The Real Life Efficiency of Gas Phase Filters Used in General Ventilation and their Influence on the Indoor Air Quality of an Office Building

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ABSTRACT

Gas phase filters have been installed within the air handling unit of an HVAC system feeding 100 % fresh (outdoor) air to an office building. The filters efficiency for ozone (O_3) and nitrogen oxides (NO_2 and NO) has been measured continuously over a one year period as function of time and outdoor air parameters (temperature, relative humidity). The results show that the filters efficiency varies along time and depends on temperature and relative humidity of air. It has also been shown that the use of this kind of filters improves the indoor air quality as the indoor / outdoor concentration ratio is lower with the use of the gas phase filters than without.

KEYWORDS

Gas phase filters, real life efficiency, ozone, nitrogen oxides, indoor air quality.

INTRODUCTION

In urban cities, there are a lot of pollutants amongst which ozone (O_3) and nitrogen oxides (NO_2 and NO) which penetrate indoors through the mechanical ventilation systems. There are health risks of breathing ozone and nitrogen oxides and these chemicals can react with other indoor pollutants to produce compounds that can affect health and comfort. General ventilation filters exist on the market for the gas phase removal but there are very few publications reporting on the real life performances of this kind of filters. The aim of our work was to study (for one year) the real life efficiency for O_3, NO_2 and NO of gas phase filters installed within an air handling unit of an HVAC system feeding 100 % fresh (outdoor) air to an office building and to assess their impact on the indoor air quality of the building.

LITTERATURE REVIEW

The results published by Shair (1981) have shown the (positive) influence of gas phase filters (protected by prefilters) on the indoor ozone concentration (less than 0.2 times the outdoor concentration) after 1, 2 and 3 years of use (the air handling unit was running only when the outdoor ozone concentration exceeded 0.2 ppm, mainly in summer time) but this influence was not correlated with any of the parameters of

the air (temperature, relative humidity, etc.). Gas phase filters (protected by coarse and fine filters) installed in three separate air handling units have been studied by Weschler, Shields and Naik (1999) concerning their ability to remove ozone after extensive use. For the first air handling unit, it has decreased by only 5 % after 5 years of use (95 to 90 %) while the decreasing of filters efficiency is by 25 % for the second air handling unit after 3 years of use (85 to 60 %, same efficiency after 8 years of use) and also by 25 % for the third air handling unit (95 to 70 % after 7 years of use, the efficiency was unchanged during the first 3 years). The authors report that the efficiency may sometimes decrease for a short period and they explain this by an increase of the relative humidity of (outdoor) air (this parameter was not measured). Other interesting results have been published by Partti-Pellinen et al (2000). These authors have studied the effect of ventilation and air filtration on indoor air quality in a children's day care centre: nitrogen oxides readily penetrate indoors without gas phase filters while 50 to 70 % of them could be removed with the use of gas phase filters (carbon and aluminium oxide saturated with potassium permanganate).

METHOD

The gas phase filters were studied when installed in an air handling unit providing 100 % fresh (outdoor) air to an office building located in Lyon (France). The air handling unit is located on the roof of the building, 9th floor, and air is distributed to the offices through ceiling air diffusers. Air exhausts also on the ceiling are connected to an other air handling unit. Four full size and two half size gas phase filters (26 kg including 12.5 kg of activated carbon per filter, provided by France Air) were installed in parallel and were each protected by pleated F6 (EN 779) prefilters (glass fiber medium, provided by Camfil Farr) installed just upstream (Figure 1). Activated carbon is coconut base made and 95 % in mass of the grains have a diameter greater than 2.5 mm. Specific surface of the activated carbon is 800 m²/g. The air handling unit is continuously running 5 days a week (Monday to Friday) from 6:00 am to 8:00 pm. O_3, NO_2 and NO gas concentration measurements are carried out just upstream of the filters (outdoor air), just downstream of the filters (supplied air) and on the exhaust air duct (indoor air). These measurement are operated with automatic specific analyzers (UV absorption analysis for O_3 and chemiluminescence for NO_2 and NO). The filtration efficiency is calculated from the results of the gas concentrations measured upstream and downstream of the filters. Temperature and relative humidity of air are also measured upstream of the filters. These measurements are done each month during a one week period. Gas analyzers are connected to sample lines and electric valves which allow alternated sampling between the 3 measurement points. Data are collected by an acquisition system connected to a computer. The air flow rate of the air handling unit is calculated from the air velocity profile in the duct measured with an anemometer. For comparison purpose, measurements have been done during a one week period just before the prefilters and the gas phase filters have been installed (June 3, 2005).

RESULTS

Results of the air flow rate measurements are reported in Figure 2. Air flow rate has remained more or less constant during 3 months then began to decrease as the

filters became loaded by particles (both type of filters) and gases (gas phase filters). The air flow rate has increased after the prefilters have been changed.

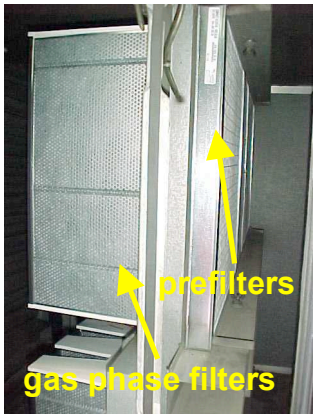

Figure 1: Filters within the air handling unit.

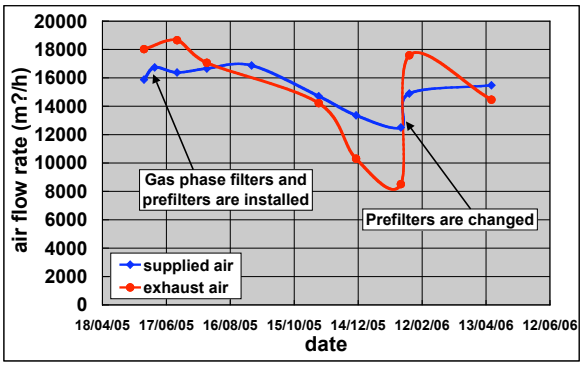

Figure 2: Air flow rate of the air handling units.

Figures 3 to 8 show gas concentration results for O_3, NO_2 and NO before (the air handling unit was at that time equipped with G4 and F6 particulate air filters in series) and after the new filters (prefilters and gas phase filters) have been installed. Outdoor O_3 concentration values show typical trend for summer time with a continuous increase from the beginning to the middle of the day. Before the installation of the gas phase filters, the efficiency of the filters was equal to zero as the O_3 concentration downstream of the filters is the same than upstream (Figure 3). The O_3 concentration is lower indoors than outdoors but the trend indoors (increase or decrease) is the same than outdoors. O_3 does not disappear indoors but reacts with material surfaces and other chemicals. The efficiency of the gas phase filters is evident as the concentration is lower downstream than upstream (Figure 4). For NO_2 and NO, the maximum of the outdoor concentration is generally obtained twice a day during automotive traffic peaks, first early in the morning and then at the end of the afternoon (Figures 5 to 8). Before the installation of the gas phase filters, the filters efficiency was equal to zero as the NO_2 and NO concentrations downstream of the filters were the same than upstream (Figures 5 and 7). NO_2 and NO penetrate readily indoors and this is done with a short time delay. For NO_2, the efficiency of the gas phase filters is evident as the concentration is lower downstream than upstream (Figure 6). The gas phase filters are ineffective to remove NO and the concentration is sometimes higher downstream than upstream (Figure 8).

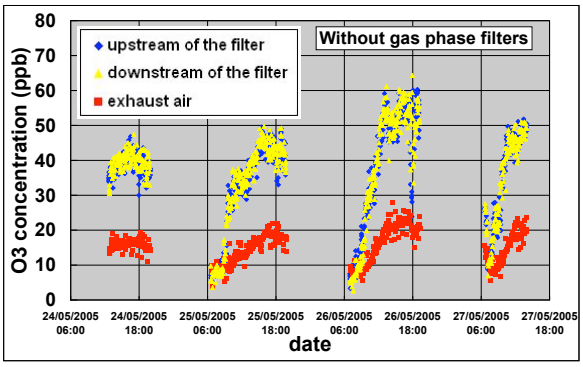

Figure 3: O_3 concentrations.

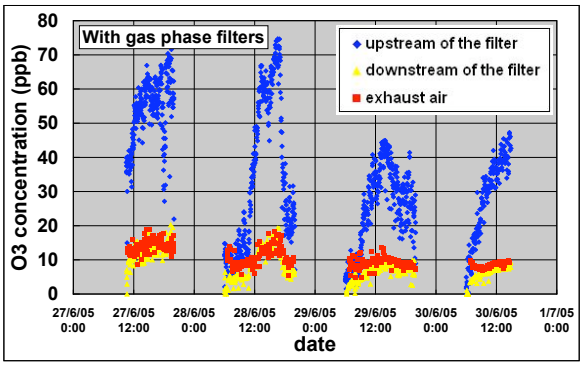

Figure 4: O_3 concentrations.

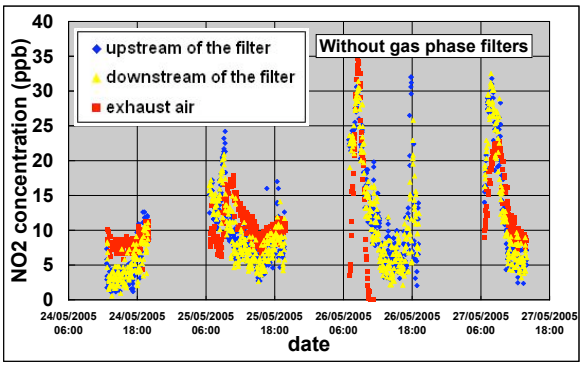

Figure 5: NO_2 concentrations.

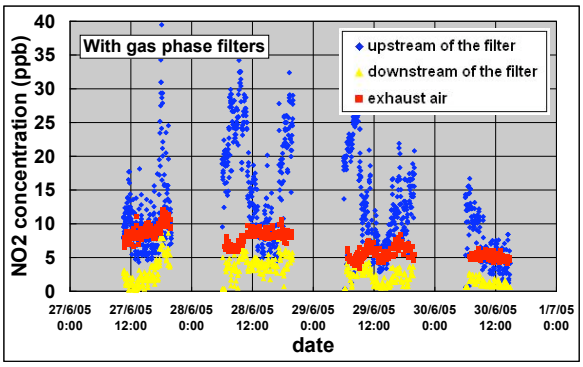

Figure 6: NO_2 concentrations.

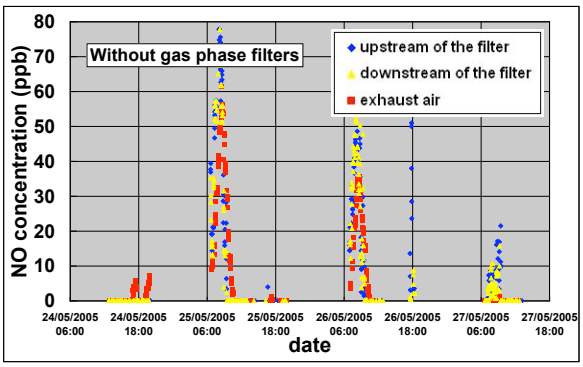

Figure 7: NO concentrations.

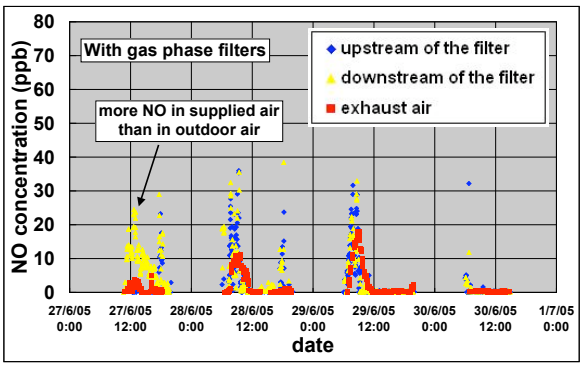

Figure 8: NO concentrations.

The climatic conditions (outdoor air) encountered during the measurements, whose results are presented later in the text (examples), are shown in Figures 9 and 10.

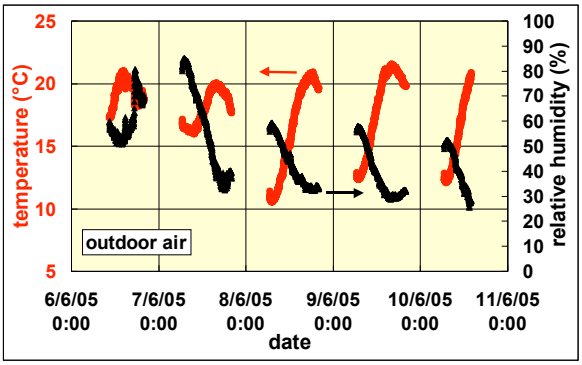

Figure 9: Climatic conditions (June 2005).

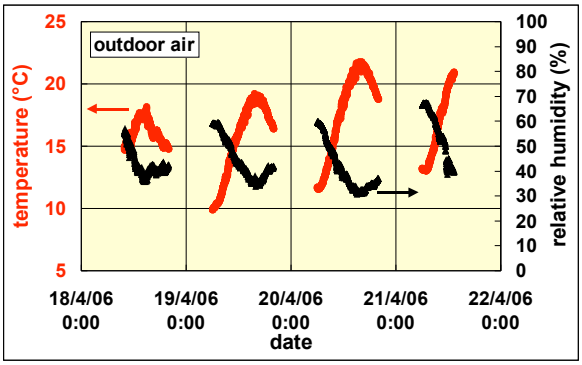

Figure 10: Climatic conditions (April 2006).

For O_3, the initial efficiency of the filters (June 2005) is about 60 to 80 % (Figure 11) and appears lower 10 months later (Figure 12). The efficiency was lower during winter time (results are not presented here). The efficiency increases as the air temperature increases (Figure 13) when the relative humidity is constant, which means that the main removal mechanism for ozone is chemical reaction. When the air temperature is constant, the efficiency of the filters remains constant as the

relative humidity increases (up to around 70 %) then decreases (Figure 14). In this case, O_3 would probably not be able to react with molecular compounds which cannot be adsorbed onto the activated carbon. For NO_2, the initial efficiency of the filters (June 2005) is about 60 to 90 % (Figure 15) and appears lower 10 months later (Figure 16). There is no clear relationship between the filtration efficiency and the climatic conditions.

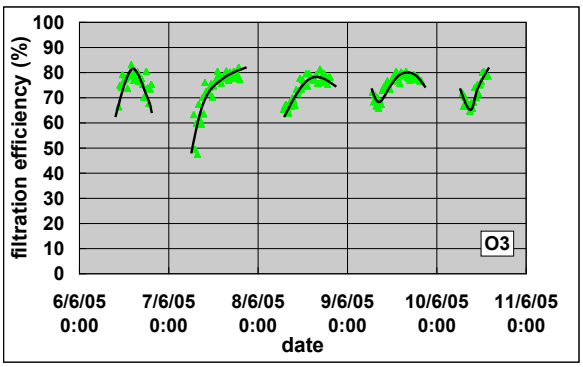

Figure 11: Filtration efficiency (O_3).

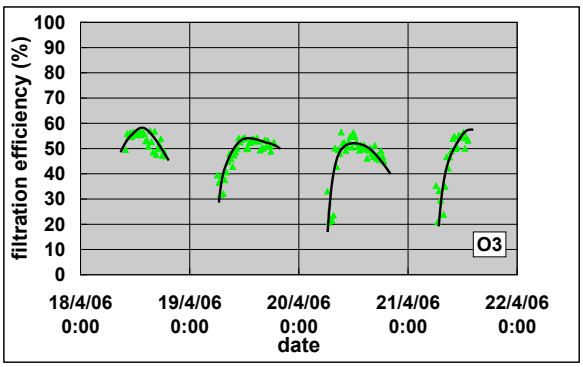

Figure 12: Filtration efficiency (O_3).

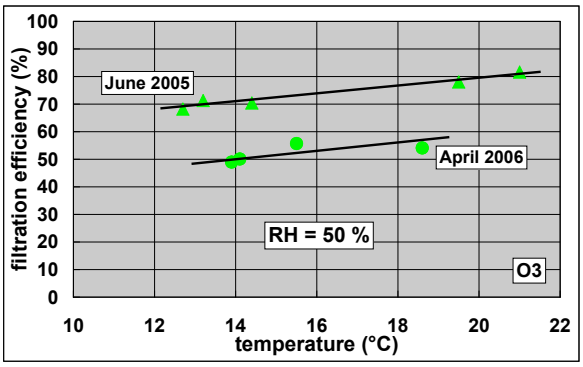

Figure 13: Filtration efficiency (O_3).

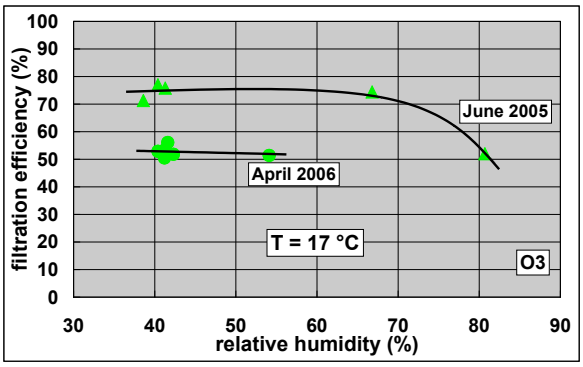

Figure 14: Filtration efficiency (O_3).

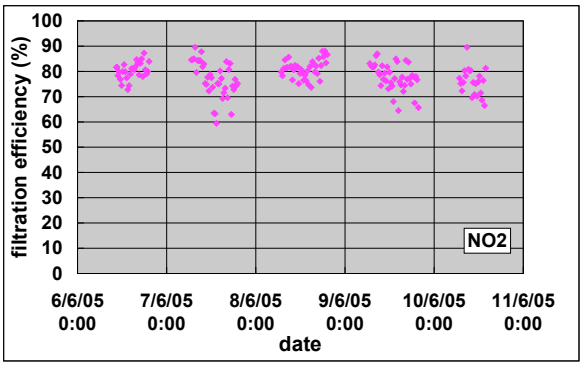

Figure 15: Filtration efficiency (NO_2).

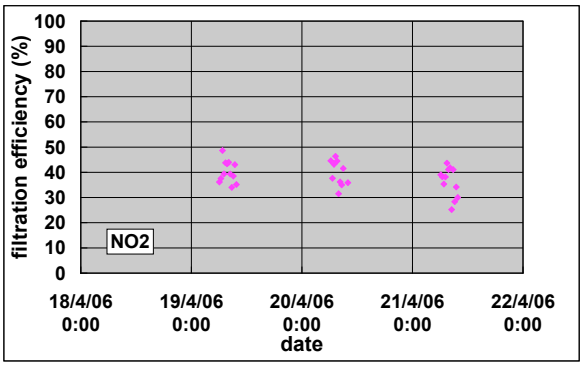

Figure 16: Filtration efficiency (NO_2).

The results presented in Figures 17 and 18 show that the indoor / outdoor concentration ratio is lower with the use of the gas phase filters (decrease from 0.4 to 0.2 for O_3).

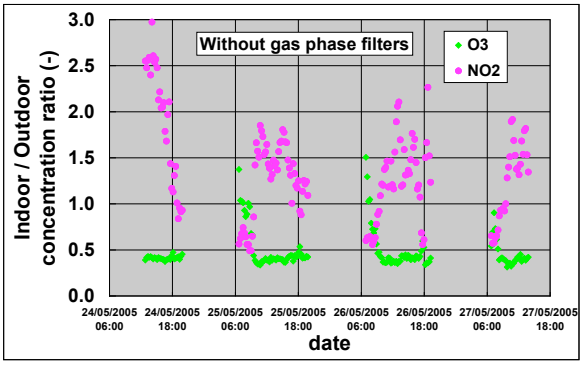

Figure 17: Indoor / outdoor concentration ratio.

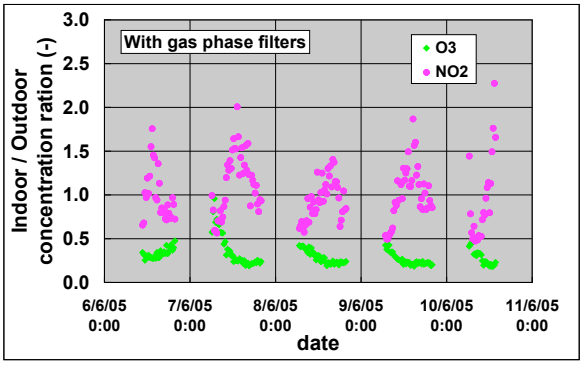

Figure 18: Indoor / outdoor concentration ratio.

CONCLUSION

Regarding O_3 the efficiency of the gas phase filters is dependent on the temperature and the relative humidity of air and has decreased by around 20 % after more than 10 months of use. For NO_2, there is no clear relationship between the filtration efficiency and the climatic conditions but the efficiency has decreased after more than 10 months of use. The gas phase filters are ineffective to remove NO and the NO concentration is sometimes higher downstream than upstream. This is not due to a desorption phenomenon as NO has not been previously adsorbed but to a chemical transformation of NO_2 into NO. Additional work is necessary in order to better understand this phenomenon and to know which parameter has an effect on it. The use of gas phase filters has a positive effect on the indoor air quality as the indoor / outdoor concentration ratio is lower with the use of the gas phase filters. The use of gas phase filters may be recommended for general ventilation applications and the method along the apparatus presented here can be use in real situation to assess the efficiency of gas phase filters.

ACKNOWLEDGMENTS

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REFERENCES

Partti-Pellinen, K., Marttila, O., Ahonen, A., Suominen, O. and Haahtela, T. (2000). Penetration of nitrogen oxides and particles from outdoor into indoor air and removal of the pollutants through filtration of incoming air. *Indoor Air*, **10**, 126-132.

Shair, F.H. (1981) Relating indoor pollutant concentrations of ozone and sulfur dioxide to those outside : economic reduction of indoor ozone through selective filtration of the make-up air. *ASHRAE Transactions*, **Part 1**, 116-139.

Shields, H.C., Weschler, C.J. and Naik, D. (1999). Ozone removal by charcoal filters after continuous extensive use (5 to 8 years). *The 7th International Conference on Indoor Air Quality and Climate Indoor Air'99*, Edinburgh, Scotland, 8-13 August 1999.