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What Is a Potential Source of Ozone in the Health Care Environment?

A hospital employee with pre-existing reactive airways disease reported the onset of upper airway irritation and wheezing when in close proximity to a deployed mobile ultraviolet (UV) room sterilizing device. Low-level ozone exposure was suspected as a contributing factor. An investigation was conducted in an effort to further evaluate the situation. The question was whether this device would produce sufficient amounts of ozone to induce symptoms in an employee.

Mobile UV room disinfection devices, often employed in hospital settings, have been shown to be effective in reducing the presence of pathogens. These devices are increasingly being used as an adjunct to standard cleaning and disinfection practices in health care settings to dose an enclosed area (ie, patient room, operating room, and so on) with high-intensity UV light utilizing special bulbs that typically emit only UV-C light. They have been used in an effort to combat hospital-acquired infections due to bacteria such as *Clostridium difficile*, *Acinetobacter* spp., Vancomycin-resistant enterococcus, and methicillin-resistant *Staphylococcus aureus,* as well as fungi and viruses.[1] These devices are also effective against the Ebola virus.[2]

Ozone is the unstable triatomic allotrope of oxygen first considered to exist in 1785 by Van Marum and discovered by Schönbein in 1840. The molecular formula was elucidated in 1865 by Soret.[3] It has a characteristic "clean," "electrical" odor, which is often noticed after a thunderstorm. Ozone is created naturally either by UV radiation or high-energy static electricity (lightning), which ruptures the di-oxygen double bond creating two oxygen-free radicals, which then join with other di-oxygen molecules to create ozone. Ozone then naturally decays back to oxygen with a variable half-life depending on temperature and pressure. Because it is unstable, and cannot be stored, ozone is industrially manufactured at point-of-use by corona effect, UV light, or electrolysis, for use as an oxidant, deodorant, disinfectant, or bleaching agent. Ozone is also a byproduct of electrical arc welding processes, high-voltage electrical equipment operations, and high-intensity UV light processes.[4]

Ozone, ubiquitous in the Earth's stratosphere, serves to protect the planet from harmful solar UV-B and UV-C radiation. Both UV-B and UV-C can cause DNA damage, dermatologic and ophthalmologic sequelae, and environmental deterioration. The *stratospheric* ozone "layer" filters all UV-C and approximately 90% of UV-B radiation. Ground level, or *tropospheric,* ozone appears as smog via photochemical production when oxygen is combined with pollutant nitrous oxides and volatile organic compounds in the presence of warm, humid air, and solar UV radiation. It is then trapped in close proximity to the ground by weather inversion phenomena and can cause respiratory tract and mucus membrane irritation and environmental damage.[4]

The characteristic odor of ozone is readily detectable by the human nose at variable levels ranging anywhere from 1 to 50 parts per billion (ppb) depending on individual olfactory sensitivity to the molecule.[5] Minor irritant symptoms usually occur when ozone levels exceed 0.1 parts per million (ppm). More serious symptoms can occur when levels are above 0.5 to 1 ppm, and atmospheres with at least 5 ppm ozone are considered immediately dangerous to life and health (IDLH). For those reasons, the Occupational Safety and Health Administration (OSHA) mandated that workplace ozone levels not exceed 0.1 ppm averaged over an 8-hour work day (8-hr TWA). This mandate was based on information from the National Institute of Occupational Safety and Health. The Environmental Protection Agency, via the Clean Air Act and the National Ambient Air Quality Standards, set the atmospheric ozone action level at 0.075 ppm 8-hour TWA.[4,6]

With technological advances in preventing health care associated infections, the unintentional presence of ozone within health care facilities is now more prevalent. Given that ozone is produced by intense UV light processes, technologies that utilize UV radiation, such as automated room sterilizing devices, can potentially generate clinically significant ozone levels.[7] The lamps used in these devices are made to emit UV-C light in the 100 to 290 nm range, which is in the range where ozone is produced. The characteristic odor of ozone was noted to be distinctly present while utilizing one of these devices in this environment. This finding is important because ozone is a known respiratory and mucus membrane irritant, exerting its destructive oxidative potential on the sensitive pulmonary epithelium. Those with pre-existing respiratory conditions may be more sensitive to the ill effects of ozone and may have reactions to levels far below the regulatory limits set by OSHA.[8]

An ozone monitor with a detection limit, accuracy, and precision of 1.5 ppb was used in this investigation. Monitoring revealed baseline ozone levels inside the patient room to be less than 1 ppb. When the mobile UV device was actively deployed, ozone levels reached a maximum of 6.0 ppb. Ozone levels were not measured outside the room, but the distinct odor of ozone was present during deployment.

A quantitative risk analysis was applied. Assuming OSHA has set the Permissible Exposure Limit (PEL) at 0.1 ppm to protect 98% of workers from harm, an estimated level of risk based on the ozone levels recorded at this institution was calculated. The maximum ozone level measured was 6 ppb, which is 17 times lower than the OSHA PEL. If one expects

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a 2% ill effect, then based on the previous assumption, one can divide that percentage by 17 in order to derive an estimate of 12 in 10,000 (or about 1:1000) individuals who may potentially experience an ill effect from an ozone level of 6 ppb. Assuming that the ozone levels outside the room were half that inside the room, then it might be expected that as many as six employees who come in the vicinity of the deployed device could be adversely affected, given an employee base of 10,000.

Employing environmental controls can limit hospital employee, patient, and visitor exposure to the small amounts of ozone produced by these mobile high-intensity UV-C room-sterilizing devices. Setting the ventilation system to provide negative pressure inside the room, if available, and taping the door jambs with painter's tape when the device is deployed will help prevent leak of ozone outside of the room under treatment. Limiting employee, patient, and visitor foot traffic in the area where and when the devices are deployed will also reduce the potential for unexpected exposure to trace ozone.

For occupational medicine physicians responsible for promoting and preserving the health and safety of hospital employees, this is one potential environmental health hazard that should be considered. As technology advances to improve health care and reduce hospital-acquired infections, more such hazards may emerge. This case of an unintentional health care employee ozone exposure is an example of the need for continued vigilance for environmental and other health hazards on the part of occupational medicine physicians.

Suggested Readings:

NIOSH: Occupational Health Guideline for Ozone. September 1978.

http://www.cdc.gov/niosh/docs/81-123/pdfs/0476.pdf.

NIOSH/IPCS: International Chemical Safety Card – Ozone. April 26, 1993.

http://www.cdc.gov/niosh/ipcsneng/neng0068.html.

OSHA Ozone Chemical Sampling Information.

http://www.osha.gov/dts/chemical sampling/data/CH_259300.html.

California Environmental Protection Agency, Office of Environmental Health Hazard Assessment, Determination of Acute Reference Exposure Levels for Airborne Toxicants, Acute Toxicity Summary – Ozone, March 1999.

http://oehha.ca.gov/air/acute_rels/pdf/10028156A.pdf.

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REFERENCES

1. Nerandzic MM, Thota P, Sankar CT, et al. Evaluation of a pulsed xenon ultraviolet disinfection system for reduction in healthcare-associate pathogens in hospital rooms. *Infect Control Hosp Epidemiol*. 2015;36:192–197.
2. Sagripanti J, Lytle S. Sensitivity to ultraviolet radiation of Lassa, vaccinia and Ebola viruses dried on surfaces. *Arch Virol*. 2011;156: 489–494.
3. Rubin MB. The history of ozone. The Schönbein period, 1839–1868. *Bull Hist Chem*. 2001;26: 40–56.
4. US Environmental Protection Agency—Ozone. Available at: http://www.epa.gov/ozone/index.html. Accessed August 1, 2015.
5. Ruth JH. Odor thresholds and irritation levels of several chemical substances: a review. Am Ind Hyg Assoc J 1986; 47:A142–A151.
6. *ACGIH: Documentation of the Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs)—Ozone*. Cincinnati, OH: American Conference of Governmental Industrial Hygienists; 2001.
7. Kowalski W. *Ultraviolet Germicidal Irradiation Handbook: UVGI for Air and Surface Disinfection*. Berlin Heidelberg: Springer Science and Business Media; 2012. p. 135.
8. Devlin RB, Raub JA, Folinsbee LJ. Health effects of ozone. *Sci Med*. 1997;May/June:8–17.