Air Pure

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1. INTRODUCTION

The idea of using ozone to remove indoor air contaminants was originally conceived more than 100 years ago. Today, ozone-generating air purifiers can be found in millions of homes, restaurants, bars, schools, and offices. Nevertheless, opinions about the efficacy and safety of ozone generators vary within the indoor environment field. Sometimes touted as the most natural and efficient method available for removing odours and contaminants and sometimes challenged as unsafe and ineffective, ozone has stirred up controversy among scientists and consumers [1] (level 9).

2. OBJECTIVE

This review is to determine the safety and effectiveness of ozone generating air cleaning devices.

3. TECHNICAL FEATURES

Some air cleaners (called ozone generators) use an electrical charge to generate ozone [2] (level 9). Ozone-generating devices are being marketed to the public as a solution to indoor quality problems. Ozone generators are available in three forms: in-duct units for central air systems, portable indoor units, and personal units that are worn on the body. They are promoted as effective "air purifiers," especially to people sensitive to indoor air pollutants [3, 4] (level 9). Manufacturers often refer to the ozone as activated oxygen, trivalent oxygen or nature’s air purifier to suggest that it is safe [4] (level 8). There are many brands and models of ozone generators on the market. They vary in the amount of ozone they can produce. In many circumstances, the use of an ozone generator may not result in ozone concentrations that exceed public health standards. But many factors affect the indoor concentration of ozone so that under some conditions ozone concentrations may exceed public health standards [5] (level 8).

4. METHODOLOGY

Search engines such as PUBMED, EBSCO, Proquest, Medline and Google were used using the following keywords; “air cleaner”, “ozone generator”, “ozone-generating devices”, “indoor air quality” and “ozone generator sold as air cleaner”. Cross references were also carried out on the article retrieved

5. RESULTS AND DISCUSSION

5.1 Safety

In the United States, strict health standards have been set to limit human exposure to ozone. The FDA has set limits of 0.05 part per million (ppm) of ozone for indoor air. The Occupational Safety and Health Administration require that workers should not be exposed to an average concentration of more than 0.10 ppm for 8 hours. The National Institute of Occupational Safety and Health recommends that the upper limit of 0.10 ppm not to be exceeded at any time, while the US Environment Protection Agency recommends that the national ambient air quality standard for ozone is 0.08 ppm for a maximum of 8 hours as average outdoor concentration [5] (level 8). These exposure limits are summarized in Table 1.

As part of the atmosphere we breathe, ozone is a potent lung irritant. It can have damaging health effects [2] (level 9). Exposures to ozone concentrations can cause various health effects [4, 6, 7, 8, 9] (level 8). Moderate levels can irritate the eyes, nose, throat, and lungs; low-level exposures have been shown to cause significant temporary decrease in lung capacity in healthy, exercising adults. Some asthmatic individuals are especially susceptible to ozone toxicity, which includes constricting airways; short-term exposures can cause increased sensitivity to airborne allergens and other irritants, and it can impair the body's immune system. Summertime ozone episodes in the north eastern U.S. lead to 10-20% increases in hospital admissions and emergency room visits. Human population studies of long-term exposures to low-level ozone indicate that it may lead to permanent reduction in lung capacity. Animal studies have shown that chronic high-level exposures can cause lasting structural damage in the lungs. Children, especially asthmatics, are most at risk from exposure to ozone.

An even greater concern about the use of ozone generators is that they can readily produce unsafe ozone levels in the rooms where they are used. Numerous studies on commercial and residential units have found that the devices produce room concentrations far in excess of the FDA outdoor air standards for workers. While most units on the market can produce dangerous levels of ozone, few include controllers to prevent ozone levels from exceeding safe limits. Some new models have "ozone sensors," but their effectiveness has not been independently evaluated. Ozone gas initially produces a sharp odour. However, it dulls the sense of smell after a brief period of continuous use. Hence, perceived odour is not a reliable indicator of ozone's presence [3, 4].

5.2 Effectiveness

Some manufacturers or vendors suggest that ozone will render almost every chemical contaminant harmless by producing a chemical reaction whose only by-products are carbon dioxide, oxygen and water. A review of scientific research shows that, for many of the chemicals commonly found in indoor environments, the reaction process with ozone may take months or years [10, 11]. For all practical purposes, ozone does not react at all with such chemicals. Contrary to specific claims by some vendors, ozone generators are not effective in removing carbon monoxide [10, 12] or formaldehyde [10].

Ozone readily reacts with many chemicals which can form a variety of harmful or irritating by-products. For example, in a laboratory experiment that mixed ozone with chemicals from new carpet, ozone reduced many of these chemicals, including those which can produce new carpet odour. However, in the process, the reaction produced a variety of aldehydes, and the total concentration of organic chemicals in the air increased rather than decreased after the introduction of ozone. In addition to aldehydes, ozone may also increase indoor concentrations of formic acid, both of which can irritate the lungs if produced in sufficient amounts [5].

Marketers of ozone generators often claim that these units will rid the air of mold, mildew, bacteria, viruses, and household odours such as tobacco smoke. Research conducted over the past seven years casts serious doubt on these claims (see Table 2) [11]. Some data suggest that low levels of ozone may reduce airborne concentrations and inhibit the growth of some biological organisms while ozone is present, but ozone concentrations would have to be 5 - 10 times higher than allowed public health standards before the ozone could decontaminate the air sufficiently to prevent survival and regeneration of the organisms once the ozone is removed [5, 14(level 8)].

The actual concentration of ozone produced by an ozone generator depends on many factors. Concentrations will be higher if a more powerful device or more than one device is used, if a device is placed in a small space rather than a large space, if interior doors are closed rather than open and, if the room has fewer rather than more materials and furnishings that adsorb or react with ozone and, provided that outdoor concentrations of ozone are low, if there is less rather than more outdoor air ventilation.

Ozone generators typically provide a control setting by which the ozone output can be adjusted. The ozone output of these devices is usually not proportional to the control setting. That is, a setting at medium does not necessarily generate an ozone level that is halfway between the levels at low and high. The relationship between the control setting and the output varies considerably among devices, although most appear to elevate the ozone output much more than one would expect as the control setting is increased from low to high. In experiments to date, the high setting in some devices generated 10 times the level obtained at the medium setting [15] (level 8). Manufacturer’s instructions on some devices link the control setting to room size and thus indicate what setting is appropriate for different room sizes. However, room size is only one factor affecting ozone levels in the room. The known methods for testing ozone require expensive equipment and extensive training in their use.

Ozone has been used extensively for water purification and in food processing plants but ozone chemistry in water is not the same as ozone chemistry in air. In the absence of occupants, high concentrations of ozone in air are sometimes used to help decontaminate an unoccupied space from certain chemical or biological contaminants or odours (e.g. fire restoration, to get rid of strong odours due to tobacco smoke or chemicals, sewage or mold. However, little is known about the chemical by-products left behind by these processes. Ozone can adversely affect indoor plants and damage materials such as rubber, electrical wire coatings, fabrics and art work containing susceptible dyes and pigments (U.S. EPA, 1996a).

Ozone generators are also marketed as air cleaners. The efficiency of these devices is a controversial subject [13] (level 8). The Federal Trade Commission (FTC) took action in 1995 against 3 manufacturers of ozone-generating devices. The FTC charged that they made unsubstantiated claims about the ability of their products to clean air off various indoor air pollutants and to prevent or relieve allergies, asthma and other conditions. Under the FTC's settlement, the manufacturers are prohibited from making marketing claims that ozone is effective in cleaning indoor air, that their products do not create harmful by-products, and that they prevent or provide relief from allergies, asthma, and other specified conditions, unless the claims are supported by reliable and adequate substantiation (FTC, 1995) [16] (level 8). On December 30, 1997, the Federal Trade Commission (FTC) filed suit against the industry's leading manufacturer (Alpine Industries, Inc.) for violating their 1995 consent order with FTC [4,17(level 89)].

The California Department of Health Services (DHS) issued a warning about ozone air cleaning devices in April 1997 [4, 18(level 8)]. In recent years, Minnesota, North Carolina, and Florida have taken a variety of actions to prevent public health hazards from ozone generators in their states.

Health Canada warns the public not to use air cleaners designed to intentionally generate ozone (ozone generators) in their homes. Following a review of current information and in consultation with Health Canada and others, the Canadian Standards Association (CSA) recently made the decision not to certify these products for household use and issued new interim requirements for commercial units. Health Canada advises owners of commercial ozone generators to discontinue use in indoor occupied spaces. This warning does not apply to ozone generators designed for use in industrial applications such as fire damage restoration and water purification where occupants are not normally present. Any beneficial application using ozone requires extremely high levels of ozone to be effective and this is not safe for human exposure [19] (level 8).

6. CONCLUSION

There is sufficient evidence to support that ozone generator air cleaning devices can be harmful to health, whether it is in pure form or mixed with other chemicals, and is generally ineffective in controlling indoor air pollutants.

7. RECOMMENDATION

It is recommended that proven methods of controlling air pollution, such as removing the sources of pollution or preventing emissions from occurring, be used.

REFERENCES

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Table 1. Ozone Heath Effects and Standards		
Health Effects	**Risk Factors**	**Health Standards***
Potential risk of experiencing: Decreases in lung function Aggravation of asthma Throat irritation and cough Chest pain and shortness of breath Inflammation of lung tissue Higher susceptibility to respiratory infection	**Factors expected to increase risk and severity of health effects are:** Increase in ozone air concentration Greater duration of exposure for some health effects Activities that raise the breathing rate (e.g., exercise) Certain pre-existing lung diseases (e.g. asthma)	The **Food and Drug Administration** (FDA) requires ozone output of indoor medical devices to be no more than 0.05 ppm. The **Occupational Safety and Health Administration** (OSHA) requires that workers not be exposed to an average concentration of more than 0.10 ppm for 8 hours. The **National Institute of Occupational Safety and Health** (NIOSH) recommends an upper limit of 0.10 ppm, not to be exceeded at any time. The **Environmental Protection Agency** (EPA)'s National Ambient Air Quality Standard for ozone is a maximum of 8 hours; average outdoor concentration of 0.08 ppm.
(* ppm = parts per million)		

Table 2. Summary of Experimental Studies on the Effectiveness of Ozone to Remove Chemicals and Odours from Air		
Experimental Study	**Results**	**Reference**
New carpet samples were placed in chambers with and without O^3 and instrumentally monitored.	With ozone, only alkene compounds reacted and were converted into aldehydes, organic acids, and ketones. Total volatile organic compound concentration increased.	Weschler, C., A.T. Hodgson, and J.D. Wooley: Indoor Chemistry: Ozone, Volatile Organic Compounds, and Carpets. Environ. Sci. Technol. 26:2371-2377 (1992).
Sewage sludge air was treated with ozone in wet scrubbing process.	Ozone produced multiple new compounds as determined by UV spectrometry.	Arnold, D.L.B.: Chemical Oxidation of Odors by Ozone. Chem. Ind. Issue 22: 899-902, 16 Nov. (1974).
Formaldehyde concentration monitored in chamber, and effect of ozone-generating device was evaluated.	Ozone was not found to influence disappearance of formaldehyde in air.	Esswein, E.J. and M.F. Boeniger: Effect of an Ozone Generating Air Purifying Device on Reducing Concentrations of Formaldehyde in Air. Appl. Occup. Environ. Hyg. 9:139-146 (1994).
Panel of odour judges rated intensity of odour before and after ozone was introduced into a room.	Ozone was not found to decrease odours once ozone dissipated, indicating lack of chemical removal.	Witheridge, W.N. and C.P. Yaglou: Ozone in Ventilation--Its Possibilities and Limitations. ASHVE Trans. 45:309-522 (1939).
Concentration of several organic compounds in air was monitored in presence of ozone.	Ozone did not affect organic compound concentration in air, although ability to smell odorous compounds decreased in the presence of ozone.	Erlandsen, A. and L. Schwarz: Experimental Investigations with Ozone in Air. Z. Hyg. Infekionskrankh 67:391 (1910).
Tobacco smoke odours instrumentally monitored and panel of judges was used to determine odour after ozone was introduced into test chamber.	Ozone was not found to have effectively decreased the odour from tobacco smoke after an overnight exposure.	Anonymous: Household Air Cleaners. Consumer Reports 10:657-662 (1992).

APPENDIX 1-LEVELS OF EVIDENCE SCALE

Level	Strength of evidence	Study design
1	Good	Meta-analysis of RCT, Systematic review
2	Good	Large sample RCT
3	Good to fair	Small sample RCT
4		Non-randomised controlled prospective trial
5	Fair	Non randomised controlled prospective trial with historical control
6	Fair	Cohort studies
7	Fair	Case-control studies
8	Poor	Non-controlled clinical series, descriptive studies multi-centre
9	Poor	Expert committees, consensus, case reports, anecdotes

SOURCE: ADAPTED FROM CATALONIAN AGENCY FOR HEALTH TECHNOLOGY ASSESSMENT (CAHTA), SPAIN