Electronic Cigarettes in the Indoor Environment

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Anatomy of an E-Cigarette

**How it works**

- **LED**: Lights up when inhaled to simulate a lit cigarette. It also lets you know if the battery is working or running low.
- **BATTERY**: Most kits come with two rechargeable lithium 3.7 volt batteries. The battery is what makes the device work by charging the atomizer to produce the vapor.

**The atomizer**

When a user inhales the personal vaporizer, the rechargeable battery in the device creates a solid contact with positive and negative wires inside the metal casing of the atomizer that turns it on to produce the vapor in the metal mesh dome. It then pulls the liquid from the cartridge to produce the vapor. The virtually odorless vapor that simulates smoke quickly dissipates in the air when exhaled.
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 on the market.*
- Over 7,700 unique e-cigarette flavors.** As of January 2014
- China produces approximately 90% of the world’s e-cigarettes and 91% of US imports
- Chinese manufacturers shipped more than 300 million e-cigarettes to the US and Europe in 2014
- 2016 GAO import data are in dollars (includes parts, liquids, and devices) = $342,257,308.00


E-cigarette sales in the U.S. were estimated at $2.2 billion in 2014.

In 2015, 99.0% of e-cigarette products contained nicotine.

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.

In 2016, CDC says the number is “more than 2 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.


Cloud Chasing

https://www.youtube.com/watch?v=EVPz7uu4LQs
Long-term Public Health Concerns?

- 1949 Cigarette Ad
  https://www.youtube.com/watch?v=cKMn_-aQoPk
Primary Components

- Propylene Glycol/
  Vegetable Glycerin
- Nicotine
- Flavorings
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
  - Irritated mucous membrane symptoms associated with acute exposure to glycol-based fogs
  - Systemic symptoms (acute headache, dizziness, drowsiness, tiredness) associated with glycol fog

Propylene Glycol/Vegetable Glycerin

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


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
  o Addictive
  o Teratogenic
  o Can harm adolescent brain development
  o Increases heart rate, respiratory rate, blood pressure, and level of alertness

• E-Cig Labeling
  o Some cartridges labeled as containing no nicotine did, in fact, contain detectable levels of nicotine
  o Concentration and delivery inconsistencies

• Nicotine found in the vapor, but lower than what’s emitted from conventional cigarettes
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

- PINK SPOT
- BANANA NUT BREAD
- BLACK MAMBO
- BLU SPOT
- BLUEBERRY COBBLER
- BLUE RAZ COTTON CAN
- BUBBLE GUM
- CHERRY LIMEADE
- CHOCO LOCO TOBACCO
- FROZEN LIME DROP
- FRESH STRAWBERRY
Other Additives

Other Additives
Generally Recognized as Safe (GRAS)?
Diacetyl as a food additive is GRAS, but aerosolized exposures can cause bronchiolitis obliterans.

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

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**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 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

More Diacetyl

- In a different study, diacetyl found in the vapor, but not in the liquid, of 39 of 51 different e-liquid flavors that were tested

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

Additional Potential Exposures

- Tin
- Lead
- Nickel
- Zinc
- Copper
- Chromium
- Silicon fibers
- Nanoparticles
Additional Potential Exposures

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

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?
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
When Cloud Chasing Spills Over: A Different Kind of ‘Vapor Intrusion’

- Floyd (2017) showed that e-cig aerosols can spread through HVAC systems to adjacent parts of a building.
- Nicotine contamination was found to be elevated on surfaces in shops adjacent to small vape shops.
- Cleaning regimens in the vape shops were very aggressive (daily or twice daily) and this seems to control surface contamination adequately within the shops, but adjacent shops did not clean display cabinets as frequently, resulting in elevated nicotine contamination.

Some Reported Health Effects

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

- Acrolein, formaldehyde, acetaldehyde all individually shown to reduce mucociliary clearance

- Chronic exposure to propylene glycol alone stimulated mucociliary clearance, but chronic, daily, 20 min-exposure to nicotine/propylene glycol mixture slowed mucociliary clearance


Mucociliary Clearance

• Both traditional cigarette and e-cigarette exposure decrease the expression of genes involved in cilia assembly and movement
  • E-cigarette aerosol impacts less pronounced traditional cigarette exposure
  • E-cigarette products containing nicotine more pronounced than those without

• Susson et al. (2015) exposed mice to e-cigarette vapor containing menthol and 1.8% nicotine via a whole-body exposure system for 1.5 hours, twice per day for 2 weeks and then infected those mice with *S. pneumoniae*.
  • The e-cigarette exposed mice had significantly increased bacterial burden after infection than control mice, indicating that e-cigarette exposure suppresses bacterial clearance by alveolar macrophages.

Life Cycle Issues

• Some are single use or disposable
• Lithium ion batteries
• Nicotine (acute hazardous waste)
  o 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 and disposal companies offer recycling programs, disassembling the components, recycling the batteries, metal, and plastic components, then disposing of the nicotine by incineration.

Safety Issues

• Several incidents of fires and explosions have been reported from the lithium-ion batteries used to charge e-cigarettes.
  • 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.

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
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.
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)
In reviewing the literature about the constituents in and exposures from e-cigarettes, the committee made nine conclusions:

- **Conclusion 3-1.** There is **conclusive evidence** that e-cigarette use increases airborne concentrations of particulate matter and nicotine in indoor environments compared with background levels.

- **Conclusion 3-2.** There is **limited evidence** that e-cigarette use increases levels of nicotine and other e-cigarette constituents on a variety of indoor surfaces compared with background levels.

- **Conclusion 4-1.** There is **conclusive evidence** that exposure to nicotine from e-cigarettes is highly variable and depends on product characteristics (including device and e-liquid characteristics) and how the device is operated.

- **Conclusion 4-2.** There is **substantial evidence** that nicotine intake from e-cigarette devices among experienced adult e-cigarette users can be comparable to that from combustible tobacco cigarettes.
Conclusion 5-1. There is conclusive evidence that in addition to nicotine, most ecigarette products contain and emit numerous potentially toxic substances.

Conclusion 5-2. There is conclusive evidence that, other than nicotine, the number, quantity, and characteristics of potentially toxic substances emitted from e-cigarettes is highly variable and depends on product characteristics (including device and e-liquid characteristics) and how the device is operated.

Conclusion 5-3. There is substantial evidence that except for nicotine, under typical conditions of use, exposure to potentially toxic substances from ecigarettes is significantly lower compared with combustible tobacco cigarettes.

Conclusion 5-4. There is substantial evidence that e-cigarette aerosol contains metals. The origin of the metals could be the metallic coil used to heat the eliquid, other parts of the e-cigarette device, or e-liquids. Product characteristics and use-patterns may contribute to differences in the actual metals and metal concentrations measured in e-cigarette aerosol.
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.”
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
White Paper:
Electronic Cigarettes in the Indoor Environment

American Industrial Hygiene Association®

October 19, 2014

Sponsored by the AiHA®
Indoor Environmental Quality Committee and Risk Assessment Committee
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”
Bibliography

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

• NIOSH *Current Intelligence Bulletin 67: Promoting Health and Preventing Disease and Injury Through Workplace Tobacco Policies* (NIOSH Publication No. 2015-113)
  

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