Removal of Indoor Ozone with Reactive Materials: Preliminary Results and Implications

Clement Cros[1], Elliott Gall[1], Jeffrey Siegel[1], Glenn Morrison[2], Richard L. Corsi[1,*]

[1]University of Texas at Austin
[2]Missouri University of Science and Technology

[*]*Corresponding email: corsi@mail.utexas.edu*

SUMMARY

Ozone is an air pollutant that not only has adverse health effects on its own, but is also a strong reactive indoor, creating even more harmful by-products, at rates that can compete with air exchanges. Hence, passively removing ozone from indoor environments, using Passive Reactive Materials (PRM), would have beneficial health effects and would conform with reductions in building energy consumption. Short-term experiments have shown that activated carbon has this ability. The current study will focus on evaluating how the ozone removal efficiencies of activated carbon mats and three green building materials vary over time in real environments. Samples of each material are placed in five fields locations in Austin, where environmental conditions are monitored. The samples ozone removal efficiencies and ozone related secondary emissions are measured monthly.

KEYWORDS

Ozone, Passive Reactive Materials, Activated Carbon, Green building materials, longevity

INTRODUCTION

Ozone has been recognized for years as a pollutant harmful to human health. Numerous studies have shown a link between exposure to ozone and decrease in lung function and asthma (U.S. EPA, 2006; Mc Donnell et al., 1999). Other studies have also shown up to a 0.87% increase in mortality per 10-ppb increase in daily ozone (Bell et al., 2005; Levy et al., 2005; Ito et al., 2005).

Weschler (2006) showed that indoor exposure to ozone can be as much as 43 to 76% of total daily ozone exposure. Moreover, indoor exposure to ozone is accompanied by exposure to the products of ozone-initiated chemistry. They generally come from reactions of ozone with organic compounds that contain unsaturated carbon=carbon double bounds. Sources of such compounds have been described by Weschler (2006), and include the following major sources: occupants themselves, soft woods, carpets, linoleum, certain paints, cleaning products, air fresheners and soiled fabrics. This creates a large amount of compounds that can potentially react with ozone at rates fast enough to compete with air exchange rates (Weschler, 2000). Those products tend to have higher concentration levels indoors than outdoors (Weschler, 2006) and often have even more adverse health effects than ozone itself (Weschler, 2004). The current push for more energy efficient buildings also increases the importance of indoor chemistry. To reduce energy consumption associated with space conditioning, more buildings are being built with tighter envelopes that reduce the number of air exchanges between indoors and outdoors. This allows reactions that were previously too slow to compete with air exchange to have an effect on indoor air quality.

Removing ozone from indoor environments could have very beneficial effects on human health and comfort, as long as such removal does not create new harmful by-products. This should be done with no or minimum energy use to conform with reductions in building energy consumption. Passive Reactive Materials (PRM), which are materials that react with ozone without creating by-products, have been previously studied during short-term experiments at the University of Texas at Austin (UT). Virgin gypsum wallboard and activated carbon mats proved to be efficient PRMs. 12% of wall surfaces covered with activated carbon mat will reduce indoor ozone concentration by 50% (Kunkel et al., 2008).

The current study will focus on evaluating how the ozone removal efficiencies of activated carbon mats and three green building materials (perlite-based ceiling tile, green paint on green gypsum wallboard, and recycled carpet tile) vary over time in real environments. This study is needed to ascertain how variations in environmental conditions, and material interactions with reactive and sorptive gases, as well as with particulate matter (soiling) affect the reactivity of, and secondary emissions of ozone reactions products, from PRMs.

METHODS

Materials

Fibrous activated carbon mat (AC) is constructed with non-woven polyester base fabric (thickness = 0.5 cm) and coated with activated carbon (Area normalized mass = 136 g/m^2). It was chosen for long-term experiments because its ozone removal capacity is large and past studies indicate little harmful by-product formation when ozone is reacted with AC (Dusenbury and Cannon, 1996). The green ceiling tiles are made of 100% recycled, non-fibrous materials, including a blend of perlite and an inorganic binder. The carpet is made of about 50% post-industrial recycled products. The paint and primer are 100% acrylic latex products marketed as having low odor and low VOC emissions. All materials were new when obtained. The gypsum wallboard sheets were painted upon arrival and aired out for a month under ambient conditions in a test house before experiments began. Other materials were stored in their original packaging under ambient conditions until the beginning of experiments. The test materials and abbreviations used are listed in Table 1.

Table 1: Test materials, designations, origin and applications

Material	Designation	Manufacturer/Model
Activated carbon mat	AC	Gremarco, Inc./CO150
Perlite-based ceiling tiles	Ceiling	Chicago Metallic/Terric
Carpet with 50% of recycled content	Carpet	InterfaceFLOR/
Green gypsum wallboard	GWB	USG Sheetrock/Synthetic from Galena
Green primer and paint		Benjamin Moore/Eco Spec Primer and Paint

Field measurements

In order to observe temporal variations in ozone removal efficiency of the tested materials in real environments, samples are placed in real homes and commercial buildings for a five month period. The ozone deposition velocity on the materials was measured in the laboratory before the materials were placed in the field. The materials are being removed from the field on a monthly basis for one day, and brought back to the laboratory for new ozone deposition velocity measurements. Following laboratory analysis the materials are returned to their initial field locations. Samples of activated carbon, ceiling tiles, carpet and painted gypsum wallboard have been placed in five different locations around Austin, Texas. Each location represents a specific type of indoor environment. Table 2 lists the different locations.

Table 2: Field locations and characteristics

#	Building type	Room type	Number of samples			
			AC	Ceiling	Carpet	GWB
1	Office building	Office	1	3	1	1
2	House	Kitchen	1	1	3	1
3	House	Entertainment room	1	1	1	3
4	House	Living room	3	1	1	1
5	Test House	Living room	3	1	1	1

Indoor environmental conditions are monitored at each test location. Continuous temperature and relative humidity (RH) measurements are taken using a HOBO U12-013 (Onset Corporation, USA). Dust samples are taken monthly using adhesive Scotch Magic tape (3M, USA) in the vicinity of the samples before they are brought back to the laboratory and analyzed by a microscope (BX40, Olympus, USA) with image processing software to characterize number of particles per area of tape (as a gross measure of dustiness near the PRM). Finally, the organic gaseous content of the air is measured using passive samplers made of a GC large volume glass liner containing Tenax-TA and placed in each location. The samples are then analyzed using a HP5890 GC/FID equipped with a 30 m long column (RESTEK, Rxi-5Sil MS, 0.25 mm ID, 0.5 μm df). See Figure 1 for a description of the passive sampler.

Figure 1: Organic gaseous compounds passive sampler

Experimental system

A diagram for the experimental system, used to measure deposition velocity of ozone on the selected materials, is provided in Figure 2. Three identical 48-L electro-polished stainless steel chambers (dimensions: 25 cm x 38 cm x 50 cm) are used in parallel. The chambers are cleaned with deionized water and a heat gun before each experiment. Two of the three chambers contain a sample and the third acts as a control chamber. Room air is passed through a column containing 8 mesh Indicating Drierite (Drierite Company, USA) to dehumidify, through an activated carbon filter to be cleaned and then mixed with a flow of ozone produced by an ozone generator (Yanco model OL80W/FM500V). This ozonated air is passed through a bubbler before being introduced in the chambers. Relative humidity (RH) is measured at the inlet of the chambers using an RH probe (TSI, Inc., Q-Trak 8551). Mass flow controllers (Aalborg, USA) were used to maintain a constant volumetric flow rate entering each chamber. The air enters the chamber through perforated stainless steel tubes extending across the interior length of each chamber. Ozone concentrations in the inlet and exhaust streams are measured using a single UV-cell ozone monitor (model 202, 2B Technologies).

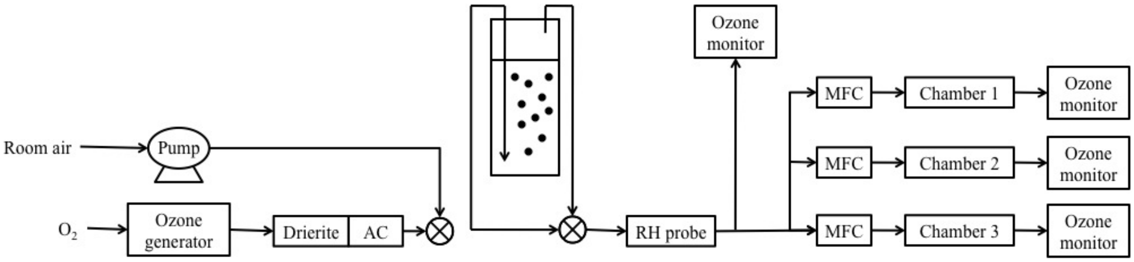

Figure 2: diagram of the experimental system

Laboratory tests are run under the following experimental conditions: 50% RH, 150 ppb inlet ozone concentration, two air exchanges per hour.

Data analysis

Chamber experiments will be used to determine the deposition velocity of ozone on the materials tested. A simple mass balance at steady-state on the chamber leads to the following expression for v_d, the deposition velocity of ozone on the material tested:

$$v_d = \frac{\lambda V}{A_s}\left(\frac{c_0}{c} - 1\right) - v_{d,w}\left(\frac{A_w}{A_s} - 1\right) \tag{1}$$

where λ is the air exchange rate of the chambers, V the volume of the chambers, A_s is the area of the sample, A_w is the total area of the chamber walls, c_0 is the inlet ozone concentration, c is the outlet ozone concentration, $v_{d,w}$ is the ozone deposition velocity on the chamber walls.

PRELIMINARY RESULTS

A complete set of results will be presented at September Healthy Buildings 2009.

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