

# ELECTRONIC CIGARETTE LIQUIDS AND VAPORS: IS IT HARMLESS WATER VAPOR

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TRDRP Electronic Cigarette Webinar

2013

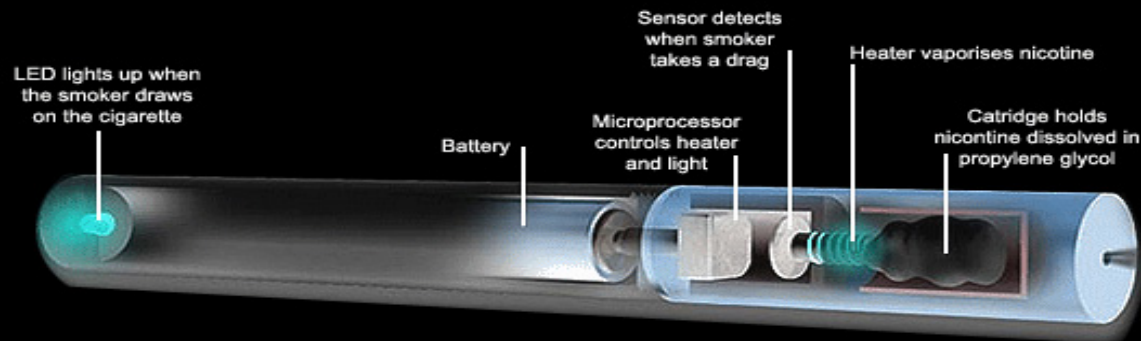
- Conflict of Interest: None
  - Disclosure: I have been supported by a TRDRP Cornelius Hopper Award.
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# OUTLINE

- Background
  - Electronic Cigarette Fluid Composition
  - Chemicals Unique to Electronic Cigarette Aerosol
  - Composition of Electronic Cigarette Exhale
  - Variation in Electronic Cigarette Performance
  - Conclusions
  - Significance
  - Acknowledgments
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# BACKGROUND

- Electronic cigarettes (EC) are novel tobacco-free nicotine delivery devices that aerosolize a nicotine containing solution.
- They are used for two major reasons:
  - Alternative to conventional cigarettes
  - To aid in smoking cessation
- Three major components:
  - Battery
  - Atomizing unit
  - Cartridge (contains the nicotine solution)
- Devices are not currently FDA regulated.



# FLUID COMPOSITION



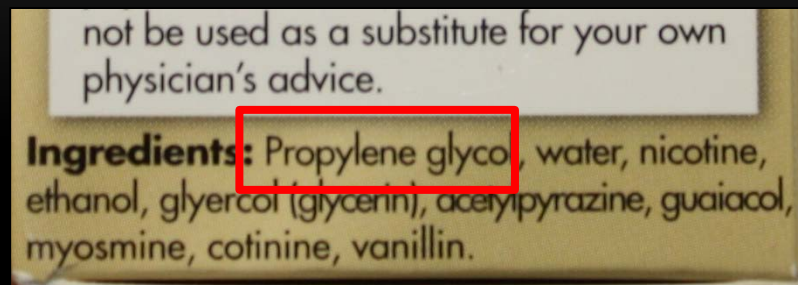
# EC FLUID COMPOSITION

- Many fluids come premixed from China, but some are now being made in United States, Germany, and Europe.
- The origins and quality of the of ingredients are generally not known.
- Fluids contains:
  - Humectant(s), Nicotine, and Flavorings



# ELECTRONIC CIGARETTE FLUID: MAIN INGREDIENTS

- Humectant(s): propylene glycol (or glycerin) for vapor production.



- Flavorings (tobacco, menthol, coffee, chocolate, cinnamon, vanilla, etc.)

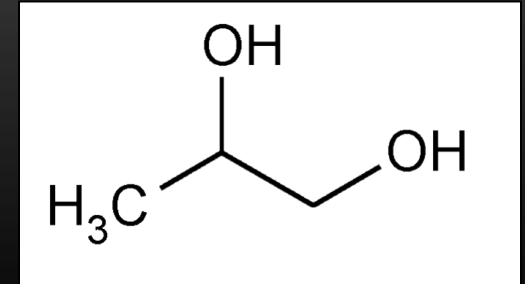
- Nicotine: varying concentrations
  - 0-24 mg/mL in cartridges/cartomizers
  - Up to 100 mg/mL in refill fluids

Regular Cigarette	E-liquid Nicotine
Unfiltered, very strong	Super High - 36mg
Full Flavored, Strong	Extra High - 24mg
Regular (most)	High - 16mg
Light	Med - 11mg
Ultra-light	Low - 8mg
Freedom from Nicotine!	No Nicotine - 0mg

30 ml

10 ml

# PROPYLENE GLYCOL

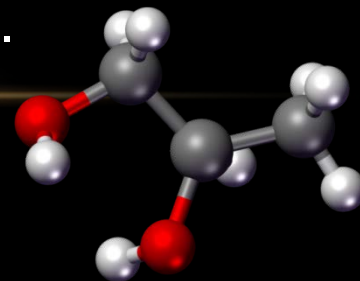


- A humectant used to produce aerosol in EC.
- FDA approved food additive (humectant, solvent for colors and flavors), cosmetics, and medicines.
  - Also found in antifreeze and de-icing agents for cars, planes, and boats.
- MSDS:
  - Forms explosive gas mixtures
  - Generally safe for oral intake
  - May be different when heated and inhaled

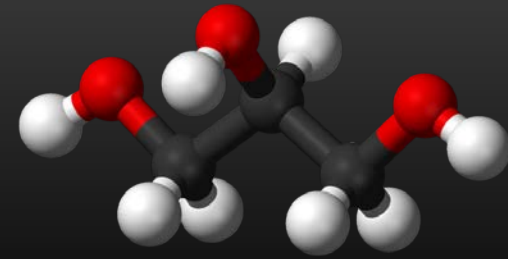


# PROPYLENE GLYCOL

- Studies have shown that inhalation exposure to propylene glycol affects airways.
  - Short term exposure causes eye, throat, and airway irritation. (Wieslander et al 2001, **Occup Environ Med**; Vardavas et al 2012, **Chest**)
  - Long term exposure can result in children developing asthma. (Choi et al 2010, **PlosOne**)
- Also used in theatrical fog/smoke machines.
  - Individuals exposed to theatrical propylene glycol based fog/smoke suffer from respiratory, throat, and nose irritation. (Moline et al 2000)
- Above data support the idea that inhalation of propylene glycol can cause respiratory irritations in some individuals.



# GLYCERIN



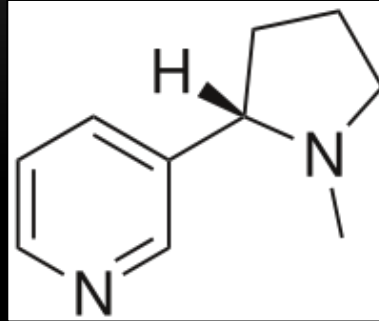
- A humectant used instead of or in combination with propylene glycol in EC fluids for aerosol production.
  - Most common glycerin used is vegetable glycerin.

Ingredients: Distilled Water, Nicotine, FCC Grade Vegetable Glycerin, Natural Flavors, Artificial Flavors, Citric Acid. Nicotine content 13 - 16 mg per cartridge.

- FDA considers it relatively safe to ingest
  - Used as solution carriers in flavors
- MSDS
  - Slightly hazardous in case of skin and eye contact, ingestion, and inhalation.
  - Prolonged exposure may cause organ damage.

# NICOTINE

- Is the addictive component of conventional and electronic cigarettes.



- Large amounts of nicotine are lethal
  - Is also an insecticide and toxicant
  - 60 mg adult; 6 mg children
- Some EC manufacturers have caution labels in regards to nicotine use.

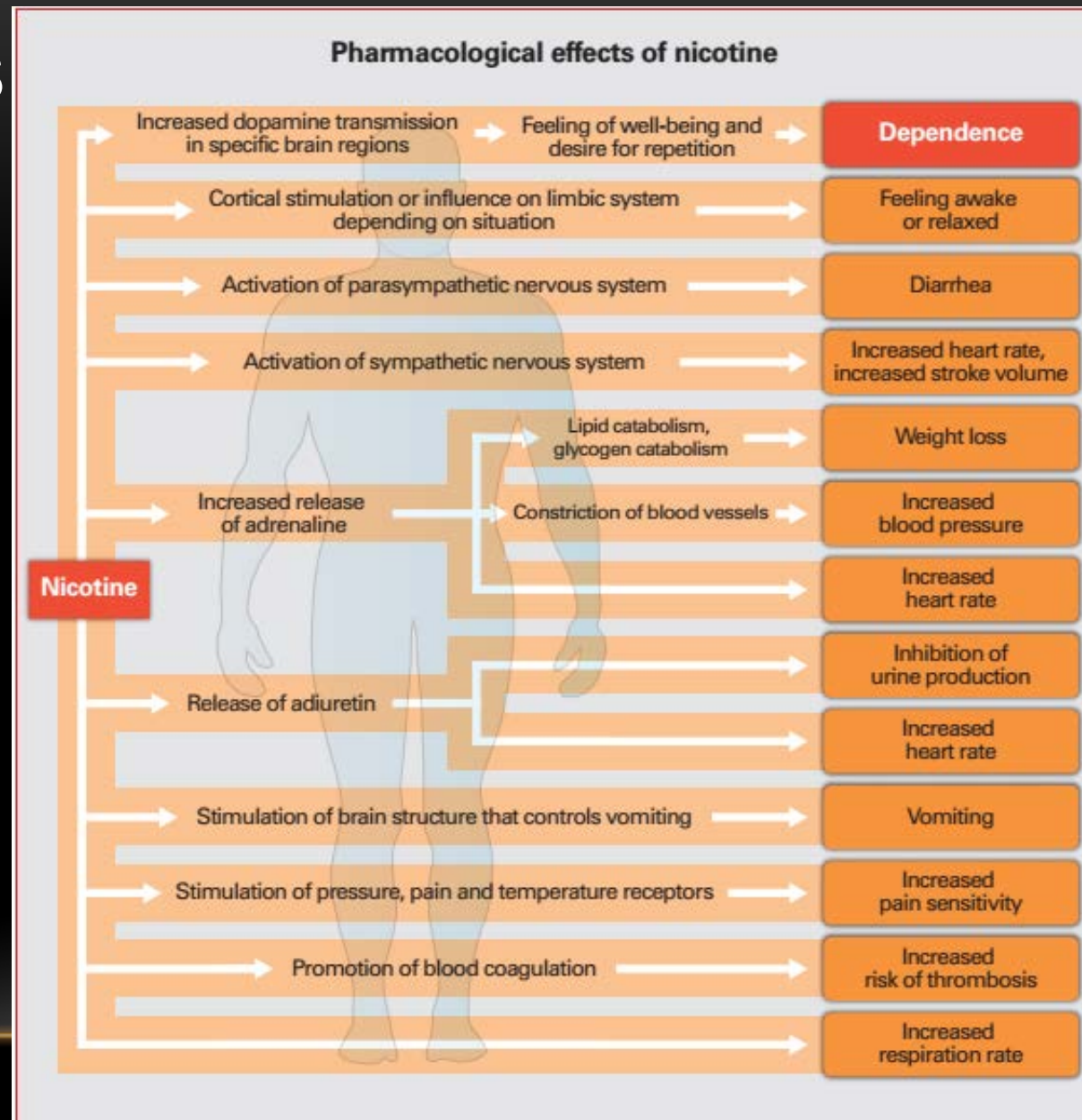
**CALIFORNIA PROPOSITION 65**  
**Warning:** This product contains nicotine, a chemical known to the state of California to cause birth defects or other reproductive harm.

**WARNING:**  
Nicotine is highly addictive. Use only if above legal age. Do not use this product to treat any medical condition or habit. Consult a doctor prior to use if pregnant, breast-feeding or suffer from any medical condition. Stop use if you show any sensitivity to this product. This product contains nicotine, a chemical known to the State of California to cause birth defects or other reproductive harm.

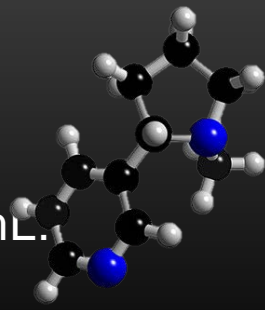
**WARNING:** NJOY products are not smoking cessation products and have not been tested as such. The U.S. FDA has not approved NJOY products for any use and they are not intended to diagnose, cure, mitigate, treat, or prevent any disorder, disease, or physical or mental condition. NJOY products contain nicotine, a chemical known to the State of California to cause birth defects or other reproductive harm. Nicotine is addictive and habit forming, and it is very toxic by inhalation, in contact with the skin, or if swallowed. Ingestion of the non-vaporized concentrated ingredients in the cartridges can be poisonous. Physical effects of nicotine may include increased heart rate and accelerated blood pressure. If the cartridge is swallowed, seek medical assistance immediately. NJOY products are intended for use by adults of legal smoking age (18 or older in California), and not by children, women who are pregnant or breast feeding, or persons with or at risk of heart disease, high blood pressure, diabetes or taking medicine for depression or asthma. NJOY products may not be sold to minors. Identification of all persons under 26 will be required before purchase. **KEEP OUT OF REACH OF CHILDREN.**

# NICOTINE: HEALTH EFFECTS

- Nicotine has many effects on the human body.
- In addition: provides the feeling of being awake or relaxed, curbs appetite, promotes blood coagulation (Schaller et al 2013, **Electronic Cigarettes – An Overview**)
- Nicotine also crosses the placenta and can have negative effects (damage lungs, heart, and central nervous system) on the developing fetus. (Maritz 2009 **Ther Adv Respir Dis**).



# NICOTINE



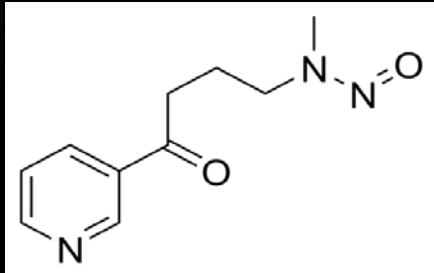
- In cartridge/refill fluid nicotine concentration range form 0-100 mg/mL.
- EC manufacturers do not always accurately label the amount of nicotine in their products. (Cheah et al 2012, **Tob Control**; Trtchounian et al 2011, **Tob Control**)
- Nicotine concentration for multiple brands of EC cartridges are not always accurately labeled on the product. (Trehy et al 2012 **J Liq Chromatogr R T**)
  - One brand had a third of the labeled nicotine.
  - One brand labeled no nicotine measured 12 -21 mgs.
  - One brand labeled 24 mg nicotine measured <1 mg.
- Nicotine concentrations were measured in 35 different brands and most EC cartridges contained less nicotine than labeled. (Goniewicz et al 2013, **Tob Control**)

# Brands	Accuracy of Label
7	More nicotine
10	Accurate
18	Less nicotine

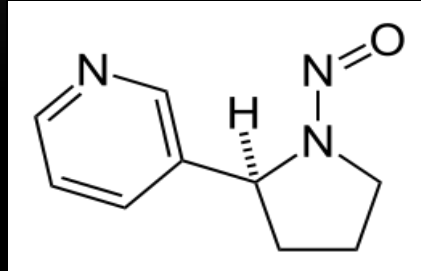


# TOBACCO-SPECIFIC NITROSAMINES

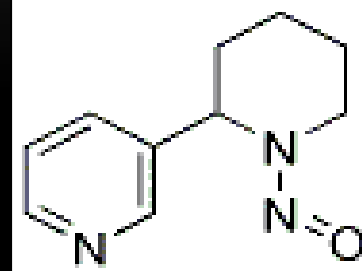
- Tobacco specific nitrosamines (TSNAs) are carcinogenic compounds found in tobacco and tobacco smoke.



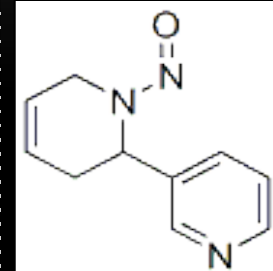
NNK



NNN



NAB

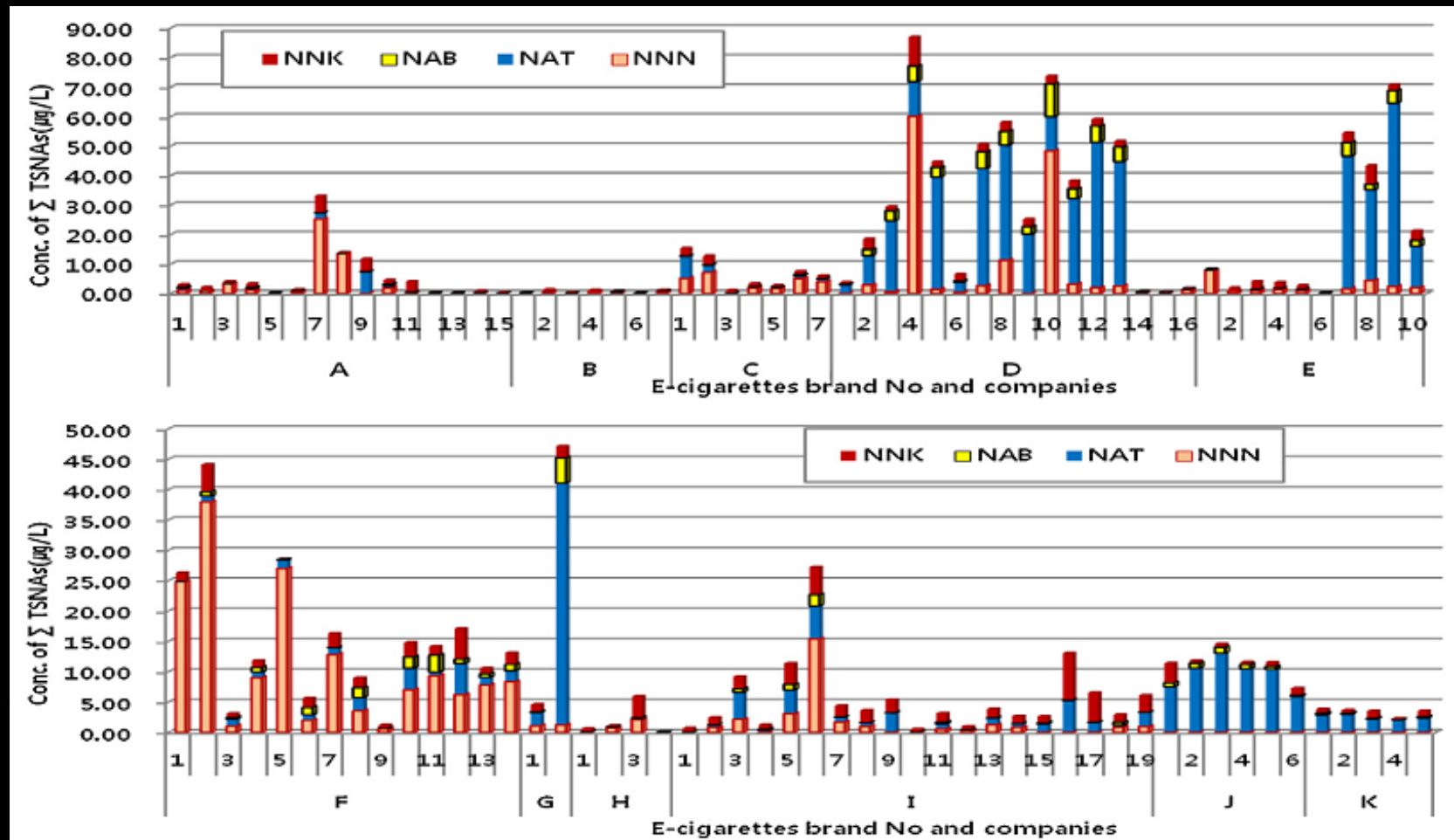


NAT

- Small amounts of nitrosamines have been found in EC fluids.
- As nicotine concentration increased, the number and concentration of TSNA's increased. (Laugesen 2008, Health New Zealand Ltd.)
- One brand contained small amounts of all four TSNA's (shown above), and only NNK and NNN were found in other. (Westenberger 2009, Dept Health & Human Services FDA)
- NNN and NNK were detected in 9/12 EC brands. (Goniewicz et al 2013, Tob Control)

# TOBACCO SPECIFIC NITROSAMINES

- TSNAs were measured in 105 replacement fluids for eleven brands. (Kim et al 2013, J Chromatogr A).
  - Concentration of TSNAs varied within and between brands.



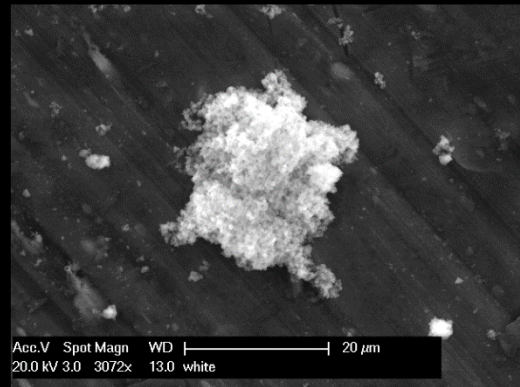
# METALS IN FLUID

- ICP ESR analysis was not able to detect arsenic, cadmium, chromium, nickel, and lead. (Laugesen 2009, Society for Research on Nicotine and Tobacco (SRNT)).
- SEM identified metal particles and tin whiskers in EC cartridge fluid and fibers. (Williams et al 2013, **PlosOne**)

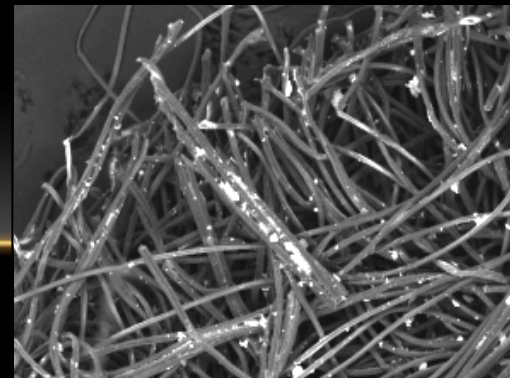
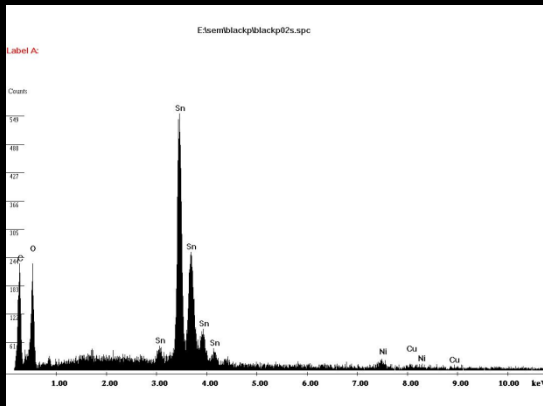


Tin Pellet

Tin Particles



Tin Whiskers



Tin particles on fibers



# AEROSOL COMPOSITION



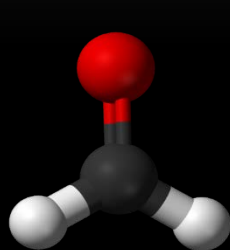
# AEROSOL COMPOSITION

- Propylene glycol
- glycerin
- Flavorings (many)
- **Nicotine**
- **NNN**
- **NNK**
- NAB
- NAT
- **Ethylbenzene**
- **Benzene**
- P,m, xylene
- **Toluene**
- **Acetaldehyde**
- **Formaldehyde**
- **Naphthalene**
- **Styrene**
- **Benzo(b)fluoranthene**
- Chlorobenzene
- **Crotonaldehyde**
- **Propionaldehyde**
- Benzaldehyde
- Valeric acid
- Hexanal
- Fluorine
- Anthracene
- Pyrene
- Acenaphthylene
- Acenaphthene
- Fluoranthene
- **Benz(a)anthracene**
- **Chrysene**
- Retene
- **Benzo(a)pyrene**
- **Indeno(1,2,3-cd)pyrene**
- Benzo(ghi)perylene
- **Acetone**
- **Acrolein**
- Silver
- **Nickel**
- Tin
- Sodium
- Strontium
- Barium
- Aluminum
- **Chromium**
- Boron
- Copper
- **Selenium**
- **Arsenic**
- **Cadmium**
- Silicon
- Lithium
- **Lead**
- Magnesium
- Manganese
- Potassium
- Titanium
- Zinc
- Zirconium
- Calcium
- Iron
- Sulfur
- Vanadium
- **Cobalt**
- Rbuidium

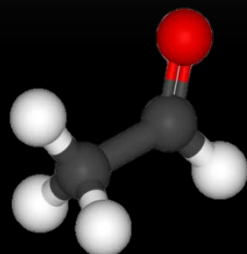
Compounds in **yellow** are from FDA 2012,  
Harmful and Potentially Harmful  
Substances – Established List

# CARBONYL COMPOUNDS

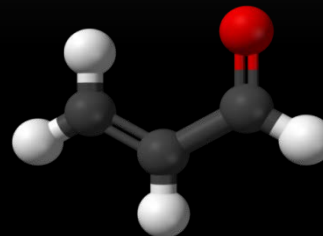
- Formaldehyde, acetaldehyde, and acrolein were found in small amounts in EC (McAuley et al 2012, **Inhal Toxicol**; Goniewicz et al 2013, **Tob Control**)



Formaldehyde



Acetaldehyde

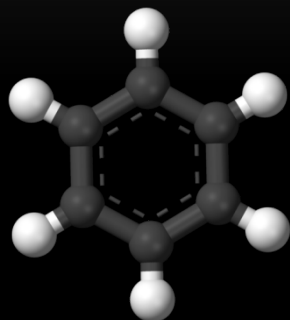


Acrolein

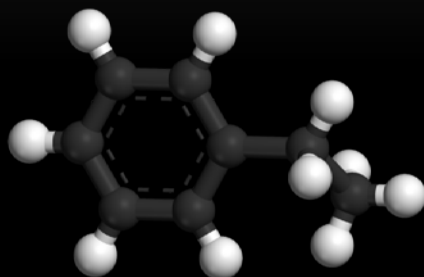
- Formaldehyde and acrolein were found in glycerin based EC fluid. (Schaller et al 2013, **Electronic Cigarettes – An Overview**)
  - Probably formed from heating glycerin
- Formaldehyde and acetaldehyde could form from oxidation of propylene glycol. (Schripp et al 2013, **Indoor Air**)

# VOLATILE ORGANIC COMPOUNDS

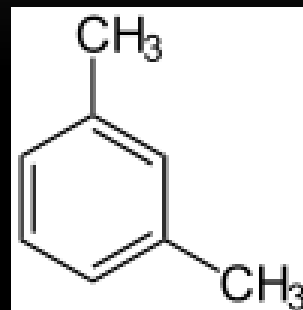
- Most common VOCs found in EC: benzene, toluene, ethylbenzene, and p,m, xylene.



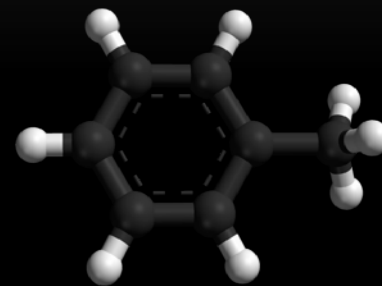
Benzene



Ethylbenzene



p, m, o, xylene



Toluene

- 10/12 brands contained detectable levels of toluene and p, m, xylene. (Goniewicz et al 2013, **Tob Control**)
- All four VOCs (above) were found in EC aerosol. (McAuley et al 2012, *Inhal Toxicol*)

# METALS IN AEROSOL

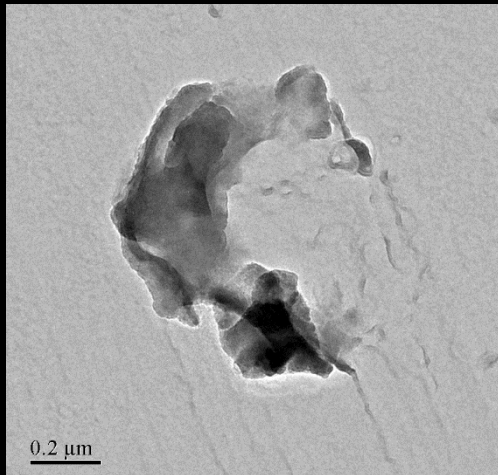
Aluminum	Zinc	Titanium	Bismuth	Indium	Rhodium	Yttrium
Iron	Barium	Zirconium	Dysprrium	Iridium	Ruthinium	Ytterbium
Nickel	Boron	Arsenic	Erbium	Lanthenum	Scandium	
Sodium	Calcium	Cadmium	Europium	Luteium	Samarium	
Chromium	Lithium	Cobalt	Gallium	Molybdenum	Tantium	
Copper	Silicon	Rhubidium	GadolInium	Palladium	Terbium	
Magnesium	Silver	Selenium	Germanium	Palladium	Tellerium	
Manganese	Strontium	Vanadium	Gold	Preseodymium	Thorium	
Lead	Sulfur	Antimony	Hafnium	Platinum	Thullium	
Potassium	Tin	Beryllium	Holmium	Rhenium	Tungsten	

(Goniewicz et al 2013, **Tob Control**; Williams et al 2013, **PlosOne**)

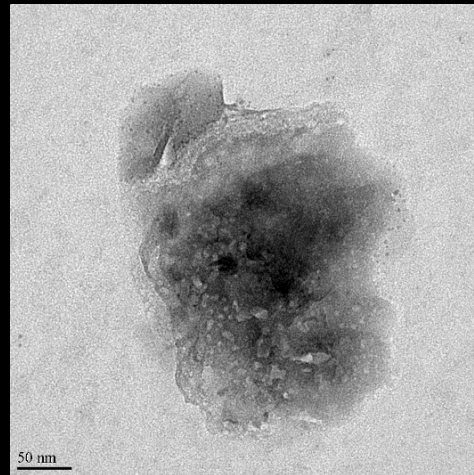
Legend		
Elements higher in aerosol than smoke	Elements lower in aerosol than smoke	Elements Goniewicz et al report
Elements equal in aerosol than smoke	Elements Williams et al report	Elements not found in aerosol

# METALS IN AEROSOL

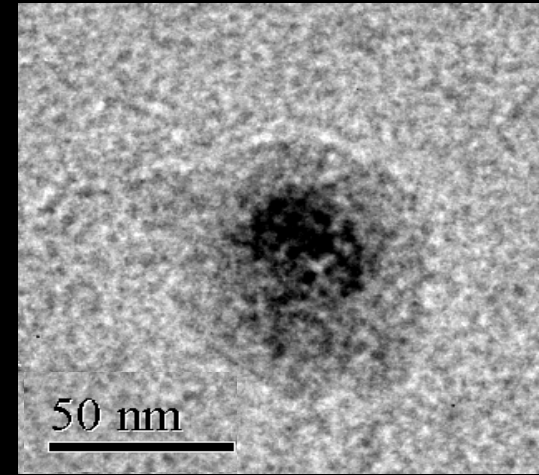
- Chromium, nickel, and tin nanoparticles were found in one brand of EC. (Williams et al 2013, **PlosOne**)



Chromium



Nickel



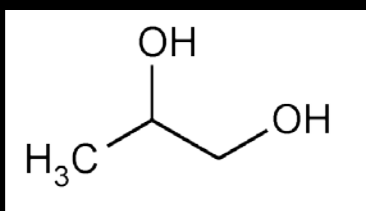
Tin

# COMPOSITION OF EXHALE

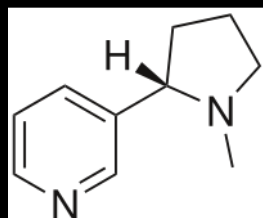


# E-CIGARETTE EXHALE

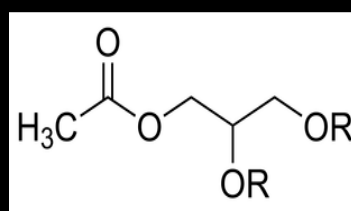
- Schripp et al 2013, **Indoor Air**
- Exhaled aerosol contained propylene glycol, glycerol, flavorings, and nicotine.
  - Also contained: acetone, formaldehyde, acetaldehyde, propanal, diacetyl, and triacetyl.



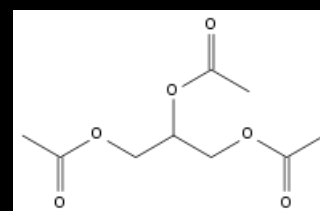
Propylene glycol



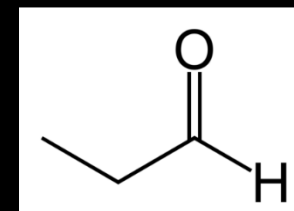
Nicotine



Diacetyl



Triacetyl



Propanal

- In addition ultrafine/fine particles (30-100 nm) were found in the exhale of EC users.
- Above data support the idea that EC users' exhale contains a number of chemicals.



# E-CIGARETTE USERS' EXHALE



“Overall, the EC are a new source of VOCs and ultrafine/fine particles in the indoor environment. Therefore, the question of “passive vaping” can be answered in the affirmative.”

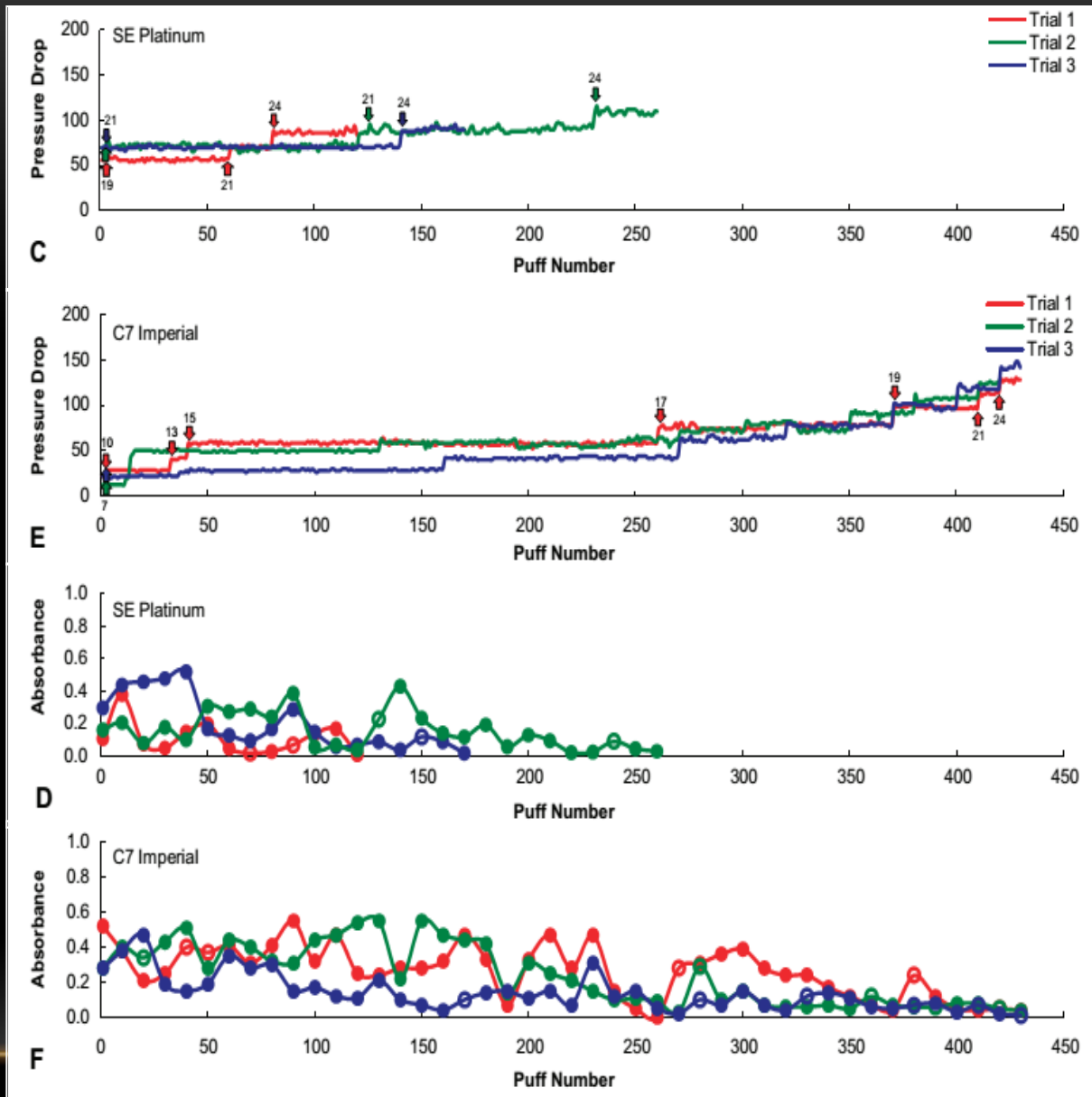
- Schripp et al 2013, **Indoor Air**

# PERFORMANCE CHARACTERISTICS



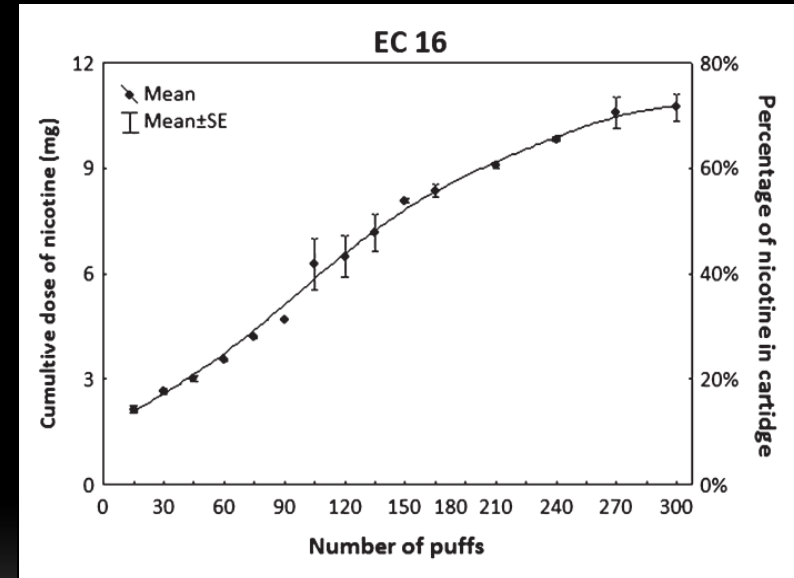
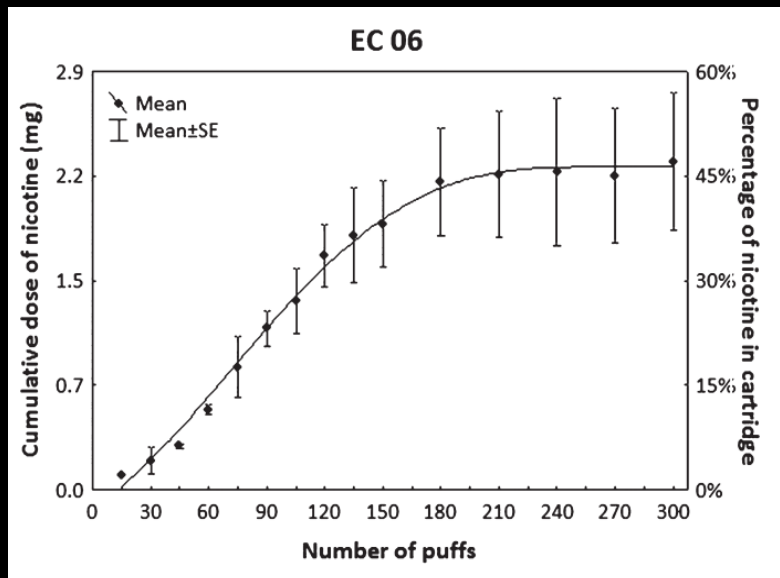
# PERFORMANCE VARIATION

- All EC brands perform differently with respect to:
  - Higher suction (Trtchounian et al 2010, Nicotine Tob Res).
  - Puff duration (Hua et al 2011, Tob Control)
  - Aerosol production (Williams et al 2011, Nicotine Tob Res).
- Variation within and between brand performance.



# PERFORMANCE VARIATION

- Nicotine was measured in the aerosol of 16 brands over time. (Goniewicz et al 2013, *Nicotine Tob Res*)
  - The maximum nicotine measured was between 150-180 puffs.
  - Variation within and between brands.



# CONCLUSIONS

- EC fluid and aerosol contain carbonyls, VOCs, TSNAs, and metals, and overall have fewer chemicals than conventional cigarettes.



- While many carcinogens are found in small amounts in EC fluid, aerosol, and exhale and may reduce cancer, the effects of EC products on cancer may not be known for many years.
- Based on a single study, exhaled EC aerosol contain propylene glycol, ultrafine particles, nicotine, metals, and carcinogens which are added to indoor air.
- Performance variation within and between brands results in variation in the amount of chemicals EC users and non-users will be exposed to.

# ACKNOWLEDGEMENTS

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An To  
Ivana Lacey  
Michael Dang



- Tobacco Related Disease Research Program
- Environmental Toxicology Program

**Thank You!!**