

Electronic Cigarettes in the Indoor Environment

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White Paper: Electronic Cigarettes in the Indoor Environment



American Industrial Hygiene Association®



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Risk Assessment Committee*

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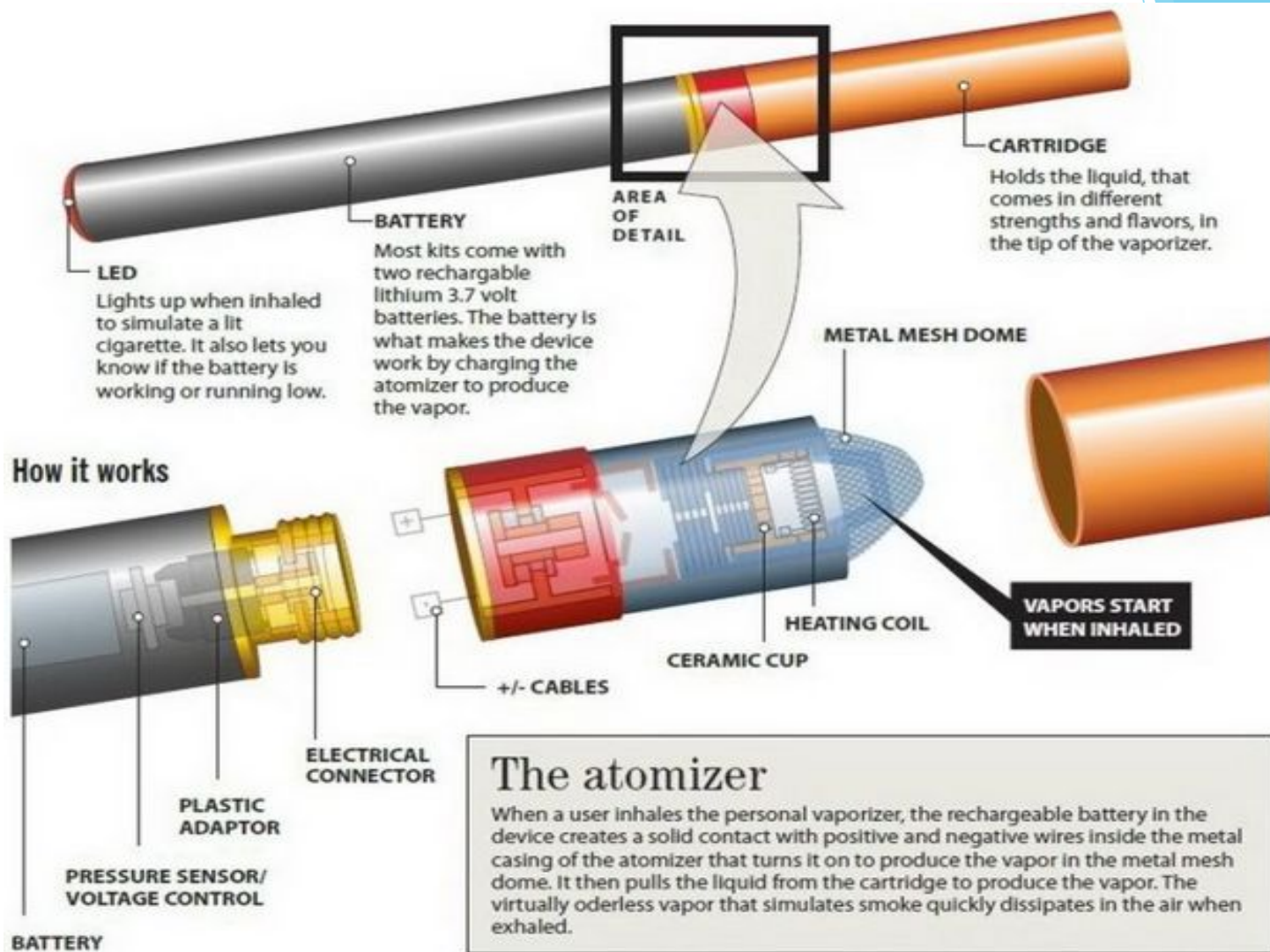
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Presentation Graphics

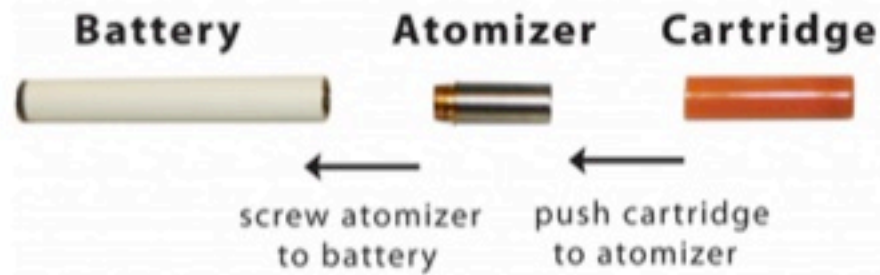
Courtesy of John P. (Jack) Springston Jr., MS, CIH, CSP
TRC Environmental Corp.

Thanks, Jack!

Anatomy of an E-Cigarette



First Generation ECs (‘cigalikes’)



- Disposable
- Re-chargeable with pre-filled cartridges



Second Generation ECs



- Refillable with liquids



Third Generation ECs ('mods')



Statistics

- More than 460 different e-brands currently on the market*
- Over 7,700 unique e-cigarette flavors*
* As of January 2014
- China produces approximately 90 percent of the world's e-cigarettes
- Chinese manufacturers are expected to ship more than 300 million e-cigarettes to the US and Europe this year

Barboza, D. (2014, December 13). China's e-cigarette boom lacks oversight for safety. *The New York Times*. Retrieved from http://www.nytimes.com/2014/12/14/business/international/chinas-e-cigarette-boom-lacks-oversight-for-safety-.html?_r=0

Zhu, S. (2014). Four hundred and sixty brands of e-cigarettes and counting: Implications for product regulation. *Tobacco Control*. doi:10.1136/tobaccocontrol-2014-051670

Statistics

- E-cigarette sales in the U.S. were estimated at \$2.2 billion in 2014
- Sales expected to grow nearly 50% per year through 2018
- In 2014, an estimated 2.5 million middle and high school students used e-cigarettes
- In 2015, this number increased to more than 3 million

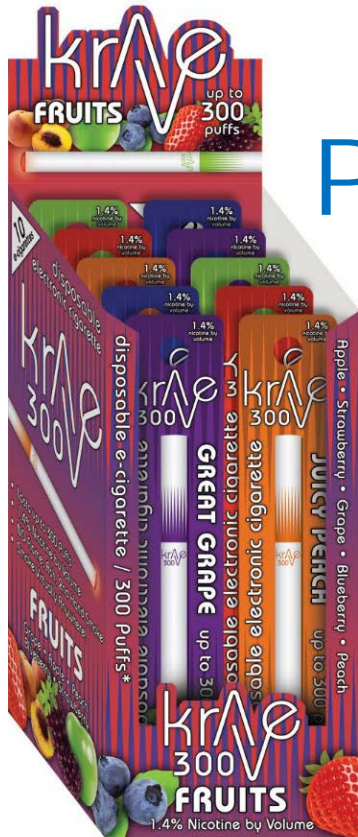
Statistics

- There is some evidence that e-cigarette use is prospectively associated with increased risk of combustible tobacco use initiation during early adolescence
- An estimated 16% of U.S. tenth graders have tried e-cigarettes, of whom 43% have never smoked combustible cigarettes (August, 2015)
- Among high school students that were electronic nicotine delivery system (ENDS) users, 25% went on to be conventional tobacco product users, compared with 9% in the population that had never used an ENDS

Leventhal, A.M., Strong, D.R., Kirkpatrick, M.G., Under, J. B., Sussman, S., Riggs, N.R., Stone, M.D., Khoddam, R., Sarnet, J.M. & Audrain-McGovern, J. (2015). Association of electronic cigarette use with initiation of combustible tobacco product smoking in early adolescence. *JAMA*. doi:10.1001/jama.2015.8950

Rigotti, N.A. (2015). E-cigarette use and subsequent tobacco use by adolescents: New evidence about a potential risk of e-cigarettes. *JAMA*, 314(7), 673-674. doi:10.1001/jama.2015.8382





Primary Components

- Propylene Glycol/
Vegetable Glycerin
- Nicotine
- Flavorings

- Typical makeup is 70%v VG, 30%v PG, 20 mg/mL nicotine, non-flavored

Dautzenberg, B. & Bricard, D. (2015) Real-time characterization of e-cigarettes use: The 1 million puffs study. *Journal of Addiction Research & Therapy* 6, 229. doi:10.4172/2155-6105.1000229

Propylene Glycol/Vegetable Glycerin

- Used in theatrical fog
 - Exposure may contribute to both acute and chronic health issues, such as asthma, wheezing, chest tightness, decreased lung function, respiratory irritation, and airway obstruction*



*Varughese, S., Teschke, M., Brauer, Y. Chow, C. Van Netten, C. & Kennedy, S.M. (2005). Effects of theatrical smokes and fogs on respiratory health in the entertainment industry. *American Journal of Industrial Medicine*, 47, 411–418

Propylene Glycol/ Vegetable Glycerin

- Pyrolysis/heating glycerin forms acrolein, formaldehyde and acetaldehyde in the vapors

Geiss, O., Bianchi, I., Barhona, F., & Barrero-Moreno, J. (2014). Characterisation of mainstream and passive vapours emitted by selected electronic cigarettes. *International Journal of Hygiene and Environmental Health*, 281, 169-180

Goniewicz, M.L., Knysak, J., Gawron, M., Kosmider, L., Sobczak, A. Kurek, J., Prokopowicz, A. ...& N. Benowitz. (2013). Levels of selected carcinogens and toxicants in vapour from electronic cigarettes. *Tobacco Control*. 0:1-7 doi:10.1136/tobaccocontrol-2012-050859.

Lauterbach, J.H. & Laugesen, M. (2012). Comparison of toxicant levels in mainstream aerosols generated by Ruyan® electronic nicotine delivery systems (ENDS) and conventional cigarette products. *Toxicologist*, 126, 1

Lauterbach, J.H., Laugesen, M., Ross, B.B., 2012. Suggested protocol for estimation of harmful and potentially harmful constituents in mainstream aerosols generated by electronic nicotine delivery systems (ENDS). *Toxicologist*, 126, 1

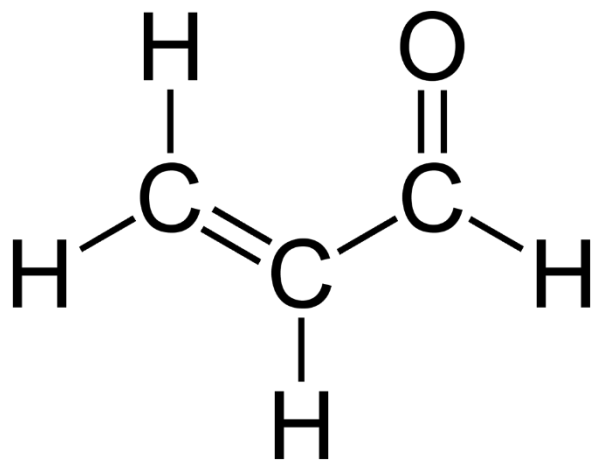
Uchiyama, S., K. Ohta, Y. Inaba, & N. Kunugita. (2013). Determination of carbonyl compounds generated from the e-cigarette using coupled silica cartridges impregnated with hydroquinone and 2,4-dinitrophenylhydrazine, followed by high-performance liquid chromatography. *Analytical Sciences*, 29 (12), 1219-1222

Formaldehyde

- A known degradation product of propylene glycol and glycerin
- Found in vapor and in small amounts in some studies of some liquids
- Higher airborne concentrations with higher voltage second and third generation units
- Known human carcinogen



Acrolein

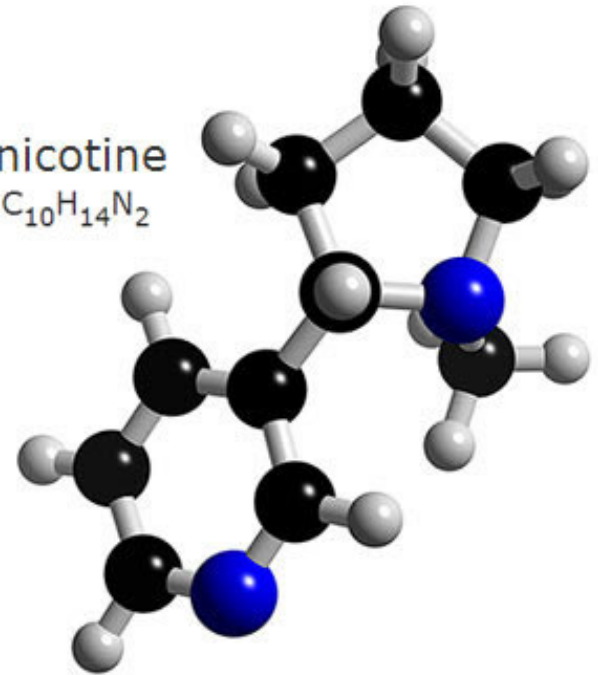


- Causes irritation to the nasal cavity, damage to the lining of the lungs and is thought to contribute to cardiovascular disease in cigarette smokers
- Found in vapor only (formed as a result of heating process)

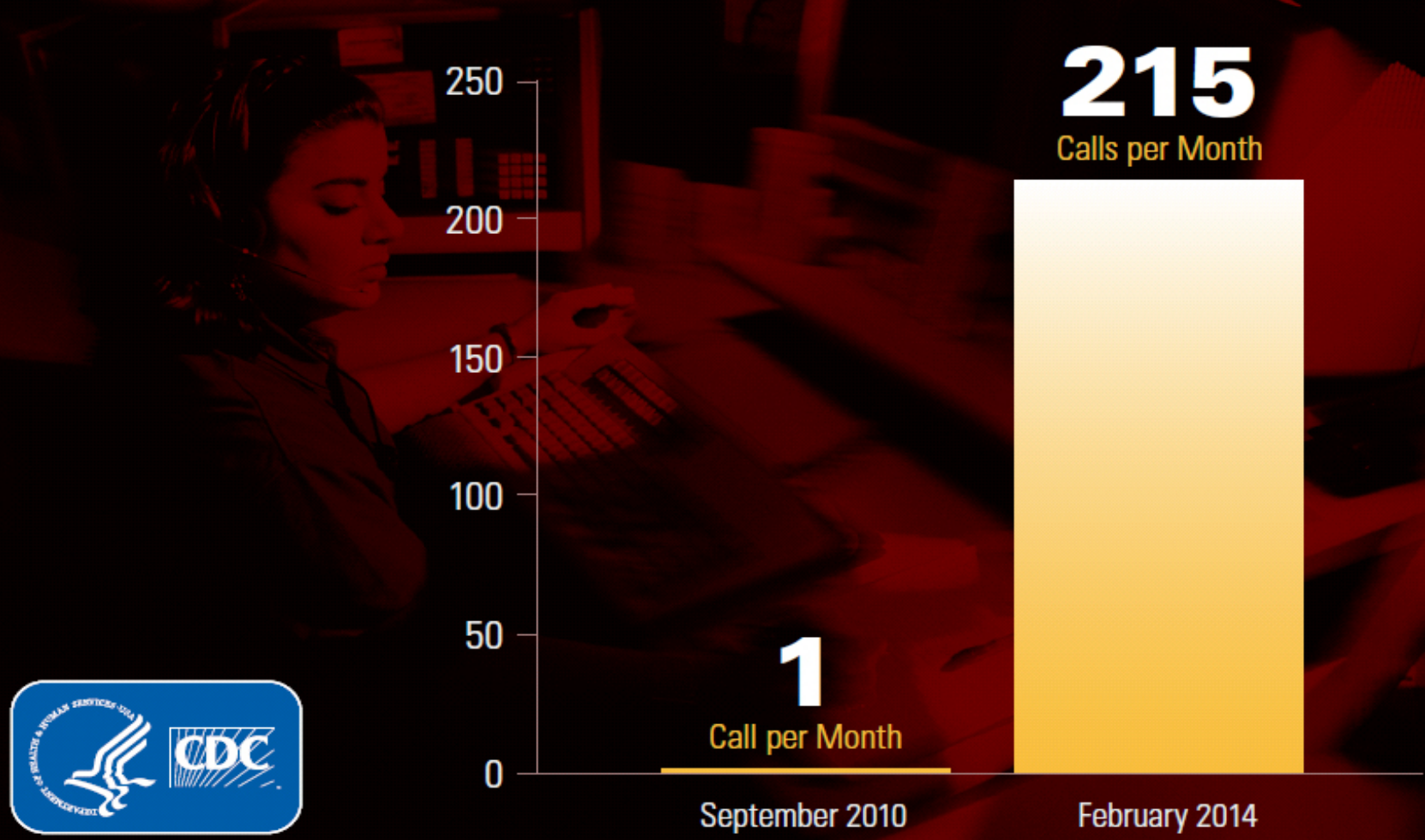
Nicotine

- Health Effects
 - Addictive
 - Teratogenic
 - Increases heart rate, respiratory rate, blood pressure, and level of alertness
- E-Cig Labeling
 - Some cartridges labeled as containing no nicotine did, in fact, contain detectable levels of nicotine
 - Concentration and delivery inconsistencies
- Nicotine found in the vapor, but lower than found emitted from conventional cigarettes

nicotine
 $C_{10}H_{14}N_2$



Poison center calls involving e-cigarettes





**Works
for You**

**NICOTINE POISONINGS UP AS E-CIG POPULARITY GROWS
ONE THIRD OF VICTIMS ARE TWO YEARS OLD**

The first reported child's death from accidentally ingesting e-liquid was in early December of 2014 involving a 1-year old in Fort Plain, New York.

Flavorings





Other Additives



Food and Drug Administration. (2010). Warning letter. Retrieved from <http://www.fda.gov/ICECI/EnforcementActions/WarningLetters/ucm225187.htm>

Other Additives



Generally Recognized as Safe (GRAS)?



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[Int J Occup Environ Health](#). 2012 Jan-Mar;18(1):29-42.

Bronchiolitis obliterans and consumer exposure to butter-flavored microwave popcorn: a case series.

[Egilman DS](#), [Schilling JH](#).

Department of Family Medicine, Brown University, Providence, Rhode Island, USA. degilman@egilman.com

Abstract

Respiratory exposure to diacetyl and diacetyl-containing flavorings used in butter-flavored microwave popcorn (BFMP) causes lung disease, including bronchiolitis obliterans (BO), in flavorings and popcorn manufacturing workers. However, there are no published reports of lung disease among BFMP consumers. We present a case series of three BFMP consumers with biopsy-confirmed BO. We review data relating to consumer exposures, estimate case exposures, and compare them to diacetyl-containing flavoring-exposed manufacturing workers with lung disease. These consumer cases' exposure levels are comparable to those that caused disease in workers. We were unable to identify any other exposures or diseases known or suspected to cause BO in these cases. BFMP poses a significant respiratory risk to consumers. Some manufacturers have substituted diacetyl with other alpha-diketones that are likely to pose a similar risk. Simple consumer practices such as cooling the popcorn bag would eliminate the risk of severe lung disease.

PMID: 22550695 [PubMed - in process]

Diacetyl as a food additive is GRAS, but aerosolized exposures can cause bronchiolitis obliterans



Diacetyl and Acetyl Propionyl

- Diacetyl and acetyl propionyl are GRAS but are associated with respiratory disease when inhaled
 - The risks associated with inhalation of acetyl propionyl may be as high as from diacetyl based on inhalation studies with rats
- 159 samples purchased from 36 manufacturer and retailers in 7 countries*
- Diacetyl and acetyl propionyl were found in 74.2% of the samples
 - Even found in samples from manufacturers who clearly stated that these chemicals were not present

*Farsalinos, K. E., Kistler, K. A., Gilman, G., Voudris, V. (2015) Evaluation of electronic cigarette liquids and aerosol for the presence of selected inhalation toxins. *Nicotine & Tobacco Research*, 168-174, doi: 10.1093/ntr/ntu176

Flavoring Concerns

- No research on potential health effects of aerosolized vapor exposure
- No research on pyrolysis products of flavorings
- Manufacturing of many flavoring sources are outside the US (China)



Flavoring Concerns

- Benzaldehyde was detected in cherry flavoring, but also in 75% of 145 e-cig refill liquids*
 - Cytotoxic and genotoxic to cell cultures
- Cinnamaldehyde present in 51% of 39 refill liquids*
 - Highly cytotoxic
- Methyl anthranilate was detected in grape flavoring
- 1-hexanol was detected in apple flavoring

*Behar, R.Z., Luo, W., Lin, S.C., Wang, Y., Valle, J., Pankow, J.F. & Talbot, P. (2016). Distribution, quantification and toxicity of cinnamaldehyde in electronic cigarette refill fluids and aerosols. *Tobacco Control*. doi:10.1136/tobaccocontrol-2016-053224

Additional Potential Exposures

- ▶ Tobacco-Specific Nitrosamines (TSNAs)
- ▶ Acetic Acid
- ▶ BTEX
- ▶ Isoprene
- ▶ Diethylene Glycol (antifreeze)*

*Food and Drug Administration. (2009) FDA news release: FDA and public health experts warn about electronic cigarettes. Retrieved from www.fda.gov/newsevents/newsroom/pressannouncements/ucm173222.htm

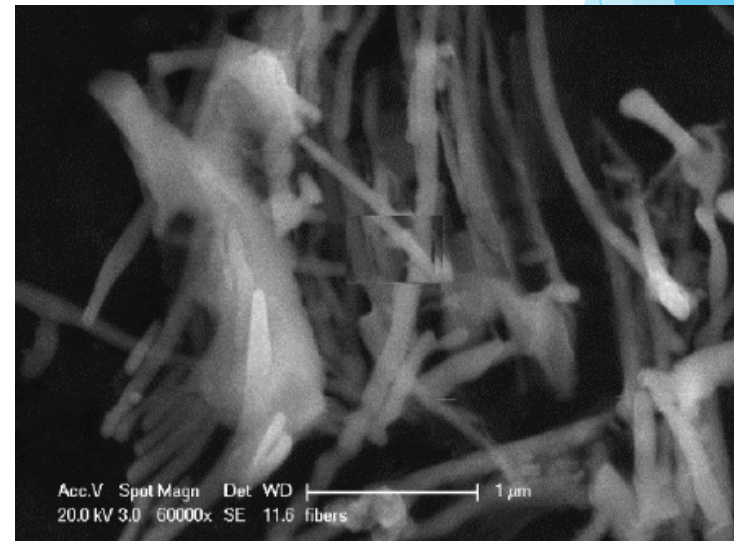
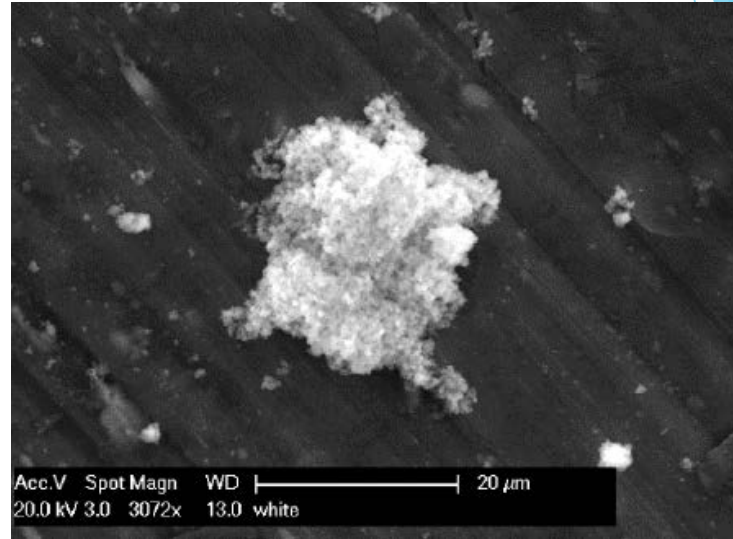
Tobacco-Specific Nitrosamines (TSNAs)

- Some TSNAs are known human carcinogens and are suspected to contribute to the cancer burden of smokers
- Small amounts of TSNAs have been found in e-liquids and vapor
- Residual nicotine from tobacco smoke has been shown to react with ambient nitrous acid to form TSNAs over time
 - Third-hand exposure?

Sleiman, M., Gundel, L.A., Pankow, J., Jacob, P., Singer, B. & Destailats, H. (2010). Formation of carcinogens indoors by surface-mediated reactions of nicotine with nitrous acid, leading to potential thirdhand smoke hazards. *Proceedings of the National Academy of Sciences of the United States of America*, 107(15), 6576-6581. doi: 10.1073/pnas.0912820107

Additional Potential Exposures

- Tin
- Lead
- Nickel
- Zinc
- Copper
- Chromium
- Silicon fibers
- Nanoparticles



Some Reported Health Effects

- Mouth and throat irritation
- Dry cough
- Nausea
- Dizziness
- Changes in heart rhythm
- Changes in blood pressure

IT'S **NOT JUST
"HARMLESS WATER VAPOR"**

E-cigarette aerosol contains at least **10 chemicals** on California's Prop 65 list of chemicals known to cause **cancer, birth defects or other reproductive harm.**

ACETALDEHYDE
CADMIUM
ISOPRENE
LEAD
NICKEL
N-NITROSONORNICOTINE
FORMALDEHYDE
BENZENE
TOLUENE



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Second-Hand Exposure Concerns

- Nicotine (teratogen and addictive)*
- Flavorings (nut and other allergies)
- Formaldehyde (carcinogen)
- Acrolein (listed as a Hazardous Air Pollutant by the EPA)
- Acetaldehyde (possible human carcinogen)
- Fine/ultrafine particles
- Tin, lead, nickel, chromium



*Nicotine levels have been measured in an exposure chamber at levels approximately 10 times below that of traditional cigarette emissions

Czogala, J., M.L. Goniewicz, B. Fidelus, W. Zielinska-Danch, W. Travers, and A. Sobczak: Secondhand exposure to vapors from electronic cigarettes. *Nicotine and Tobacco Research*. 2013. doi:10.1093/ntr/ntt203

Cloud Chasing



<https://www.youtube.com/watch?v=ZgouBVNItQA>



Second-hand Emissions

- ▶ Most vapers don't go to that extreme, and with stealth vaping, they purposely retain the vapor
- ▶ St. Helen et al. determined that systemic retention of nicotine from e-cigarettes is high, averaging 94% (meaning only 6% of the nicotine is emitted) and little to no aerosol is seen when individuals 'stealth vape'
- ▶ Many research protocols use a puffing machine that does not represent what the user emits, but instead, what the device emits
- ▶ Be sure to review how the data were collected to understand the implications

Safety Issues

- ▶ Several incidents of fires and explosions have been reported from the lithium-ion batteries used to charge e-cigarettes
- ▶ Most common causes of fires have been using incorrect chargers or over-tightening of the screwed connection to the charger, which can damage the battery cells and lead to overheating
- ▶ Many lithium-ion batteries used in e-cigarettes do not have overcurrent or overcharge protection, so if they are left charging, the coil can overheat and cause the battery to explode

Long Term Public Health Issues?

- ▶ In 10, 20, 30 years, we could have an entire generation of vapers with unforeseen health effects (COPD, asthma, ???)
- ▶ Long term public health implications?

WHO

- The World Health Organization (WHO) has recommended that consumers be strongly advised not to use electronic nicotine delivery systems, including e-cigarettes, until they are deemed safe and effective and of acceptable quality by a competent national regulatory body.

Food and Drug Administration (FDA)

- August 8, 2016, the FDA regulation banning the sale of e-cigarettes to minors became effective.
 - Photo ID required
 - Retailers may not hand out free samples
 - No sales in vending machines
- The FDA now requires manufacturers, importers, and retailers to report ingredients and place health warnings on products and advertisements
- Vape shops that mix e-liquids will be regulated as a retailer and a manufacturer

Food and Drug Administration (FDA)

- **Manufacturers must:**
 - Stop distributing products that claim it is a modified risk tobacco product
 - Register their establishments and submit a list of products, including labeling and advertisements
 - Submit tobacco health documents by 2017
 - Submit ingredient listing by 2017
 - Submit a premarket application for “new” tobacco products

NIOSH

- NIOSH Current Intelligence Bulletin 67 published April 2, 2015 recommends that employers “establish and maintain smoke-free workplaces that protect those in workplaces from involuntary, secondhand exposures to tobacco smoke **and airborne emissions from e-cigarettes and other electronic nicotine delivery systems.**”

(emphasis added)

ANSI/ASHRAE 62.1

- ASHRAE Standard 62.1 contains requirements for ventilation of spaces that are free of environmental tobacco smoke (ETS).
- Also contains requirements for separation of an ETS-free area from any spaces containing ETS.
- Addendum c to ANSI/ASHRAE Standard 62.1-2013 clarifies that the definition of ETS “includes smoke produced from the combustion of cannabis and controlled substances **and the emissions produced by electronic smoking devices.**”
- “The existing requirements for separation of ETS-free spaces from ETS spaces remains unchanged.”

ANSI/ASHRAE 62.1

- ETS-free areas at positive pressure to ETS areas
- Solid walls, floors, ceiling, and doors with automatic closing mechanisms to separate ETS areas from ETS-free areas
- No recirculation or transfer of air from ETS area to ETS-free area
- Signage for ETS areas

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AIHA White Paper: Electronic Cigarettes in the Indoor Environment

Recommendation:

“E-cigarettes should be considered a source of volatile organic compounds (VOCs) and particulates in the indoor environment that have not been thoroughly characterized or evaluated for safety.”*

*Quoted by NIOSH in the 2015 Current Intelligence Bulletin 67 “Promoting Disease and Injury Through Workplace Tobacco Policies”

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Research on e-cigarettes should be conducted in at least the following areas:

1. Health effects from inhaling e-cigarette ingredients that are reported to be generally recognized as safe (GRAS) via ingestion, but which have not yet been evaluated for inhalation toxicity, as well as their thermal degradation products;
2. Effects of second-hand emissions, third-hand exposures, and nicotine addiction from e-cigarettes;
3. Understanding the dynamics of pre- and post-respiration aerosols and their fate in the environment; and
4. Lifecycle and end-of-use issues.*

Life Cycle Issues

- Some are single use or disposable
- Lithium ion batteries
- Nicotine (acute hazardous waste)
 - EPA: “unused (unsold, expired, or returned) nicotine-containing products, including patches, gums, lozenges, inhalers, nasal sprays, and e-cigarettes, are classified as P075 listed acute hazardous wastes when discarded.”
- Some manufacturers offer recycling programs
- There is at least one disposal company that is disassembling the components, recycling the batteries, metal, and plastic components that can be recycled, then disposing of the nicotine by incineration.



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Four areas of regulation relating to the safety of primary users and people exposed to second-hand vapors or e-juice products should be considered:

1. All e-cigarette devices, whether they are used for therapeutic or recreational purposes, should be evaluated for potential physical and/or electrical hazards by a regulatory agency;
2. The health risks and economic consequences of accidental exposure to e-juices by children, adults and pets should be addressed, including proper labeling and child-resistant packaging requirements;

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Risk-based regulation recommendations (cont.):

3. All future e-juice components that may be used by consumers should be fully evaluated for any potential hazards (e.g., toxicity, flammability, safety hazards, secondary exposures, etc.) prior to introduction into the marketplace; and
4. As e-cigarettes are a source of pollutants, their use in indoor environments should be restricted, consistent with current smoking bans, until, and unless, research documents that they will not significantly increase the risk of adverse health effects to occupants.

Resources

- **AIHA White Paper: *Electronic Cigarettes in the Indoor Environment***

https://www.aiha.org/government-affairs/Documents/Electronic%20Cig%20Document_Final.pdf

- **NIOSH *Current Intelligence Bulletin 67: Promoting Health and Preventing Disease and Injury Through Workplace Tobacco Policies***

http://www.cdc.gov/niosh/docs/2015-113/pdfs/fy15_cib-67_2015-113_v3.pdf

- **ANSI/ASHRAE Addenda a, c, j, k, q, r, and s to ANSI/ASHRAE Standard 62.1-2013: *Ventilation for Acceptable Indoor Air Quality***

https://www.ashrae.org/File%20Library/docLib/StdAddenda/62_1_2013_2015Supplement_20150203.pdf

Questions?

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