

Indoor Air Quality Update[®]

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Report: Ozone Generators Not Effective, Pose Added Health Risk

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Despite voluminous adverse research results, ozone generators keep reappearing as the "solution" to indoor air problems, with their proponents claiming they do things as simple as "remove odors" or as complex as destroying the contaminants in an occupied space.

A new research report from a scientist at the US National Institute of Occupational Safety and Health (NIOSH) concludes that ozone generators are neither practical nor effective in improving indoor air quality. The report also examines potential adverse health effects and concludes that this danger justifies concern over the generators' use in occupied environments.

Mark E. Boeniger, who works in NIOSH's Industrywide Studies Branch (Cincinnati, Ohio) compiled the report and published his results in the *American Industrial Hygiene Journal* in June (1995; 56:590-598).

Among the major conclusions:

- Ozone is a potential health hazard;
- Some units can control ozone emission rates, but not concentrations;
- Odor masking may come from olfactory fatigue or from ozone overwhelming the existing odor; and
- At safe concentrations, ozone can't eliminate the most common indoor air contaminants.

IAQU has noticed a recent increase in advertising for ozone generators and has received inquiries from many people about ozone's safety and efficacy. Those marketing the units recommend them for applications including homes, schools, offices, stores, nail and beauty salons, and funeral homes.

The advocates of using ozone technology to eliminate air contaminants claim that the ozone molecule, with three oxygen atoms, oxidizes or-

ganic compounds while producing only water vapor and carbon dioxide.

Health Effects

While many researchers have studied ozone's toxicity, most studies have focused on short-term exposure, around one day. Above 120 parts per billion (ppb), humans will experience eye irritation, visual disturbances, headaches, dizziness, dryness in the mouth and throat, chest tightness, and coughing.

At lower levels — 60-120 ppb, which are more likely to occur in indoor spaces — ozone can bring about diminished lung function, cough, inflammation associated with biochemical changes, and increased responsiveness to allergens. However, individual responses vary.

Boeniger reports that exposure at this level raises concerns over susceptibility to infections and impaired clearance of inhaled particles. Also, simultaneous exposure to ozone and other compounds can produce additive or synergistic effects.

Some humans exhibit increased ozone tolerance with repeated exposure. Boeniger hypothesizes that this results from damaged irritant receptor cells. Animal studies indicate that chronic exposure can cause permanent damage, despite the short-term tolerance. Some animals, after chronic exposure, have developed increased lung disease.

Epidemiological studies of humans chronically exposed to high levels of environmental ozone have shown lung deficiencies consistent with the animal data.

Odor Detection

The odor threshold for ozone differs widely among people, with the detectable levels ranging from 2 ppb to 100 ppb. For most people who go from an uncontaminated to a contaminated space, the detection level ranges around 10-15 ppb.

Olfactory fatigue differs with various ozone levels. Research has shown that olfactory fatigue occurs in an average of 5 minutes at 20 ppb; 13 minutes at 50 ppb; and 22 minutes at 110 ppb. From this Boeniger concludes that the olfactory sense may not necessarily warn of elevated ozone levels during continuous exposure.

Contaminant Removal

Some proponents of ozone generators claim that ozone reacts with and eliminates numerous contaminants in indoor air. While studies have indeed shown reactions with contaminants, whether that reaction purifies the air is another matter. This stems from two concerns: whether the reaction occurs quickly enough at expected concentrations to be effective and whether the ozone-contaminant reaction produces other, potentially irritating compounds.

Boeniger explains that the rate of reaction between ozone and any concentration of an organic substance is a function of the ozone concentration and is independent of the contaminant concentration. Therefore, when the ozone concentration is 50 ppb, it will take twice as long for the reaction to occur than when it is 100 ppb. Table 1 shows the calculated half-life of various indoor air pollutants at 100 ppb.

The only compound listed for which the half-life is on the order of hours instead of years is styrene, an alkene compound. Among the 68 most common indoor air contaminants, only 6 are in the alkene class.

Studies by Charles Weschler *et al.*, previously reported in *IAQU* (January 1993), found that while some contaminant concentrations declined in the presence of ozone, other contaminants increased — and some new compounds became

Table 1 — Estimated Half-Life of IAQ Contaminants

Compound	Half life at 100 ppb O ₃
n-Hexane	>880 years
n-Heptane	>880 years
Cyclohexane	>880 years
Methylcyclohexane	>880 years
Toluene	>0.9 years
m,p-Xylene	>9 years
Trichloroethylene	0.9 years
1,1,1-Trichloroethylene	>880 years
Tetrachloroethylene	880 years
Isobutanol	>0.9 years
Formaldehyde	>4,400 years
Acetaldehyde	>0.9 years
n-Hexanal	>9 years
Styrene	3.9 hours

Source: Mark Boeniger

evident. These most notably included formaldehyde and the C₅-C₁₀ aldehydes.

Thus, introducing ozone in these chamber studies reduced some organic irritants but created new compounds. As a result of this study, the researchers warned that ozone might react with the alkene compounds in such commonly encountered products as detergents, waxes, cleaners, and scented "room fresheners," and might produce other unwanted contaminants.

Odor Control

Some people report that ozone controls odors within a space — thus, their popularity in nail and beauty salons and some other retail establishments. However, Boeniger's literature search discovered that researchers have failed to find that this odor control results from destroying the contaminants.

Instead, it seems that for ozone to work in this way, it must overpower other smells in the space. The subjects usually will detect whichever odor is stronger. If the ozone is strong enough to mask the other odors, occupants won't smell the offending odor. However, once the ozone degrades, which is quickly, the original odor becomes noticeable again.

Boeniger cautions that because of olfactory fatigue and the fact that most ozone-generating

air purifiers lack controls for monitoring or regulating the concentration in a space, changing ambient conditions create the possibility of unacceptably high ozone levels in a space.

Conclusion

Citing numerous authorities who have cautioned against using ozone generators as air purifiers in occupied spaces, Boeniger suggests the more commonly accepted IAQ strategies of source control and dilution ventilation to deal with both contaminants and odors. Boeniger notes that his report specifically doesn't deal with such issues as using ozone in controlling microbiological growth and removing odors from surfaces, such as after a fire.

He concludes: "Introducing ozone in indoor air may present a risk to human health, especially if it is present with other air contaminants.... There is a lack of evidence in the scientific literature that would support ozone as effective at low concentrations to remove organic contaminants from indoor air."

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TOOLS & TECHNIQUES

Photocatalyst for VOCs May Be Close to Market, Developer Says

An affordable photocatalytic reactor, capable of destroying volatile organic compounds (VOCs) in indoor air, may be available next year, according to the president of a firm specializing in the technology.

Ephraim Heller, president of LightStream Photocatalytic LLC (Alameda, California), told *IAQ* that his firm, which recently received a US \$2-million government grant, plans to market its first such reactor to deal with formaldehyde. Later models will be effective against a broad range of VOCs in the indoor environment.

Heller said current plans call for models suitable for commercial nonindustrial and residential applications. Photocatalysis, according to Heller, will prove a cost-effective way to destroy indoor air pollutants rather than diluting them with in-

creased outdoor air. The photocatalytic approach should lower heating and cooling costs.

Photocatalysis relies on combining ultraviolet (UV) light and a catalytic surface. The catalytic surface — usually a semiconductor such as titanium dioxide (TiO₂) — absorbs UV light photons that create electron-hole pairs on the surface.

The electrons and holes initiate oxidation and reduction reactions that can completely convert organic pollutants to carbon dioxide (CO₂) and water. Heller said. The net reaction is equivalent to burning the pollutants at room temperature."