VENTILATION SYSTEMS FOR BUILDINGS IN URBAN AREAS

Ove Strindehag[1], Stig Torkelsson[1], Gunnar Jansson[1] and Peter Kjaerboe[2]

[1] ABB Indoor Climate Technology AB, Jönköping, Sweden
[2] Royal Institute of Technology, Dept. of Heating and Ventilation, Stockholm, Sweden

ABSTRACT

The properties of particulate filters and gas adsorption filters have been studied to determine the opportunities available for effectively cleaning the outdoor air supplied to buildings located in urban environments. Class F85 fine filters were studied to determine their collecting efficiency for both atmospheric dust and particulate PAH. Activated carbon adsorption filters were tested to establish their collecting efficiency for toluene, m-xylene and benzene in the concentration range of 1-10 ppm. Long-term tests were also run on a carbon filter in a building in central Stockholm. Moreover, the indoor pollutant concentrations that can be expected following briefly increased outdoor contents were calculated.The results show that a reduction in the outdoor air flow under such circumstances may be advisable as a supplement to cleaning of the outdoor air.

INTRODUCTION

As a result of the demands for good air quality indoors, intensive efforts are currently being made to restrict the emissions of pollutants from sources inside the buildings, including those from building materials. In many cases, it has also been considered necessary to supply outdoor air at higher flow rates than in the past, in order to restrict the pollutant contents in the indoor air. But the increased supply air flow rate will produce the required results only if the outdoor air has low content of hygienically harmful pollutants. If not, the supplied outdoor air must be cleaned efficiently.

In an urban environment, substances such as CO, NO_2, SO_2 and a number of hydrocarbons would appear to be the principal cause of serious hygienic problems. Among the latter, special attention should be focused on polycyclic aromatic hydrocarbons (PAH). It is therefore vitally important to equip ventilation systems with filters that are capable of collecting the mentioned pollutants, as well as particulate pollutants.

The time-related variation of pollutant contents in urban air, particularly over a 24-hour period, is also of major importance, above all in work premises. A realistic measure may be to reduce the outdoor air supply rate for brief periods during which the traffic load is high. This applies particularly to buildings that already have high grade ventilation systems with modern control equipment, so that their method of operation can easily be modified.

The study reported in this article was aimed at determining the opportunities available for using various types of filters for cleaning the outdoor air supplied. Both particulate filters and commercially available versions of gas adsorption filters were therefore studied. Various methods of controlling the outdoor air supply were also studied with regard to the variation in the pollutant concentrations over a 24 hour period.

High-class fine filters (class F85 or better) can also reduce substantially the concentration of particulate PAH. It should be possible to use gas adsorption filters of above described types for efficient collection of PAH in gaseous form. Moreover, such filters can be impregnated and can then be used for collecting SO_2 and NO_2, which is important in many urban environments.

Advantage should be taken of opportunities available for improving the quality of the indoor air, by reducing the outdoor air flow rate during temporary increases in outdoor concentrations, particularly in buildings located close to streets carrying heavy traffic.

Table 1. Calculated dose increase during a working day caused by an increased concentration of pollutants outdoors, the increase being in the form of a square-wave pulse of duration t_1 and with an amplitude C_1. The duration of the working day is 9 h, the nominal time constant of the ventilation system is 40 min, and the background concentration is C_0.

C_1/C_0	D_1/D_0								
	t_1(min)								
	10	20	30	40	50	60	70	80	90
2	0.04	0.07	0.11	0.15	0.19	0.22	0.26	0.30	0.33
5	0.09	0.19	0.28	0.37	0.46	0.56	0.65	0.74	0.83
10	0.19	0.37	0.56	0.74	0.93	1.11	1.30	1.48	1.67
20	0.37	0.74	1.11	1.48	1.85	2.22	2.59	2.96	3.33

REFERENCES

1. Pejtersen J, Bluyssen P, Kondo H, Clausen G, Fanger PO. Air pollution sources in ventilation systems. Proc of the Second World Congress CLIMA 2000, Aug 27-Sept 1, 1989, Sarajevo.
2. Liu RT. Modeling activated carbon adsorbers for the control of volatile organic compounds in indoor air. Proc of the ASHRAE Conf. on Environmental Quality, Nov 5-8, 1991, Hong Kong.
3. Strindehag O, Norell L, Kvarnström S. Improved indoor air quality by supervision of the CO_2 content. Proc of the Fifth Int Conf on Indoor Air Quality and Climate, July 29-Aug 3, 1990, Toronto.
4. Burtscher H, Scherrer L, Siegman HC, Schmidt-Ott A, Federer B. Probing aerosols by photoelectric charging. J Appl Physics 1982;53(5):3787-91.
5. Strindehag O, Ekberg LE. Particulate PAH concentrations in office buildings. Proc of the ASHRAE Conf IAQ'92, Oct 18-21, 1992, San Francisco.
6. Graham JR, Bayati MA. The use of activated carbon for the removal of trace organics in the control of indoor air quality. Proc of the Fifth Int Conf on Indoor Air Quality and Climate, July 29-Aug 3, 1990, Toronto.

DEVELOPMENT OF
ABSORPTION MEMBR

Jan F. van der Wal[1], Rob Klaas

[1] TNO Building and Constructic
[2] TNO Environmental and Ener

ABSTRACT

The aim of the presented study
absorber as an air cleaner with
with different fibre lengths and
been tested as a membrane absc
nitrogen dioxide, ammonia and
filtration efficiency has been
optimal membrane module has
selected module for ETS in a te
efficiency of at least 95%. The
for hydrocarbons (as expected).
two different methods, the thre
were about 50%. Recommendati

INTRODUCTION

Environmental tobacco smoke
both in the particulate phase an
the non smoking persons may
exposure to ETS. Existing guid
to guarantee a good air quali
mechanical ventilation systems
possibility to improve the ind
recirculates the air through a filt
Existing air cleaners contain
sometimes also a charcoal filte
gaseous components generated b

The gas absorption membrane
contactors. (1) A membrane is
Gaseous pollutants diffuse thro
surface area between gas an
independent of the gas and t
determined by the absorbent.
physical partition or by a chem
modules (Figure 1) it is possi
majority of absorbents used in
membrane absorbers. A membr
use of hollow membrane mod

METHODS

Strict requirements have been set on the particulate filters installed in the ventilation systems used in work premises. Employing fine filters of a class as high as F85 (EU7) is becoming increasingly common. Field tests on six class F85 fine filters (in which the filter medium consists of micro glass fibre) have been carried out in this study, with the aim of determining how well the filters maintain their collecting efficiency during their useful life. Until now, the useful life of particulate filters has usually been determined by the permissible increase in pressure drop, but due to the fact that particulate filters may give rise to odour problems after a long period of service (1), it may be justifiable to change particulate filters after they have been coated with a fairly moderate dust deposit. The status of these particular filters was examined after a maximum of 2500 hours of effective operating time. All premises in which the filters were tested can be described as work premises located in an urban environment.

The ability of particulate filters to collect particulate PAH was the subject of a separate study, in which fine filters of different classes and operating at different dust load were studied. In all cases, these tests were carried out in buildings located in central Stockholm.

The studied gas phase filters were adsorption filters using activated carbon as the adsorption agent. In buildings located close to streets carrying heavy traffic, filters of this type can be used for direct cleaning of the outdoor air supplied to the building, although they can also be used for cleaning the recirculated air (2), e.g. in cases when the outdoor air flow rate is reduced because the outdoor air is temporarily seriously polluted.

During the laboratory investigation, four different filter media were tested, particularly in regard to efficiency, pressure drop and scope available for regeneration. In one of these filter media, the activated carbon is in the form of small balls secured to a polyurethane foam bed, whereas in the other three, the activated carbon is in granular form. Toluene in a concentration range of 1-10 ppm was used for determining the collecting efficiency. Certain tests were also carried out with m-xylene and benzene within the same concentration range. The first filter medium, i.e. that of foam bed type, was also subjected to a field test in an office building in central Stockholm.

To allow for quick reduction in the outdoor air flow rate when the outdoor air pollution is temporarily high, a suitable indicator must be found for the outdoor air quality, and a suitable sensor must also be available. CO_2 has been successfully used as indicator (3) for the indoor air quality. Suitable CO_2 sensors have now also been available for a number of years.

In an urban environment, particulate polycyclic aromatic hydrocarbons (PAH) would appear to be suitable indicators for the quality of outdoor air. Moreover, the total content of particulate PAH can be measured by means of a relatively simple sensor operating on the principle of aerosol photoemission (4). Sensors of this type have been used for measurements in a number of major cities in Sweden in an earlier study (5). In particular, the correlation between PAH concentration and the concentration of CO has been studied in the vicinity of streets carrying heavy traffic.

RESULTS

The experimental programme carried out on particulate filters and gas adsorption filters has provided valuable information concerning the opportunities available for improving the indoor air quality in buildings located close to streets carrying intensive traffic. The results are here reported separately for the various filter types.In addition, calculations were made of pollutant concentrations in indoor air in conjunction with a brief increase in the concentrations outdoors.

Tests on particulate filters

Field tests on the six class F85 fine filters were concluded using the collecting efficiencies of the filters measured in a filter test rig (built in accordance with ASHRAE Standard 52-76). In these tests, an optical particle counter was used for measuring the content of atmospheric dust upstream and downstream of the filters.The measured collecting efficiency for five different particle size intervals is shown in Figure 1 as a function of the effective operating time of the filter.

As shown in Figure 1, all filters have a collecting efficiency of 85-95% for particles larger than 1.0 micrometre. Moreover, in the various particle size intervals, the collecting efficiency appears to be largely constant during the relevant operating times. It should be noted that one of the filters, i.e. that with an operating time of 1400 h, is a "short filter" (400 mm deep), whereas the other filters are 600 mm deep and thus have a larger total filter area. Judging by the results, the filter area does not appear to have any influence on the collecting efficiency within the relatively short operating times involved here.

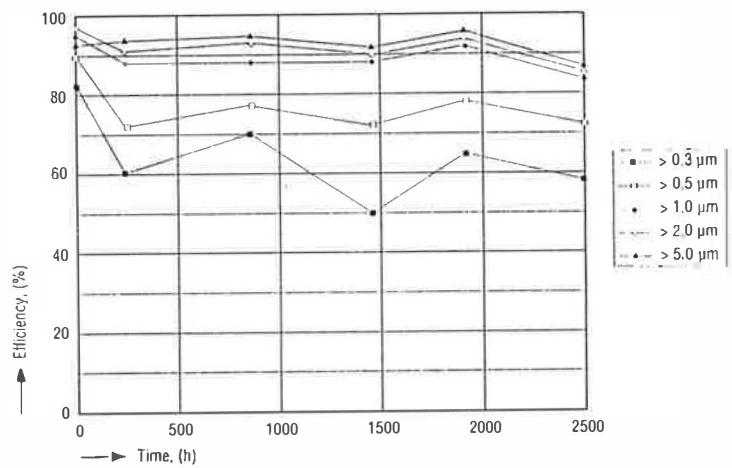

Fig. 1. Collecting efficiency of class F85 fine filters as a function of the effective operating time (from measurements of atmospheric dust).

In conjunction with the field test on fine filters in central Stockholm, the collecting efficiencies of the filters for particulate PAH were also studied. The results show, for instance, that a brand-new F85 filter has a collecting efficiency of around 75 % for particulate PAH, whereas a filter of the same class has a collecting efficiency of more than 85 % after an operating time of 1 year. An earlier field study (5) also demonstrated that the collecting efficiency of a fine filter varies with the thickness of the dust deposit.

Tests on gas adsorption filters

Out of the filter media tested, that of the foam bed type displays the highest adsorption capacity, while also causing a relatively low pressure drop. Tests on such a filter with a thickness of 60 mm, for instance, showed that the pressure drop was only around 90 Pa at an air velocity of 0.8 m/s through the filter medium. (Filter media of this particular type are normally arranged in a V form in order to reduce the air velocity through the medium. In a typical case, a velocity of 0.8 m/s through the filter medium corresponds to a face velocity of approx. 3 m/s.)

The measured adsorption capacity of a foam bed filter with a thickness of 60 mm is shown in Figure 2. The adsorption capacity, stated as filter efficiency, is shown here as a function of the test duration for the case in which the toluene concentration upstream of the test filter was 2.5 ppm. The test was carried out at an air velocity of 0.8 m/s through the filter medium, which corresponds to a contact time of 75 ms.

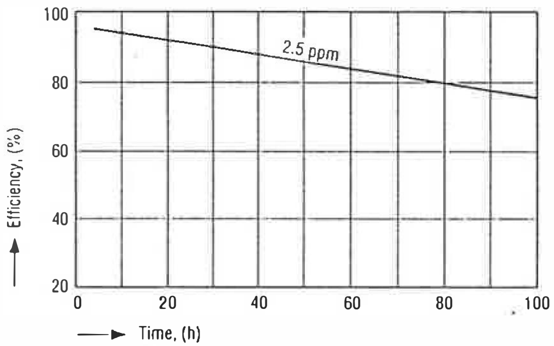

Fig. 2. Efficiency of an activated carbon filter of foam bed type as a function of time at a toluene concentration of 2.5 ppm and an air velocity of 0.8 m/s. The thickness of the filter medium is 60 mm.

When carrying out tests on carbon filters, it is usual to specify the adsorption capacity of the filter, i.e. the maximum weight of a certain hydrocarbon that can be adsorbed per unit weight of activated carbon at a given concentration level and temperature. Tests using m-xylene, toluene and benzene at an air velocity of 0.8 m/s, a temperature of 20°C, and a concentration of 4 ppm showed that the adsorption capacities for these substances were in the ratio of 1:0.80:0.19 for a foam bed filter with a thickness of 40 mm. As expected, the adsorption capacity thus declines with the molecular weight and the boiling point.

Long-term tests on a foam bed filter (with a thickness of 40 mm) in an office building in central Stockholm demonstrated that carbon filters can maintain a high efficiency over a long period of time, if the hydrocarbon concentrations amount to only a few ppb. For several hydrocarbons with concentrations in the range of 1-10 ppb, the efficiency of the

filter is more than 70 %, even after eight months of operation. Favourable experiences from several years of operation of carbon filters have also been reported in the past, with hydrocarbon concentrations in the ppb range (6).

Control of outdoor air flow rate

In order to assess the benefits of reducing the outdoor air flow rate in conjunction with temporarily impaired air quality outdoors, the pollutant concentrations indoors under various conditions have been calculated, principally concerning work premises. Depending on the nature of the pollutant, both peak values and mean values (dose values) may be of interest in this case.Moreover, depending on the design of the ventilation system, a reduction in the outdoor air flow may involve either an increase in the rate of recirculated air flow and a constant supply air flow, or a direct reduction also of the supply air flow rate.

How quickly an increased pollutant concentration outdoors will result in a higher concentration indoors depends on the nominal time constant (T) of the ventilation system, i.e. the ratio of the volume of the building (premises) to the total air flow. As an example, assuming that the work premises in the building are supplied with air at a rate of 10 l/s per person which, in a typical case, gives T = 40 min (if every person is assumed to occupy a floor area of 10 m^2 with a height of 2.4 m). In the calculations presented below, it is assumed that the total occupancy time in the building (t_0) is 9 h and that the concentration increase in the outdoor air can be described as a square-wave pulse of duration t_1 and with an amplitude C_1, while the concentration in the outdoor air is C_0 during the rest of the working day. In addition, it is assumed that the pollutant involved is not collected in the filters of the ventilation system.

Assuming complete mixing of the air in the various work premises in the building, it will be found that a very brief increase in the concentration outdoors ($t_1 << T$) will give a maximum indoor concentration increase of only C_1 t_1/T. If the concentration increase outdoors is of long duration in relation to time constant T, the pollutant concentration indoors will eventually be the same as that outdoors. However, for many pollutants, the total dose during the working day should be of greater importance than individual peak values.

Table 1 shows a calculation of the dose increase D_1 occurring after a temporary increase in the outdoor pollutant concentration (of duration t_1 and amplitude C_1).This dose increase is compared with the dose D_0 occurring at a constant outdoor concentration C_0 throughout the working day. The temporary increase is assumed to occur at the beginning of the working day. Table 1 shows that a pulse with an amplitude of 10 C_0 and a duration of 30 min will produce a dose increase of 0.56 D_0 under the specified conditions.

DISCUSSION

The tests carried out on particulate filters and gas adsorption filters show that outdoor air can now be effectively cleaned to remove both particulates and hygienically hazardous gases, including a large number of hydrocarbons. For both types of filters, it should be possible to achieve operating times of 6 months or more,with unimpaired collecting efficiency and acceptable pressure drops. However, there are still no suitable methods available for determining when a gas adsorption filter should be changed.