There's Something in the Air
Indoor Air Chemistry – Creating the "Chemical Soup" of IAQ

By Jim Rosenthal and Stevan Brown

Indoor air is a complex mixture of gases and particles. What is not well understood is that many of the things used in indoor environments have the potential to create chemical reactions that can produce totally unintended and potentially harmful results.

Much research has been done recently regarding indoor air chemistry as a source of particles (Weschler, Corsi, Sarwar, Shields, Fick, EPA). As a result of this research, and previous research related to outdoor air, it has been found that ozone (O3) reacts with terpenes and several other volatile organic compounds (VOC's) to create hydroxyl radicals and numerous small particles. Terpenes are a class of chemicals found as the 'scent' in many household products such as cleaners, air fresheners, disinfectants, laundry detergents, furniture wax, etc. For example, the pine scent in many all-purpose cleaners is partially due to pinene. Citrus scents are a result of the presence of limonene. Terpenes are also emitted from natural and manufactured wood products and are generally observed at indoor levels that far exceed outdoor levels (Weschler, Corsi, Sarwar).

Studies of this chemical reaction have found that the substances created by the reaction of ozone and various terpenes include hydroxyl radicals, hydrogen peroxide, formaldehyde, other aldehydes, pinic acid, glyoxal, acetone and numerous other highly oxygenated compounds (Weschler, Shields, Fick, EPA, Yu, Koch) or as the EPA refers to it – a "chemical soup." There are studies that show many of these products can have adverse effects on the upper airways and the pulmonary regions. (Rohr, Bowler, Kreiss, Jones, Zeliger, American Lung Association, Wolkoff) They can cause skin irritation and produce inflammation. (Matura) Some are probable carcinogens in humans, eg., formaldehyde.

The vast majority of the particles created through the chemical reaction of ozone and terpenes are less than one micron in size, and represent the respirable sizes most likely to reach and be deposited in the alveoli of the lungs (ALA).

In principle all hydrocarbons in the atmosphere will eventually be oxidized and form CO2 and H2O. This process, however, is a complicated and lengthy one especially for complex terpenes. The reaction starts with the oxidation by ozone, NO3 and hydroxyl radicals and includes the formation of particles, radicals and stable products. (Weschler, Fick, Corsi). The hygroscopic secondary organic aerosols resulting from these oxidation reactions may carry other species such as hydrogen peroxide deep into the lower respiratory tract. (Friedlander and Yeh, Weschler)

"Ionizers" have become very popular in recent years and are sold on television, on the radio, by direct mail, over the Internet and in retail stores. The stated features of these devices are quiet operation, no filters to replace, low electricity consumption and "air cleaning ability." Generally, “ionizers” produce ozone as a byproduct. Would the use of an “ionizer” in a room with common household products create the ozone/terpene reactions and the resulting particles?

For our demonstrations it was assumed that increases in particle counts were from ozone/terpene reactions and other reactions as reported in earlier research studies. Demonstrations were conducted using a particle counter designed to measure all particles over 0.3 microns in size. In a typical indoor environment ambient air has about 1,500,000 particles over 0.3 microns per cubic foot. When an “ionizer” was exposed to various household products such as window cleaning fluid, lemon-scented furniture polish, pine-scented cleaner, baby wipes, baby lotion and baby bath, the particles generated over 0.3 microns exceeded 9,999,999 per cubic foot of air. Many of the compounds and particles created by the ozone/terpene reactions are highly reactive themselves and have a relatively short life. (Weschler) In addition, objects and surfaces in a room such as carpeting, furniture, wall covering, etc. can absorb and adsorb particles.(Weschler) Any overall increase in particles in the room would be the excess created over these factors.

Pine-scented cleaners contain the terpene called pinene as well as other terpenes. We used 100 ml of a pine-scented cleaner in a small bowl to create the terpene source. The two test rooms were 42 square feet (Room 1) and 120 square feet (Room 2) respectively. Particles were measured with a Met One Particle Counter calibrated to measure particles over 0.3 microns per cubic foot. The maximum number that can be recorded with this meter is 9,999,999 per cubic foot.

The ambient air in the rooms before the test had a particle count of 1,250,000 particles over 0.3 microns per cubic foot. Ozone in the rooms was negligible and registered 0.00 parts per million(this would be less than 5 parts per billion) on the ozone meter. The ozone meter we used is only capable of measuring ozone in increments of 10 parts per billion.

We placed an “ionizer” in Room 1 and switched it on. We placed a HEPA Air Purifier in Room 2 and switched it on.

After one hour the particle counts were the following:

Room 1 with the “ionizer” – 9,999,999 particles per cubic foot greater than 0.3 microns in diameter
(Ozone 20 parts per billion)
Room 2 with the HEPA Air Purifier– 237,000 particles per cubic foot greater than 0.3 microns in diameter
(Ozone – negligible)

We then placed the “ionizer” in room 2 and the HEPA Air Purifier in room 1. We did not let the rooms return to the original baseline. We simply switched the machines and turned them on. The initial particle counts in each room approximated the counts recorded in the first phase of the experiment.

After 15 minutes we measured the following particle counts.

Room 1 with the HEPA Air Purifier - 290,000 particles per cubic foot greater than 0.3 microns in diameter
(ozone 10 parts per billion)
Room 2 with the "ionizer" – 703,000 particles per cubic foot greater than 0.3 microns in diameter
(ozone 10 parts per billion)

After 15 more minutes we measured the particle counts.

Room 1 with the HEPA Air Purifier - 79,000 particles per cubic foot greater than 0.3 microns in diameter (Ozone 10 parts per billion)
Room 2 with the "ionizer" – 1,694,000 particles per cubic foot greater than 0.3 microns in diameter
(Ozone 20 parts per billion)

Room 3 is 80 square feet. Tile walls. Tile floors.

We placed an "ionizer" (with UV lamp) in Room 3 with 100 ml of pine-scented cleaner. The baseline particle count was 1,560,000 particles per cubic foot greater than 0.3 microns in diameter

After 30 minutes the particle count was 9,546,000 particles per cubic foot greater than 0.3 microns in diameter

After an additional 30 minutes the particle count was 9,999,999 particles per cubic foot greater than 0.3 microns in diameter

We placed an "ionizer" in Room 1. The baseline particle count was 1,560,000 particles per cubic foot greater than 0.3 microns in diameter. We placed 3 baby wipes (Citrus Scent) in the room.

After 30 minutes the particle count was 5,640,000 particles per cubic foot greater than 0.3 microns in diameter.

After an additional 30 minutes the particle count was 3,871,000 particles per cubic foot greater than 0.3 microns in diameter.

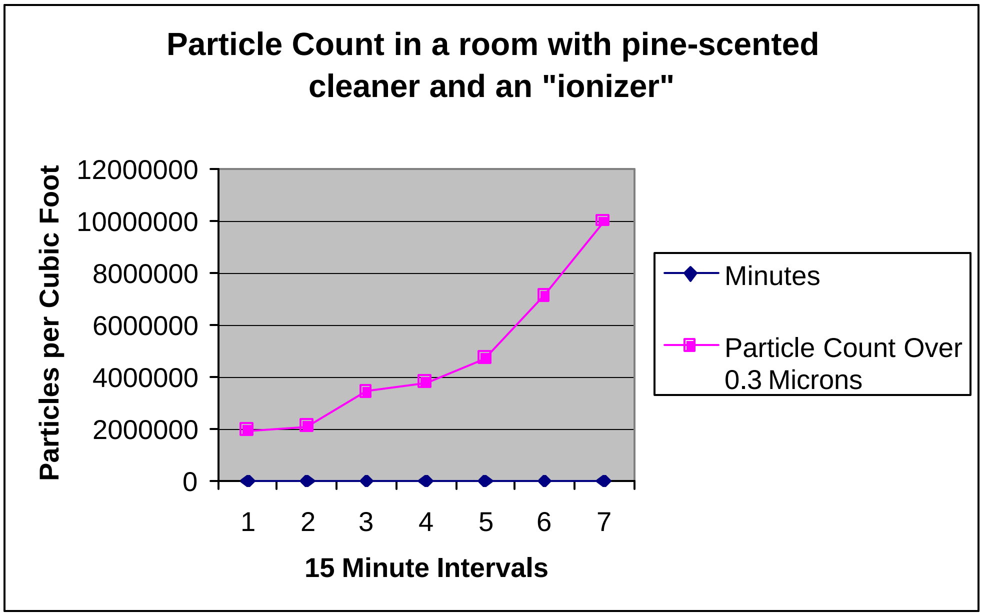
Room 4 is a small conference room of 125 square feet. Wood panel walls. Carpeting. One wood conference table and a bookshelf with books in the room.

The baseline particle count in the room was 1,964,000 particles per cubic foot greater than 0.3 microns in diameter. Temperature – 73% F. Humidity – 61%. Ozone in the room before the start of the test – 20 parts per billion.

We first added a bowl of 100ml of pine-scented cleaner to the room. After 15 minutes the particle count in the room was 2,101,000 particles per cubic foot greater than 0.3 microns in diameter.

We then turned on the "ionizer" and recorded the particle counts every 15 minutes. Results are listed in the table below.

Minutes	Particle Count Over 0.3 Microns per Cubic Foot	
15	1964000	Ambient Air
30	2101000	With pine-scented cleaner Only
45	3460000	“ionizer” On
60	3815000	“ionizer” On
75	4711000	“ionizer” On
90	7140000	“ionizer” On
115	9999999	“ionizer” On



Note: At the termination of the experiment conditions in the room were the following. Temperature - 73%. Humidity – 61%. Ozone – less than 20 parts per billion.

After the experiment we turned off the “ionizer” and left the bowl of pine-scented cleaner in the room. Within one hour the particle count was less than 2,000,000 particles per cubic foot greater than 0.3 microns in diameter (1,870,000).

Room 4 – The 4 foot by 6 foot wooden conference table was waxed with lemon-scented furniture polish. We placed an “ionizer” (with UV lamp) in the room and turned it on. The particle counts were the following.

Baseline –	1,560,000 particles per cubic foot greater than 0.3 microns in diameter
After 30 minutes -	3,046,000 particles per cubic foot greater than 0.3 microns in diameter
After 60 minutes -	2,100,000 particles per cubic foot greater than 0.3 microns in diameter

In this case and in the demonstrations using baby wipes, the decrease in particles from the 30 minute reading to the 60 minute reading was likely due to the decrease in the terpene emission rate, and hence terpene levels in the room air over time.

In these demonstrations it was shown that when "ionizers" were exposed to common household products such as cleaners, furniture polish and baby wipes, particle counts in the rooms substantially increased. Particle counts in the test rooms often exceeded the maximum on our meter and registered 9,999,999 particles per cubic foot greater than 0.3 microns in diameter. To put this in some perspective, on a red alert ozone day in a location just 600 feet away from a major highway (with traffic counts of over 270,000 vehicles a day) the highest particle count we have ever recorded is 6,600,000 particles per cubic foot greater than 0.3 microns in diameter.

These particles are highly reactive and are breathed deep into the lungs. Studies have shown that sub-micron particles may have adverse effects on the respiratory system and may cause other health problems.

These demonstrations also illustrate the complexity of indoor air. A "clean, fresh smell" may just be another source of indoor air pollution. The use of "ionizers" and other products such as ozone generators and UV lamps that produce ozone either intentionally or as a by-product has to be questioned. Ozone is a highly reactive compound. As we have seen, it reacts readily with terpenes. It has also been shown to react with other VOC's (Weschler). It is unknown what types of potentially troubling reactions are taking place with ozone and the multitude of chemicals in something like cigarette smoke. Even in relatively small amounts (less than current FDA standards) ozone can significantly alter the composition of indoor air with unexpected and potentially damaging results.

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