Secondhand and Thirdhand Smoke from Cigarettes, Marijuana and E-Cigarettes

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Thanks

• **Lab Staff**
  - Kelly Pratt, Adam Whitlatch, Abel Huang, Kathryn Jee

• **UCSF**
  - John Balmes, Neal Benowitz, Peter Ganz, Peyton Jacob, Chris Havel, Lisa Yu, Pura Tech

• **Lawrence Berkeley Lab**
  - Lara Gundel, Mohamad Sleiman, Hugo Destaillats

• **UC Tobacco-Related Disease Research Program**
  - Grant #s 12FT-0114, 21 ST-011, 20PT-0184 and 24RT-0039
Outline

• Smoke basics
• Secondhand smoke
• Thirdhand smoke
• Tobacco and Marijuana
• E-Cigarettes
• Cardiovascular Effects of Secondhand Smoke and E-Cigs
• Summary
What is an aerosol?

- Gases + Droplets of oils and waxes + small particles
- Smoke is an aerosol
- E-cigarette “vapor” is an aerosol
- Marijuana “vapor” is an aerosol
- Air freshener spray is an aerosol
Cigarettes as a Model Combustion Aerosol

Or: Burning Leaves in Your House is a Bad Idea
Sidestream smoke is more toxic than mainstream smoke

• Sidestream is chemically different from mainstream
  – Sidestream
    • Lower temperature $\rightarrow$ larger molecules
  – Mainstream
    • Higher temperature $\rightarrow$ smaller molecules
What is Secondhand Smoke?

- 85% Sidestream: 15% exhaled Mainstream

- Combustion creates thousands of different chemical compounds:
  - **Gas phase inorganic:** CO$_2$, H$_2$O, CO, NH$_3$
  - **Very volatile organic compounds (VVOCs):** formaldehyde, acrolein, 1,3-butadiene
  - **Volatile organic compounds (VOCs):** benzene, toluene, NMDA
  - **Semi-volatile organic compounds (SVOCs):** Nicotine, some PAHs and TSNAs
  - **Particulate matter:** benzo(a)pyrene, NNK, THC
Thirdhand Smoke

Indoor Surfaces

SHS

THS
What part of secondhand smoke creates thirdhand smoke?

• Particles and droplets of oils and waxes (Tar)
• 10% of secondhand smoke is tar

Thirdhand Smoke starts with Tar
What is Thirdhand cigarette smoke?  

**The 3 R’s**

Chemicals in cigarette smoke that:

- **Remain** on surfaces and in dust
- **Re-emit** back into the gas phase
- **React** with other chemicals in the environment to make new chemicals
Remain

• Tar chemicals stick to surfaces before they can be removed by ventilation
  • Walls, carpet, dust, people...

• Tar absorbs into porous materials

• Tar contains nicotine and many toxins and carcinogens
  • Nitrosamines
  • Polycyclic aromatic hydrocarbons

• Persistence increases exposure time
Nicotine persists in surfaces
(after smoking ends)

![Graph showing the persistence of nicotine in different surfaces over days of clean air ventilation.](image-url)
Re-Emit

• Combustion forces tar chemicals (normally solids or liquids) into the air
• Tar cools, condenses and sticks to surfaces
• Once on a surface, each chemical reaches equilibrium
• Fraction in the air depends on the chemical
Paper exposed to smoke off-gasses volatile chemicals

Parts per billion

- Acetonitrile
- Acetone
- Methanol
- Isopropyl Alcohol
- Acetaldehyde
- Ethyl alcohol
- Ammonia
- Furan
- Chloromethane
- Acrolein
- 2-Butanone
- Pyrazine
- Acrylonitrile
- Formaldehyde
- 1,3-Butadiene
React

• Where there are chemicals, there are chemical reactions

• Which reactions do we know about?
  
  – Nicotine + nitrous acid = **NNK**
    » Carcinogen
  
  – Nicotine + ozone = **formaldehyde**
    » Carcinogen

  – Tar + ozone = **ultrafine particles**
    » Can cause heart and lung disease
NNK persists in surfaces (after smoking ends)

NNK (ng/cm²) vs Days of clean air ventilation

- **Curtain**
- **Carpet**
- **Wallpaper**

Days of clean air ventilation

0 10 20 30 40 50 60 70 80 90 100 110
Thirdhand Smoke Emits Particles
“Secondary” particles from Thirdhand Smoke

[Graph showing the concentration of secondary particles over time from 9:30 to 11:00, with a peak at 9:45, and a gradual decrease thereafter.]
Thirdhand Smoke is a persistent environmental contaminant

• Remains
  – Weeks and months of ventilation do not remove Thirdhand Smoke
  – Re-Emits
    – Nicotine, formaldehyde, acetonitrile, acetone and other volatile chemicals

• Reacts
  – Nicotine reacts to form NNK
  – THS reacts to form particles
Charting the Unknown: Data from Marijuana and E-Cigarettes
Similarities between tobacco and marijuana smoke

• Leaf contains high concentrations of oils and waxes
• Nicotine and THC both survive combustion
• It doesn’t matter what you burn: **Combustion creates complex, toxic aerosols**
Toxins in Sidestream

<table>
<thead>
<tr>
<th></th>
<th>Health Effects</th>
<th>Tobacco</th>
<th>Marijuana</th>
</tr>
</thead>
<tbody>
<tr>
<td>weight (mg)</td>
<td></td>
<td>788</td>
<td>769</td>
</tr>
<tr>
<td>puffs</td>
<td></td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>tar (mg)</td>
<td>Multiple</td>
<td>24</td>
<td>50</td>
</tr>
<tr>
<td>CO (mg)</td>
<td>Inhibits respiration</td>
<td>62</td>
<td>54</td>
</tr>
<tr>
<td>Ammonia (mg)</td>
<td>Irritant</td>
<td>5.6</td>
<td>14.3</td>
</tr>
<tr>
<td>Nicotine (mg)</td>
<td>Addictive</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>NOx (mg)</td>
<td>Inflame lung</td>
<td>1.2</td>
<td>2.3</td>
</tr>
<tr>
<td>Formaldehyde (μg)</td>
<td>Carcinogen</td>
<td>886</td>
<td>383</td>
</tr>
<tr>
<td>Acrolein (μg)</td>
<td>Cardiotoxin</td>
<td>437</td>
<td>566</td>
</tr>
<tr>
<td>HCN (μg)</td>
<td>Toxin</td>
<td>84</td>
<td>685</td>
</tr>
<tr>
<td>Benzo (a) pyrene (ng)</td>
<td>Carcinogen</td>
<td>91</td>
<td>101</td>
</tr>
<tr>
<td>NNK (ng)</td>
<td>Carcinogen</td>
<td>92</td>
<td>0</td>
</tr>
</tbody>
</table>

Moir et al., 2008
E-Cigarette Toxins

• Even smaller particles
  – Median diameter for cigarettes: 110-340 nm
  – Median diameter for e-cigarettes: 5-50 nm
  – E-cigarette particles evaporate faster

• Nicotine
  – No sidestream but, more spills and leaks

• Formaldehyde
  – 4-100 X less

• Acrolein
  – Equal to 10 X less

• Flavorings: benzaldehyde (cherry), cinnamonaldehyde ...
Marijuana e-cigarette aerosols

• Terpenes are odorant, active chemicals found in cannabis, tobacco and e-liquids
  • Limonene, Pinene, Linalool, Myrcene and others
• Secreted by same plant glands that make THC
• Can be used to reduce viscosity of hash oil in vape pens
• React to form particles in air
  – Research on air fresheners
# Toxin Exposure Patterns

<table>
<thead>
<tr>
<th></th>
<th>Users</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cigarettes</td>
<td>Marijuana</td>
<td>E-cigarettes</td>
<td>SHS</td>
<td>THS</td>
</tr>
<tr>
<td>Particles</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Combustion Toxins</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Nicotine</td>
<td>+++</td>
<td>-</td>
<td>++</td>
<td>+</td>
<td>++?</td>
</tr>
<tr>
<td>THC</td>
<td>-</td>
<td>+++</td>
<td>-</td>
<td>+</td>
<td>?</td>
</tr>
<tr>
<td>Formaldehyde &amp; Acrolein</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
</tbody>
</table>
Flow-mediated dilation (FMD), a predictor of heart attack risk

• Measure diameter of brachial (arm) artery by sonography
• Restrict blood flow in arm with blood pressure cuff for 5 minutes
• Release cuff and measure diameter of brachial artery again.

Healthy blood vessels respond to the rush of blood by dilating.
Flow-Mediated Dilation of the Brachial Artery Measured by Ultrasound
E-Cigarettes reduce FMD in healthy young people

<table>
<thead>
<tr>
<th>% FMD</th>
<th>Nonsmokers</th>
<th>Smokers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Smoking Cigarette</td>
<td>7.83</td>
<td>5.62</td>
</tr>
<tr>
<td>After Smoking Cigarette</td>
<td>3.96*</td>
<td>2.82*</td>
</tr>
<tr>
<td>Before Using E-Cigarette</td>
<td>7.38</td>
<td>5.88</td>
</tr>
<tr>
<td>After Using E-Cigarette</td>
<td>4.56*</td>
<td>3.99*</td>
</tr>
</tbody>
</table>

Carnavale et al. 2016
Conclusions

• If it burns, it creates smoke
  – It doesn’t matter if it is tobacco or marijuana
• Aerosols linger in the environment
  – Any aerosol can create THS
• Breathing aerosol particles can increase risk of heart attack