Experiences of measuring airborne wear particles from braking materials and wheel-rail contact

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Outline

- Short review
  - Terminology
  - Negative effect on human health
  - Current condition

- Experimental works
  - On-board measurement
  - Sub-scaled test
Terminology

- Particulate matter (PM10, 2.5, 1)

The Suspension of fine solids particles or liquid droplets or mixture of them in the gas or liquid

- Coarse region (2.5µm < dp <10µm)
- Fine region (100 nm < dp <2.5µm)
- Ultrafine region (dp <100nm)
Particles & health problems
## PM & outdoor air quality

### Outdoor air quality legislation

<table>
<thead>
<tr>
<th>Source</th>
<th>$PM_{10}$ (µg m$^{-3}$)</th>
<th>$PM_{2.5}$ (µg m$^{-3}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US EPA² website</td>
<td>Daily (24 h)</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>Annual</td>
<td>–</td>
</tr>
<tr>
<td>EU directive 2008/50/EC</td>
<td>Daily (24 h)</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Annual</td>
<td>25</td>
</tr>
</tbody>
</table>

### Typical PMC value in subway stations

<table>
<thead>
<tr>
<th>Typical PMC results in subways (Different cities)</th>
<th>$PM_{10}$ (µg m$^{-3}$)</th>
<th>$PM_{2.5}$ (µg m$^{-3}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cairo Daily (24 h)</td>
<td>938</td>
<td></td>
</tr>
<tr>
<td>London Daily (24 h)</td>
<td>1000-1500</td>
<td>270-480</td>
</tr>
<tr>
<td>Paris Daily (24 h)</td>
<td>320</td>
<td>91</td>
</tr>
<tr>
<td>Stockholm Daily (24 h)</td>
<td>357-500</td>
<td>199</td>
</tr>
</tbody>
</table>

*PMC: particle mass concentration*

### Typical PMC value in road transport

<table>
<thead>
<tr>
<th>Source</th>
<th>$PM_{2.5}$</th>
<th>$PM_{10-2.5}$ (Coarse)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust</td>
<td>73%</td>
<td>15%</td>
</tr>
<tr>
<td>Tyre</td>
<td>6%</td>
<td>11%</td>
</tr>
<tr>
<td>Brake</td>
<td>5%</td>
<td>31%</td>
</tr>
<tr>
<td>Road</td>
<td>5%</td>
<td>16%</td>
</tr>
<tr>
<td>Resuspnsion</td>
<td>N.A</td>
<td>27%</td>
</tr>
</tbody>
</table>

Abbasi *et al.*. Particle emissions from rail traffic: A literature review, *Critical Reviews in Environmental Science and Technology*, In press.
Particle measurement devices arrangement in an on-board experiment

Sampling point 'Brake pad'

DustTrak (0.1<d<10µm; mg/m3)
Grimm (0.25<d<32µm; No/dm3)
Ptrak (0.02<d<1µm; No/cm3)

Sampling point 'Global'

DustTrak (0.1<d<10µm; mg/m3)
Grimm (0.25<d<32µm; No/dm3)
Ptrak (0.02<d<1µm; No/cm3)
Temperature Measurement in brake pad:

The distance between hole bottom and contact zone was 1 mm
Recording particles in different brake levels:
Recording particles in different brake levels:
(Electro-magnetic brake activated)
Recording particles in high temp. of brake pad:

- Number of particles per Liter (0.25 μm<d<32μm)
- Normalized Speed (Max: 200 km/h)
- Normalized mechanical brake (Max: 133kN)
- Normalized electrical brake (Max: 60kN)
- Temperature (Max: 390°C)
## The comparative percentile weights of elements:

<table>
<thead>
<tr>
<th></th>
<th>Run</th>
<th>Fe</th>
<th>Cu</th>
<th>Zn</th>
<th>Ca</th>
<th>Mg</th>
<th>Al</th>
<th>Sb</th>
<th>Na</th>
<th>Ni</th>
<th>Mn</th>
<th>Ba</th>
<th>Cr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brake Pad 1</td>
<td>1</td>
<td>65</td>
<td>10.1</td>
<td>4.4</td>
<td>2.9</td>
<td>2.2</td>
<td>1.8</td>
<td>1.4</td>
<td>0.5</td>
<td>7.1</td>
<td>0.6</td>
<td>2.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Brake Pad 2</td>
<td>2</td>
<td>66.2</td>
<td>10.7</td>
<td>3.5</td>
<td>3.5</td>
<td>3.7</td>
<td>1.6</td>
<td>2.8</td>
<td>0.5</td>
<td>3.6</td>
<td>0.7</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Brake Pad 3</td>
<td>3</td>
<td>65.8</td>
<td>9.5</td>
<td>3.8</td>
<td>4.2</td>
<td>3.4</td>
<td>3.7</td>
<td>2.4</td>
<td>1.2</td>
<td>1.3</td>
<td>0.7</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>Brake Pad 4</td>
<td>4</td>
<td>64.7</td>
<td>9.9</td>
<td>3.9</td>
<td>4.9</td>
<td>4.2</td>
<td>2.6</td>
<td>2.9</td>
<td>1.6</td>
<td>0.7</td>
<td>0.7</td>
<td>0.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Global</td>
<td>1</td>
<td>60.2</td>
<td>9.7</td>
<td>3.9</td>
<td>4</td>
<td>5.7</td>
<td>1.8</td>
<td>3.2</td>
<td>1.1</td>
<td>0.6</td>
<td>0.2</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>Global</td>
<td>2</td>
<td>63.9</td>
<td>7.4</td>
<td>3.1</td>
<td>5.3</td>
<td>4.8</td>
<td>5.3</td>
<td>2.3</td>
<td>3.4</td>
<td>0.6</td>
<td>0.7</td>
<td>0.3</td>
<td>0.6</td>
</tr>
<tr>
<td>Global</td>
<td>3</td>
<td>62.8</td>
<td>8.5</td>
<td>3.3</td>
<td>5.4</td>
<td>4.1</td>
<td>6</td>
<td>2.6</td>
<td>2.2</td>
<td>1</td>
<td>0.7</td>
<td>0.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Global</td>
<td>4</td>
<td>59</td>
<td>8.1</td>
<td>3</td>
<td>6</td>
<td>4.9</td>
<td>6</td>
<td>2.6</td>
<td>3.7</td>
<td>0.5</td>
<td>0.7</td>
<td>0.2</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Notes:

a. The amounts of K, Si, As, and U were above the detection limit only in the global filters.
b. The amounts of B, Be, Se, Cd, P, S, Th, and Tl were under the detection limit in all filters in both locations.
c. The percentile weights of Li, Ag, As, U, Bi, Co, Rb, Pb, V, Sn, Sr, Ti, and Mo were under 0.5%.
d. Regarding limitations of the ICP-MS method, C, F, O, H, and N were not investigated, so all presented percentile weights were comparative values.
e. The unused Millipore filters contain Ca in addition to C, H, F, and O; the amounts of other elements in the filters were negligible. The filter composition has no effect on the results as the relative comparative weights were discussed.
f. The amounts of Ti and Sn were above the detection limit in the global filters when whole filters from the fourth run were digested.
g. Hydrofluoric and nitric acids were applied to all filters in the digestion process.

Sub-scaled laboratory test:

A: Room air; B: Fan; C: Flow rate measurement; D: Filter; E: Flexible tube; F: Inlet for clean air, measurement point; G: Closed box (Chamber); H: Pin-on-disc machine; I: Pin sample along with thermocouple; J: Air outlet, measurement points; L: Dead weight; M: Rotating disc sample, N: Air inside box, well-mixed;
A Comparison between results:

Time effects on the volume size distribution of the particles from organic brake pad & sintered brake pad

F=60 N

V=12.4 m/s
Effect of lubrication on fine & ultra fine particles in wheel-rail contact

Abbasi et al. Pin-on-disc study of the effects of railway friction modifiers on airborne wear particles from wheel–rail contact, Tribology International, In press
Cooperation toward Toxicological studies:

Swedish research defence agency

Department of applied environmental science at SU

Car brake dust
References:


