Study reveals new details on the dangers of third-hand smoke

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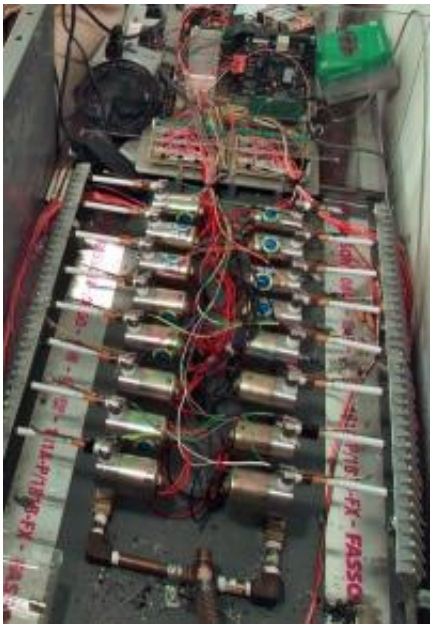

In tests at Berkeley Lab of celluose surfaces contaminated with nicotine residues from third-hand smoke, levels of newly formed TSNAs rose 10 times following a three hour exposure to nitrous acid. TSNAs are potent carcinogens. Photo by Roy Kaltschmidt, Berkeley Lab Public Affairs

Nicotine in third-hand smoke, the residue from tobacco smoke that clings to virtually all surfaces long after a cigarette has been extinguished, reacts with the common indoor air pollutant nitrous acid to produce dangerous carcinogens. This new potential health hazard was revealed in a multi-institutional study led by researchers with the

Lawrence Berkeley National Laboratory.

"The burning of tobacco releases nicotine in the form of a vapor that adsorbs strongly onto indoor surfaces, such as walls, floors, carpeting, drapes and furniture. Nicotine can persist on those materials for days, weeks and even months. Our study shows that when this residual nicotine reacts with ambient nitrous acid it forms carcinogenic tobacco-specific nitrosamines or TSNAs," says Hugo Destaillats, a chemist with the Indoor Environment Department of Berkeley Lab's Environmental Energy Technologies Division. "TSNAs are among the most broadly acting and potent carcinogens present in unburned tobacco and tobacco smoke."

Destaillats is the corresponding author of a paper published in the Proceedings of the National Academy of Sciences (*PNAS*) titled "Formation of carcinogens indoors by surface-mediated reactions of nicotine with nitrous acid, leading to potential third-hand smoke hazards."

Co-authoring the PNAS paper with Destaillats were Mohamad Sleiman, Lara Gundel and Brett Singer, all with Berkeley Lab's Indoor Environment Department, plus James Pankow with Portland State University, and Peyton Jacob with the University of California, San Francisco.

The authors report that in laboratory tests using cellulose as a model indoor material exposed to smoke, levels of newly formed TSNAs detected on cellulose surfaces were 10 times higher than those originally present in the sample following exposure for three hours to a "high but reasonable" concentration of nitrous acid (60 parts per billion by volume). Unvented gas appliances are the main source of nitrous acid indoors. Since most vehicle engines emit some nitrous acid that can infiltrate the passenger compartments, tests were also conducted on

surfaces inside the truck of a heavy smoker, including the surface of a stainless steel glove compartment. These measurements also showed substantial levels of TSNAs. In both cases, one of the major products found was a TSNA that is absent in freshly emitted tobacco smoke - the nitrosamine known as NNA. The potent carcinogens NNN and NNK were also formed in this reaction.

"Time-course measurements revealed fast TSNA formation, up to 0.4 percent conversion of nicotine within the first hour," says lead author Sleiman. "Given the rapid sorption and persistence of high levels of nicotine on indoor surfaces, including clothing and human skin, our findings indicate that third-hand smoke represents an unappreciated health hazard through dermal exposure, dust inhalation and ingestion."

Since the most likely human exposure to these TSNAs is through either inhalation of dust or the contact of skin with carpet or clothes, third-hand smoke would seem to pose the greatest hazard to infants and toddlers. The study's findings indicate that opening a window or deploying a fan to ventilate the room while a cigarette burns does not eliminate the hazard of third-hand smoke. Smoking outdoors is not much of an improvement, as co-author Gundel explains.

"Smoking outside is better than smoking indoors but nicotine residues will stick to a smoker's skin and clothing," she says. "Those residues follow a smoker back inside and get spread everywhere. The biggest risk is to young children. Dermal uptake of the nicotine through a child's skin is likely to occur when the smoker returns and if nitrous acid is in the air, which it usually is, then TSNAs will be formed."

The dangers of mainstream and secondhand tobacco smoke have been well documented as a cause of cancer, cardiovascular disease and stroke, pulmonary disease and birth defects. Only recently, however, has the general public been made aware of the threats posed by third-hand

smoke. The term was coined in a study that appeared in the January 2009 edition of the journal "Pediatrics," in which it was reported that only 65 percent of non-smokers and 43 percent of smokers surveyed agreed with the statement that "Breathing air in a room today where people smoked yesterday can harm the health of infants and children."

Anyone who has entered a confined space - a room, an elevator, a vehicle, etc. - where someone recently smoked, knows that the scent lingers for an extended period of time. Scientists have been aware for several years that tobacco smoke is adsorbed on surfaces where semi-volatile and non-volatile chemical constituents can undergo reactions, but reactions of residual smoke constituents with atmospheric molecules such as nitrous acid have been overlooked as a source of harmful pollutants. This is the first study to quantify the reactions of third-hand smoke with nitrous acid, according to the authors.

"Whereas the sidestream smoke of one cigarette contains at least 100 nanograms equivalent total TSNAs, our results indicate that several hundred nanograms per square meter of nitrosamines may be formed on indoor surfaces in the presence of nitrous acid," says lead-author Sleiman.

Co-author James Pankow points out that the results of this study should raise concerns about the purported safety of electronic cigarettes. Also known as "e-cigarettes," electronic cigarettes claim to provide the "smoking experience," but without the risks of cancer. A battery-powered vaporizer inside the tube of a plastic cigarette turns a solution of nicotine into a smoky mist that can be inhaled and exhaled like tobacco smoke. Since no flame is required to ignite the e-cigarette and there is no tobacco or combustion, e-cigarettes are not restricted by anti-smoking laws.

"Nicotine, the addictive substance in tobacco smoke, has until now been

considered to be non-toxic in the strictest sense of the term," says Kamlesh Asotra of the University of California's Tobacco-Related Disease Research Program, which funded this study. "What we see in this study is that the reactions of residual nicotine with nitrous acid at surface interfaces are a potential cancer hazard, and these results may be just the tip of the iceberg."

The Berkeley Lab researchers are now investigating the long-term stability in an indoor environment of the TSNAs produced as a result of third-hand smoke interactions with nitrous acid. The authors are also looking into the development of biomarkers to track exposures to these TSNAs. In addition, they are conducting studies to gain a better understanding of the chemistry behind the formation of these TSNAs and to find out more about other chemicals that are being produced when third-hand smoke reacts with nitrous acid.

"We know that these residual levels of nicotine may build up over time after several smoking cycles, and we know that through the process of aging, third-hand smoke can become more toxic over time," says Destaillats. "Our work highlights the importance of third-hand smoke reactions at indoor interfaces, particularly the production of nitrosamines with potential health impacts."

In the PNAS paper, Destaillats and his co-authors suggest various ways to limit the impact of the third hand smoke health hazard, starting with the implementation of 100 percent smoke-free environments in public places and self-restrictions in residences and automobiles. In buildings where substantial smoking has occurred, replacing nicotine-laden furnishings, carpets and wallboard can significantly reduce exposures.

Provided by Lawrence Berkeley National Laboratory