between the two pumps being 1.03.

During the first sampling series, the filters were changed every 24 hours. During the second series, the filters were not changed at all within each collection period. Separate tests had shown that the flow rate remained constant throughout periods of this length.

One of the pumps was placed just outside the house, the other in the living room at the ground floor. During the collections all windows, external doors and ventilation ducts, including the chimney, were closed. During the first series, also the doors to the living room, to the first floor, and to the cellar were kept closed. During the second series, all doors at the ground floor were kept open, except the doors to the cellar and to the first floor.

A plan of the ground floor is given in the figure.

During the first and second run of the first series, the air from the indoor pump was led out of the house via the chimney. The weather during the first run was overcast with 3 m/s ENE wind, and during the second run it was rainy with 3 m/s N to NE wind. During the third run the pumped air was released in the living room itself. The weather was overcast with rain on the third day and 6 m/s S breeze. During the fourth run the air was led from the indoor pump to the first floor. The weather was sunny the two first days and foggy the third. There was no wind. During this run the door to the first floor was open, and the door to the living room was not fully closed because of the plastic tube leading the air to the first floor. The door was however sealed by means of plastic foil and adhesive tape.

During all the four runs of the second series, the air from the indoor pump was released in a neighbouring room at the ground floor. The weather during the first run was sunny and warm with 6 m/s NNE wind. The second run had overcast and cool weather with 4 m/s N wind, the third changing but warm weather with 2-6 m/s S or SE wind. During the fourth run the weather was again sunny and warm with 4 m/s S wind.

After each run the filters were folded and counted. The efficiency of the geometry was not determined. If the geometry is the same for parallelly sampled filters, as was the case here, the efficiency is not needed in order to calculate the indoor-outdoor ratio (I/O ratio).

As a separate experiment in order to determine the deposition rate of the ^{7}Be, a clean perspex plate of size 2.4 m^2 was placed horisontally in the living room for 288 hours. The deposited dust was carefully removed by a smear test type filter paper and counted. The geometry was similar to the one of the second series. The indoor pump was inactive during this experiment, but the outdoor pump collected air all the time, and the filter was changed every 3 days.

RESULTS AND DISCUSSION

The results of the Finnish measurements are given in Table 1. It will be seen from this table that the I/O ratios or filtering factors of ^{7}Be are 0.33, 0.45, 0.23 and 0.37 for the four flats investigated. The uncertainties include one standard deviation counting error and a volume measurement error of 5 %.

The I/O ratios found for the Norwegian house are 0.6, 0.7, 0.9 and 0.5 for the four mentioned runs of the first series. The second series gave the ratios 0.40, 0.46, 0.47 and 0.44. These results are presented in Table 2. The uncertainties include one standard deviation counting error and a volume measurement error of 5 %.

During the three day sampling periods of the first series the filters were changed daily, as already mentioned above. As we had to enter the house in order to change the indoor filter, this may have increased the indoor concentration of ^{7}Be and may be the reason for the high I/O ratios found.

It has been shown (5,6) that the outdoor air concentration of ^{7}Be normally is higher in the period April - September than in the period October - March. Similarly, the counting rates of ^{7}Be of the filters of our second series were generally higher than those of the first, as shown in Table 2.

The undisturbed indoor sampling of the second series resulted in lower I/O ratios compared to the first series. The precision of the measurements of the second series is also better, due to the higher ^{7}Be concentration of the air. We therefore conclude that these I/O ratios are representative for this type of Norwegian house.

The air exchange measurements of the Norwegian house were performed shortly after the first series of air sampling. It was found that the air concentration of the tracer, which was helium gas, was reduced to half the initial value after 4.0 hours in the living room of the ground floor, and after 2.7 hours in the living room of the first floor. The experimental conditions were the same as during the sampling of ^{7}Be, except that the door to the first floor living room was closed. The results correspond to air exchange rates of 0.13 and 0.19, respectively.

The volume of the entire ground floor is 130 m^3 and of the living room 73 m^3. An exchange rate of 0.13 means that about 9 m^3 of air enter the living room every hour. The air flow of the pump is 19 m^3/hr. The ^{7}Be concentration of the room is thus probably affected to a significant extent, and corrections should be made on the measured indoor values of the first series, if this exchange rate is correct.

During the second series, all of the ground floor formed one volume of air. If the air exchange rate is 0.13, about 17 m^3 of air will enter every hour, which is about the same as the pump rate. Probably the true air exchange rate is even higher than the rate of the Finnish flats. Arguments for this are given below. At a rate of 0.25 about 33 m^3 will enter the first floor per hour. Corrections should therefore not be necessary in this case.

As all windows, external doors and ventilation ducts are closed during the sampling, the air exchange takes place through the cracks and leaks of the building itself. Modern buildings are normally very well isolated and tight and have small air exchange rates, as 0.2 times per hour for the Finnish flats.

The measured air exchange rates of the older Norwegian house indicate that the house may have an even better isolation than the more modern Finnish flats. Thus one should expect that the filtering effect of the Norwegian house was at least as good as of the Finnish flats, but the measurements of the second series show that its I/O ratio is about 30 percent higher, 0.44 compared to 0.35.

Both the age of the Norwegian house compared to the Finnish flats and the measured I/O ratios therefore indicate that the measured air exchange rate of the Norwegian house is too low.

The smear filter was counted for 300.000 seconds and gave 228 net counts of ^{7}Be, the uncertainty being 47 % (one std. dev.). The deposition of ^{7}Be was thus 2.6 x 10^{-6} cps/hour on the plate, which corresponds to 5.7 x 10^{-5} cps/hour for the total ground floor area of 52 m^2. The corresponding deposition rate is 0.008 cm/s.

The mean value of the measured outdoor concentration during the deposition period was 8.3 x 10^{-6} cps/m^3. The mean indoor concentration was correspondingly 3,7 x 10^{-6} cps/m^3, based on a I/O ratio of 0.44, and the total inventory of ^{7}Be in the ground floor air was 4.8 x 10^{-4} cps. The amount deposited per hour was thus about 12 % of this.

If we assume that the indoor ^{7}Be concentration during this 288 hours period has been approximately constant, and that the deposited amount per hour equals the amount entering from outside, the air volume which must enter is 15.4 m^3/hour. This corresponds to an exchange rate of 0.12, which is about the same as the measured ground floor value mentioned above.

It is, however, quite unlikely that all the amount of ^{7}Be leaves the air volume of the ground floor by deposition and nothing with the indoor air that has to be exchanged with the incoming outdoor air. Therefore either the measured deposition ratio may be too high or the measured air exchange rate too low. The latter case is most probable, as will be argued for below.

The investigations of Danish houses seem to show that the filtering factor for a room is generally independent of the wind direction. "External" rooms like kitchen, entry hall, furnace room, etc. were found to have higher filtering factors than other rooms in the house. On the other hand the filtering factor for a house having all internal doors open was not much different from the filtering factor found when the doors to the external rooms were closed (2).

The Norwegian results of the second series show that the I/O ratio is

the same whether the wind blows from a northerly or southerly direction. Similar conclusions cannot be drawn from the Finnish data, as we have only one I/O ratio measured for each flat.

We may conclude that further investigations are desirable both in Finland and in Norway in order to get an acceptable total knowledge of the filtering behaviour of representative buildings in these countries. Only one building type has been studied so far in each country. A main problem is however to find suitable and un-occupied houses and flats to study.

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TABLE 1. Measured concentrations of ^{7}Be in air inside and outside four different Finnish flats.

Collection period	No.of rooms	Vol.of flat(m^3)	^{7}Be conc.(mBq/m^3) inside(I)	outside(O)	I/O ratio
12-16.7.82	4	188	1.418	4.319	0.33 ± 0.05
19-23.7.82	3	150	1.209	2.672	0.45 ± 0.07
26-30.7.82	3	146	0.651	2.809	0.23 ± 0.05
06-10.9.82	3	140	0.571	1.553	0.37 ± 0.09

TABLE 2. Measured concentrations of ^{7}Be in air inside and outside one Norwegian wooden villa.

Collection period	^{7}Be activity (10^5 counts/m^3) inside(I)	outside(O)	I/O ratio
First series			
04-07.10.1982	0.98	1.56	0.63 ± 0.07
12-15.10.1982	0.47	0.68	0.69 ± 0.10
09-12.11.1982	0.25	0.29	0.86 ± 0.23
29.11-02.12.1982	0.23	0.47	0.49 ± 0.09
Second series			
04-08.06.1984	1.49	3.77	0.40 ± 0.03
08-12.06.1984	0.85	1.87	0.46 ± 0.04
12-19.06.1984	0.43	0.92	0.47 ± 0.06
19-21.06.1984	0.63	1.45	0.44 ± 0.08

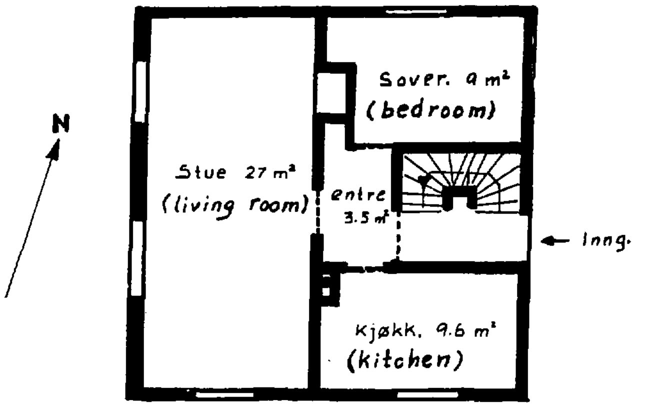

Figure. Plan view of the first floor of the Norwegian house.

Institutt for energiteknikk (IFE) ble grunnlagt i 1948 under navnet «Institutt for atomenergi». I 1953 ble Instituttet etablert som en uavhengig stiftelse. Hovedsenteret ligger på Kjeller. Virksomheten i Halden er konsentrert om det internasjonale OECD Halden Reactor Project.

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