The Deposition and Fates of Inhaled Transport Related Particulate Material

by

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Sustainable Goods Movement: Maintaining the Environment, Economy and Equity

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“All substances are poisons; There is none which is not a poison. The right dose differentiates a poison from a remedy.”
OUTLINE

* ENVIRONMENTAL PARTICLES
* THE HUMAN RESPIRATORY TRACT
* DEPOSITION OF INHALED PARTICLES
* U.S. EPA CRITERIA AIR POLLUTANTS
* CALIFORNIA DIESEL EXHAUST DOSES
* CALIFORNIA PM ISSUES
* CONCLUDING REMARKS
* REFERENCES
EM PHOTO OF PARTICLES IN IRVINE AIR
TROPOSPHERIC PARTICLES - SIMPLIFIED

Typical Particles in Each Mode

Combustion + Other Emissions + Vapor Condensation + Radioactive Decay + Gas-to-Particle Conversions

Combustion + Other Emissions + Condensation + Coagulation of Ultrafine Particles

Large Particle Emissions + Soil & Volcanic Dusts + Fog & Sea Spray + Dander, Spores & Pollen

Relative Amount

0.001 0.01 0.1 1 2.5 10 100

Aitken Nuclei Accumulation Mode

Ultrafine Particles Fine Particles Coarse Particles
TROPOSPHERIC AEROSOL USING THREE METRICS

A. Count
- Particles in Peak
- High-temperature emissions
- Gas-to-particle conversions
- Combustion products
- Vapor condensation
- Radioactive decay
- Nanoparticles

B. Surface Area
- Particles in Peak
- Combustion products
- Industrial emissions
- Condensation products
- Coagulation of ultrafine

C. Mass
- Particles in Peaks
- Large particle emissions
- Mechanically generated
- Agglomeration particles
- Soil and volcanic dusts
- Spores, pollen & etc.
- Fog & sea spray

APPROXIMATE AMOUNT PER CUBIC METER OF AIR SAMPLED

PARTICLE DIAMETER (micrometer)
THE RESPIRATORY TRACT

Nose
Mouth
Larynx

Trachea
Bronchi
Bronchioles

Terminal bronchiole
Respiratory bronchiole
Alveolar duct
Alveoli sac

Impaction
Diffusion
Interception
Electrostatic

Inflammation
Infection
Ulceration
Cancer

Mucociliary
Olfactory nerve
Sneezing
Blowing

Impaction
Sedimentation
Diffusion
Interception

Inflammation
Bronchospasm
Infection
Obstruction
Cancer

Mucociliary
Coughing
Transepithelial
(through/between cells)

Sedimentation
Diffusion
Interception

Inflammation
Infection
Edema
Emphysema
Fibrosis
Cancer

Solubilization
Phagocytosis
Interstitial uptake
INHALED PARTICLE DEPOSITION.

Deposition is dominated primarily by diffusion (Brownian motion).

Deposition is dominated primarily by sedimentation, impaction, and/or interception.

All curves are corrected for inhalability.
### NAAQS – NATIONAL AMBIENT AIR QUALITY STANDARDS

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Type*</th>
<th>Standard</th>
<th>Averaging Time</th>
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</thead>
<tbody>
<tr>
<td>Sulfur Dioxide</td>
<td>Primary</td>
<td>0.075 ppm</td>
<td>1 h</td>
</tr>
<tr>
<td></td>
<td>Secondary</td>
<td>0.5 ppm</td>
<td>3 h</td>
</tr>
<tr>
<td>Nitrogen Dioxide</td>
<td>Primary</td>
<td>0.053 ppm</td>
<td>Annual</td>
</tr>
<tr>
<td></td>
<td>Primary</td>
<td>0.1 ppm</td>
<td>1 h</td>
</tr>
<tr>
<td>Ozone</td>
<td>Primary</td>
<td>0.075 ppm</td>
<td>8 h</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>Primary</td>
<td>9 ppm</td>
<td>8 h</td>
</tr>
<tr>
<td></td>
<td>Primary</td>
<td>35 ppm</td>
<td>1 h</td>
</tr>
<tr>
<td>Lead</td>
<td>Primary</td>
<td>0.15 μg/m³</td>
<td>3 mo (rolling avg.)</td>
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<tr>
<td>PM$_{10}$</td>
<td>Primary</td>
<td>150 μg/m³</td>
<td>24 h</td>
</tr>
<tr>
<td>PM$_{2.5}$</td>
<td>Primary</td>
<td>35 μg/m³</td>
<td>24 h</td>
</tr>
<tr>
<td></td>
<td>Primary</td>
<td>15 μg/m³</td>
<td>annual</td>
</tr>
</tbody>
</table>

* Primary standards are intended to protect public health, and Secondary standards are set to protect public welfare (e.g. impacts on vegetation, crops, man-made materials, ecosystems, visibility, climate, etc). When the Secondary standard is the same as the Primary standard the Secondary standard is not listed. Source: [http://epa.gov/air/criteria.html](http://epa.gov/air/criteria.html), (accessed 11/15/2013).
PM 2.5 DOSE CALCULATIONS - 1

* Assume 24 hours of breathing at a low exertion level for 70 years at maximum EPA NAAQS (15µg/m³)

* Estimate total inhaled dose to the Pulmonary Airways.

* Total 70 year outdoor 24 hour/day dose = 1.8 grams

* Total 70 year indoor & outdoor dose = 0.65 grams
PM 2.5 DOSE CALCULATIONS - 2

* Total 70 year diesel dose in CA = 0.026 grams

* Smoking 1 cigarette dose = 0.04 grams

* CA diesel dose in 70 years = 0.65 cigarettes; i.e., 0.01 cigarettes/year.

* The TWA for soot is 3 mg/m³ giving 0.026 grams in 2 days.

* No non-infection related substance could be toxic at the average level of diesel PM exposure in CA.

* The single lethal dose of strychnine sulfate = 0.14 grams
U.S. EPA sets National Ambient Air Quality Standards (NAAQS).

CA has a dry climate, so soil dust PM 2.5 is about 1.7 to 3.5 $\mu$g/m$^3$.

PM is the only regulated air pollutant without chemical specification; mass is regulated.

PM 2.5 is mass (natural & anthropogenic) in particles under 2.5 $\mu$m diameter.

In CA total PM 2.5 is about 10 $\mu$g/m$^3$ of air. Diesel combustion contributes about 0.4 to 0.6 $\mu$g/m$^3$ (Mahmud, et al., 2012)

Epidemiology studies of PM 2.5 in CA are largely negative, as opposed to some Eastern U.S. cities.
* Further restrictions on diesels could have only negligible impacts on PM 2.5 in CA.

* CA has serious economic problems, which also have adverse health impacts.

* Any risk assessment should be done on the risks of a decision (e.g., regulation), not a chemical (or substance).

* CA should consider seeking a waiver to exempt the state from PM 2.5 NAAQS.
CONCLUSIONS

* PM 2.5 in CA air is quite low.

* Diesel exhaust is a small portion of PM 2.5 in CA.

* Doses from inhaled diesel exhaust particles in CA are very small.

* PM 2.5 in CA is less toxic than that in some Eastern U.S. cities.

* Is it logical for CA to impose additional restrictions on diesel exhaust?
REFERENCES


