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# Guest Editorial

Reactions among indoor pollutants consume the reacting pollutants and generate new pollutants, influencing the kind and concentration of chemicals in indoor air. In the absence of combustion, such indoor chemistry is the major source of highly reactive compounds indoors.

From July 12–15, 2004, approximately 70 participants from eight countries met at the campus of University of California, Santa Cruz for a Workshop titled 'Indoor Chemistry and Health' conceived and sponsored by the U.S. National Institute for Occupational Safety and Health (NIOSH) with additional support from the Harvard School of Public Health (HSPH). As implied by the title, the focus of this workshop was adverse health effects that might result from exposure to the products of reactions among indoor pollutants. Scientists from multiple disciplines – including chemistry, toxicology, medicine, epidemiology, and public health – were enlisted to address this subject. (A full list of the attendees, including presenters, can be viewed at the NIOSH NORA Indoor Environment Team website: http://www2.cdc.gov/nora/Nteamact-IE.html.)

A major goal of the workshop was to promote communication between those who are studying outdoor and indoor chemistry and those who are examining the health effects resulting from exposures to airborne pollutants. Throughout the workshop there were extensive discussions – after the various presentations, during the breaks, at the dining tables, and during the evening socials. E-mails following the meeting indicate that these cross-discipline communications continue.

Indoor chemistry is complex. There remain many gaps in our current understanding of how indoor pollutants interact (especially on surfaces) and the products that result. However, the questions concerning health effects appear to be even more complex and daunting. Numerous endpoints must be considered, from acute to chronic, from mild inflammation of mucous membranes to asthma and allergies and on to heart/lung disease and cancer. Even for stable reaction products that have been studied for decades (e.g. formaldehyde, formic acid, or nonanal) our knowledge is incomplete. For short-lived reaction products such as free radicals, relevant health studies are only just beginning. A.-T. Karlberg, University of Gothenburg, Sweden, and her colleagues have provided solid evidence concerning the ability of hydroperoxides, oxidation products of terpenes and glycol ethers, to act as contact allergens. The consequences of inhaling such species remain unknown. The health professionals at the workshop identified specific areas where large knowledge gaps exist. These include inflammation (where and how does it begin), gene activation, specific receptor binding, non-specific responses and oxidative stress. Knowledge regarding the last of these may be particularly relevant to indoor settings where occupants are exposed to a complex mix of oxidation products resulting from ozone-initiated chemistry, as well as secondary reactions involving hydroxyl and nitrate radicals.

In addition to fostering discipline-bridging communication, the workshop was also designed to discuss research needs at the interface of indoor chemistry and human health. The participants were charged with developing a list of research priorities and testable hypotheses. Those judged to be among the most important follow.

## Priority research needs

### Exposure

Conduct targeted exposure studies for specific compounds formed by reactions among indoor pollutants, as well as reaction product precursors. Focus on health-relevant compounds. Incorporate methods demonstrated to be useful in studies of outdoor pollutants. Take advantage of existing biomarkers (or identify new biomarkers) for exposure to the targeted products of indoor chemistry.

### Modeling/measurements/model evaluation

Evaluate indoor chemistry models by measuring the concentrations of key products, such as hydroxyl, nitrate, hydroperoxy and methylperoxy radicals under a variety of indoor conditions. (Techniques to do this exist and have been successfully applied to outdoor air.) Such measurements would be used to improve the models and the improved models, in turn, would point the way for further measurements. Ultimately, conduct targeted measurements of key reaction products.

Develop integrated pharmacokinetic models addressing potential irritation, inflammation and allergic responses initiated by the reaction products judged to be the most biologically significant.

#### Risk Assessment

Evaluate the health risks posed by the known products of reactions among indoor pollutants. This could be done using 'Disability Adjusted Life Years'. (DALYs reflect the total amount of healthy life lost, to all causes, whether from premature mortality or from some degree of disability during a period of time.) Further efforts related to risk assessment for reaction products would be based on toxicology, structure activity relationships and epidemiologic studies addressing both cancer and non-cancer endpoints.

#### Tissue irritation

Evaluate the contribution of the products of indoor chemistry to irritation, especially mucosal irritation, and the susceptibilities of various target organs. Evaluate the consequences of chemical reactions that might occur on biological surfaces such as skin or the human lung.

#### Screening test

Develop a rapid screening test (using, e.g. existing animal models or *in vitro* cell bioassays) that would permit an initial health-effect evaluation of the compounds generated by reactions among indoor pollutants.

#### Integrated program addressing inflammation, allergies and asthma

Screen products of indoor chemistry for their potential to exacerbate allergies or asthma and irritate mucous membranes. Following screening, evaluate the public's exposures to the compounds of greatest concern. Couple this with detailed evaluations of these compounds' toxicology.

### Top Testable Hypotheses

#### Mucosal irritation

Chemical transformations of indoor pollutants yield products that contribute to mucosal irritation and inflammation.

#### Allergies

Selected products of indoor chemistry can promote allergies (type 1 hypersensitivity).

#### Health

Products of indoor chemistry adversely affect human health.

#### Intervention

Removal of ozone from a school's ventilation air will reduce the use of medication among asthmatic children. Elimination of ozone generating 'air purifiers' will reduce adverse respiratory symptoms among users of such devices. Removal of significant sources of pollutants and their transformation products will lead to an improvement in human health.

#### Ecological labels

As a consequence of chemical transformations, various 'green' or 'ecological' materials are contributing to, rather than mitigating, health problems related to indoor air.

A common theme running through workshop discussions was the need to better characterize and understand the 'reacting' indoor environment, with an emphasis on the chemicals that most affect human health. Many of the potentially important products of chemistry are often missed by the analytical methods routinely used in indoor air investigations (i.e. they are 'stealth pollutants'). Methods that can detect such products, especially the 'biologically relevant' compounds need to be developed.

The workshop was a strong reminder that indoor chemistry is much broader than ozone/limonene reactions (the subject of considerable recent study). There are other oxidants besides ozone (e.g. hydroxyl and nitrate radicals). There are other types of reactions besides oxidation (e.g. hydrolysis and decomposition). Pesticide residues can be oxidized to more toxic species (e.g. malathion to maloxone). Esters can hydrolyze to more irritating and odorous species (e.g. di-2-ethylhexyl phthalate to its acidic monoester and 2-ethyl hexanol). The workshop was also a strong reminder that we know very little regarding the various ways in which indoor chemistry may impact human health. However, this is not an excuse to overlook or ignore indoor chemistry in studies examining the factors that influence indoor air quality and health. Such studies should consciously include chemical transformations of indoor pollutants, else we may never know how important or unimportant these transformations really are.

**Guest Editorial**

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