Environmental Health Committee (EHC) Emerging Issue Report:

Ozone and Indoor Chemistry

What is the issue?

Recent research has found that outdoor ozone levels far lower than the current outdoor standard of 75 ppb (EPA, 2008) contribute to increased mortality as well as an increase in Building Related Illness (Bell et.al. 2006, Levy 2007, Apte et.al. 2007/2008). Levels as low as 20 ppb have been shown to increase mortality and statistical approaches suggest that "safe O_3 levels would be lower than 10 ppb" (Bell et.al. 2006). Both ozone and ozone reaction products have been implicated in adverse health impacts from exposure indoors (Weschler 2006, Wisthaler & Weschler 2007). Indoor ozone levels are typically 0.2-0.7 times outdoor levels (Weschler 2000) and vary roughly proportionally to air change rates from 0.5 to 10 per hour respectively and are even higher at high air change rates not uncommon in naturally ventilated residences and other buildings where indoor O_3 levels approach outdoor levels. People spend more than 90% of their time indoors where more than 50% of their exposure to ozone occurs, but the exposure to reaction products indoors may be an even more important health concern (Weschler, 2006). This research suggests that the introduction of ozone to indoor spaces should be reduced to ALARA (as low as reasonably achievable) levels.

Methods to decrease the concentration of ozone and its indoor by-products involve steps to limit the introduction of ozone into an occupied space, whether by internal emission, or entry from outdoors, as well as steps to reduce ozone reactants (such as terpenes) and by-products of ozone indoor chemistry, such as carbonyls, secondary organic aerosols (SOA), and ultrafine particles (UFP) (Singer et al, 2006; Morrison, 2008). The selection of surface materials for air-handling equipment, ductwork and interior surfaces can significantly influence ozone and ozone reaction product concentrations (Morrison et al, 1998; Kunkel 2010; Wang and Morrison, 2006).

What action should be considered?

To minimize health impacts of ozone and associated by-products, the following actions should be considered (particularly for individuals and populations at high-risk for adverse consequences, such as infants, the elderly and those with chronic respiratory illnesses):

1. Remove ozone from outdoor air at the outdoor air intake, or as early in introduction to the occupied space as possible, using ozone removal technologies that do not result in by-product formation.
2. Minimize indoor ozone emissions by reducing the use of equipment that produces ozone (e.g. laser-based printers, and photocopiers, and some air cleaning technologies).
3. Minimize indoor ozone by filtering or exhausting the ozone produced by pertinent equipment.
4. Reduce concentrations of terpenes and other reactive organic compounds as well as carbonyls and other products of indoor ozone chemistry in indoor spaces through source reduction and gas phase removal equipment.
5. Use high efficiency particulate filters (*e.g.* MERV 13 or greater) to remove ozone reaction products in the form of SOA and UFP from outdoor and recirculated air (Fadeyi 2009)

Note: Emerging Issue Reports are developed and approved by the ASHRAE Environmental Health Committee (EHC). The Ozone and Indoor Chemistry Emerging Issue Report was approved by EHC in January 2011.

References:

Apte M.G., I.S.H. Buchanan, and M.J. Mendell. 2007/2008. “Outdoor Ozone and Building Related Symptoms in the BASE Study,” *Indoor Air* v. 18, no. 2. (also available at Lawrence Berkeley National Laboratory, Berkeley CA 94720, LBNL-62419 (available www.lbl.gov).

Bell, M. L., Peng, R.D., Cominici, F. (2006). "The exposure-Response Curve for Ozone and Risk of Mortality and the Adequacy of Current Ozone Regulations." Environmental Health Perspectives **114**(4): 532-536.

Corsi, R. L. (2006). Comment RR-07-1-4 Assessment of Maximum Ozone Emissions in Residential, Office, and School Buildings. CPSC Health Sciences Staff Report on the Work Product Resulting from CPSC Contract No. CPSC-S-04-1369, Assessing Potential Health Effects and Establishing Ozone Exposure Limits for Ozone generation Air Cleaners - Draft - September 26, 2006 CPSC**:** 21-75.

EPA, 2008, National Ambient Air Quality Standards (NAAQS) http://www.epa.gov/air/criteria.html

Fadeyi, M.O., Weschler, C.J., Tham, K.W. (2009). “The impact of recirculation, ventilation and filters on secondary organic aerosols generated by indoor chemistry.” Atmospheric Environment, **43**: 3538-3547.

Franklin, M., Schwartz, J. (2008). "The Impact of Secondary Particles on the Association between Ambient Ozone and Mortality." Environmental Health Perspectives **116**(4): 453-458.

Kunkel, D.A., Gall, E.T., Siegel, J.A.,, Novoselac, A, Morrison, G.C. and. Corsi, R.G. (2010). “Passive reduction of human exposure to indoor ozone.” Building and Environment, Volume 45, Issue 2:445-452.

Levy, J. (2007). "Mortality Risks From Ozone Exposure." Risk in Perspective **15**(2).

Morrison,G. et al, (1998). Indoor Air Quality Impacts of Ventilation Ducts: Ozone Removal and Emissions of Volatile Organic Compounds. *J. Air & Waste Manage. Assoc.* 48:941-952

Morrison, G. (2008). Interfacial Chemistry in Indoor Environments. *Environmental Science & Technology* 42 (10) 3495-3499. May 15, 2008

Schwartz, J. (2008). "Ozone and Mortality - An update." Risk in Perspective **16**(2).

Singer, B. C.; et al. (2006) Indoor Secondary Pollutants from Cleaning Product and Air Freshener Use in the Presence of Ozone. *Atmos. Environ.* 40, 6696–6710.

Trisch, E. W., Gent, J.F., Holford, T.R., Bealnger, K., Bracken, M.B., Beckett, W.S., Naeher, L., McSharry, J.E., and Leaderer, B.P. (2006). "Low-Level Ozone Exposure and Respiratory Symptoms in Infants." Environmental Health Perspectives **115**(6): 911-916.

Wang, H.; Morrison, G. C. (2006) Ozone-Initiated Secondary Emission Rates of Aldehydes from Indoor Surfaces in Four Homes. *Environ. Sci. Technol.*, 40, 5263–5268.

Weschler, C. J., and Shields, H.C. (2000). "The influence of ventilation on reactions among indoor pollutants: modeling and experimental observations." Indoor Air **10**: 92-100.

Weschler, CJ, (2000). “Ozone in Indoor Environments: Concentration and Chemistry”. Indoor Air, Volume 10, Number 4: 269-288.

Weschler, C. J. (2006). "Ozone's Impact on Public Health: Contributions from Indoor Exposures to Ozone and Products of Ozone-Initiated Chemistry " Environmental Health Perspectives **114**(10): 1489-1496.

Wisthaler, A. and C. J. Weschler (2009). "Reactions of ozone with human skin lipids: Sources of carbonyls, dicarbonyls, and hydroxycarbonyls in indoor air." Proceedings of the National Academy of Sciences

Note: Emerging Issue Reports are developed and approved by the ASHRAE Environmental Health Committee (EHC). The Ozone and Indoor Chemistry Emerging Issue Report was approved by EHC in January 2011.