Effects of vehicular air pollution and noise on human health

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Impact assessment of environmental exposures

Pekkanen, Ympäristö&Terveys 2010
Particulate air pollution and health

- Affects both respiratory and cardiovascular health
- Exposure to fine particles (PM$_{2.5}$; diameter <2.5 $\mu$m) estimated to lead to 350 000 premature deaths annually in EU25 (CAFE-programme)
  - In Finland, 1500-2000 premature deaths; tens of thousands less severe disease exacerbations
- Strongest evidence for the effects of PM$_{2.5}$
  - Also ultrafine (<0,1 $\mu$m) and coarse (inhalable) particles (2,5 $\mu$m<diameter< 10 $\mu$m) harmful
  - Particle size is related to source
  - Also black carbon associated with health effects
- Long-term (years) exposure especially harmful
Harmful component of particles?

- No single explanatory factor
  - Transition metals (Fe, Cu, Zn, Cr etc.)
  - Organic compounds (e.g. polycyclic aromatic compounds)
  - Endotoxins and other biological material
  - Ultrafine particles: unique properties due to nanoscale size (cf. risks of nanotechnology)
  - Soil minerals

- Reduction of non-exhaust emissions of traffic a challenge
  - Street dust, break/tire/clutch wear
  - Coarse inhalable particles more harmful than anticipated
  - Selection of materials for road surface and winter sanding?
Effect mechanisms of particles

Particulate air pollution

Neural reflexes

Autonomic nervous system

Inflammation

Inflammatory markers

Heart and circulation

Arrhythmia

Myocardial ischaemia

Lanki ja Pekkanen, Suomen Lääkärilehti 2008
Determinants of particle exposure

<table>
<thead>
<tr>
<th>AMSTERDAM</th>
<th>HELSINKI</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM$_{2.5}$</td>
<td>ABS</td>
</tr>
<tr>
<td>Married</td>
<td>-15*</td>
</tr>
<tr>
<td>Floor subject lived ($\geq 3$)</td>
<td>-7</td>
</tr>
<tr>
<td>Parking area or hall within 100m</td>
<td>4</td>
</tr>
<tr>
<td>Annoyance by traffic ($\geq 2$)</td>
<td></td>
</tr>
<tr>
<td>Building year (before 1980)</td>
<td></td>
</tr>
<tr>
<td>Regular smoker at home</td>
<td>86**</td>
</tr>
<tr>
<td>Major street within 100 m</td>
<td>22***</td>
</tr>
<tr>
<td>Hot meal cooked</td>
<td>20**</td>
</tr>
<tr>
<td>Living window open</td>
<td></td>
</tr>
<tr>
<td>Bedroom window open at night</td>
<td></td>
</tr>
<tr>
<td>ETS at home</td>
<td>139***</td>
</tr>
<tr>
<td>ETS elsewhere indoors</td>
<td>49***</td>
</tr>
<tr>
<td>Time spent in a motor vehicle $^1$</td>
<td>11*</td>
</tr>
<tr>
<td>Time spent indoors elsewhere $^1$</td>
<td>3</td>
</tr>
<tr>
<td>Time spent outdoors $^1$</td>
<td></td>
</tr>
<tr>
<td>Outdoor PM$_{2.5}$ or absorbance $^2$</td>
<td>27***</td>
</tr>
<tr>
<td>Number of measurements</td>
<td>315</td>
</tr>
<tr>
<td>R-squared $^3$</td>
<td>0.70</td>
</tr>
</tbody>
</table>

1 continuous variable, estimate calculated for a change of 1 hour
2 continuous variable, estimate calculated for a change of 10 µg/m3 in PM$_{2.5}$ and 1 m$^{-1}$x10$^{-5}$ in absorbance
3 generalized linear models used to obtain the value
NA not enough exposure events for analyses
* = p<0.1, ** = p<0.05, *** = p<0.01

* Lanki et al., J Expo Sci Environ Epidemiol 2007
Short-term variation in ultrafine particle exposure

An example of personal exposures during a day in comparison with outdoor concentrations measured at an urban background site.

*Lanki et al., in Cardiovascular Effects of Fine and Nano-size Particles, 2011*
Personal particle monitoring

- A wide selection of pollutants available
  - Continuous/filter sampling of PM$_{1}$, PM$_{2.5}$, PM$_{10}$, particle number count, black carbon, CO
  - Temperature and humidity
- Concurrent monitoring of health
  - Ambulatory ECG, blood pressure

Diagram showing components such as Filter holder, Cyclone, Inlet, Battery holders, Photometer, Pump, and Outlets.
Hourly PM$_{2.5}$ exposure and ST segment depressions (myocardial ischemia)

Study population = elderly persons with coronary heart disease

*Lanki et al. Occup Environ Med 2008*
Very short-term PM exposure and health

- Even 1-h spent in traffic increased the risk of myocardial infarction (Peters et al., NEJM 2004) — Role of noise and stress?
- 1-h exposure to diesel particles impaired cardiac function (Mills et al., NEJM 2007)
- 2-h walking by a very busy road worsened asthma (McCreanor et al., NEJM 2007)
- 15-min exposure to environmental tobacco smoke decreased heart rate variability (Pope et al., Environ Health Perspect 2011)
- Particulate air pollution has been suggested to be the most important trigger of myocardial infarction (Nawrot et al., Lancet 2011)
Role of urban green spaces I

- Limited importance considering mean air pollution concentrations over urban areas
- Space with cleaner air for outdoor activities
  - Especially important during heavy exercise and for sensitive population groups
  - Possible prevention of exacerbations of chronic diseases
- Simultaneous decrease in noise exposure
  - Importance of short-term relief?
- Provides alternative, 'healthier' routes for commuting
  - Steep concentration gradients along busy roads
- Number of available studies very limited
Removal of particles

Gravitational settling…

..and wet deposition

Other processes especially important for smaller particles

Large surface area enhances particle capture (conifers, evergreen)
Living near a busy road and health

- Increasing evidence on the health risks of living near a busy road (> 10,000 vehicles/day)
  - Increased risk of atherosclerosis and coronary heart disease?
  - Increased respiratory symptoms, risk of asthma attack
  - Increased incidence of asthma?
  - Adverse effects on children’s lung development?
  - Shortens life expectancy – but how much?
  - Exposure during pregnancy affects birth outcomes?

- Other potential diseases affected by particle exposure
  - Arthritis? Neuropsychological damages? Diabetes?

- Ubiquitous exposure → significant public health problem
Particle concentrations near a busy road

For comparison - noise

Energy Research Foundation Netherlands (ECN) Air Quality Group

Figure 6: Variation of traffic noise levels $L_N$ with different values of $N$ as a function of distance (From Hassall & Zaveri, 1979).
Distance to busy roads and prevalence of cardiovascular disease

<table>
<thead>
<tr>
<th>Distance to a busy road</th>
<th>Coronary heart disease</th>
<th>Peripheral atherosclerosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 - 200 m</td>
<td>1.1 *</td>
<td>1.1</td>
</tr>
<tr>
<td>50 - 100 m</td>
<td>1.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Distance &lt; 50 m</td>
<td>1.8</td>
<td>1.8</td>
</tr>
</tbody>
</table>

* Odds ratio, compared to living > 200 m from a busy road

Hoffmann B et al. 2006, 2009
Vegetation and particle concentrations

Fig. 1. Local protection against particle deposition to downwind surfaces by a windbreak, narrow in the along-wind (x) direction and located at x = 0.

Raupach et al., Atmos Environ 2001
Traffic noise and cardiovascular health

- Incidence of myocardial infarction (Sweden, 2009)
  - RR 1.4 on areas with >50 dBA outdoor noise
- Cardiovascular mortality (the Netherlands, 2009)
  - RR 2.0 for congestive heart failure (>65 dBA)
  - Adjustment for air pollution → disappearance of noise effect on coronary heart disease
- Stroke incidence (Denmark, 2011)
  - Above 60 dB L_{DEN} → RR 1.2 / 10 dB
  - Particles and railway noise – no effect
- Quantification of the effects of noise on cardiovascular disease most important
  - High prevalence of CVD, severe consequences of events, too few studies
Effect mechanisms? Sleep disturbances

- Mostly laboratory studies – generalizability?
- Observed short-term effects:
  - Night-time awakenings (loud/exceptional sounds)
  - Changes in sleep phases
  - Unconscious noise reactions (ECG, EEG, EMG)
  - Delayed sleep?
- Decrease in subjective sleep quality
- Long-term sleep disturbances and cardiovascular health?
  - Established effect for serious disturbances (sleep apnea, severe sleep deprivation)
  - Overactivation of sympathetic nervous system/lowered mood/cardiovascular reactions
Stress reaction

- Increased activity of sympathetic nervous system, activation of hypothalamic-pituitary-adrenal axis
  - Increased blood pressure and heart rate, changes in sugar metabolism
  - Associated also with inflammation?
  - Synergic effects with air pollution?

- Noise linked with short-term stress – importance of prolonged exposure?
  - Habituation or sensibilisation?

- Chronic stress presumably associated with a number of diseases
Annoying sound causes stress

- At least partly conscious reactions
  - Possibilities for self-management?
- Annoyance of noise evaluated using questionnaires
  - Proportion of ‘highly annoyed’ as the outcome
  - Annoyance may never reach zero
- Depends beside sound pressure on:
  - Other qualities of sound (tonality, frequency etc.)
  - Circumstances of exposure (e.g. work vs. free-time)
  - Time of day
  - Person (noise sensitivity, personal history etc.)
Noise – mental health - heart

- Only few studies on the association between noise and mental health
  - Possibly associated with depression and anxiety
  - *Noise sensitivity* associated with mental health

- In a study conducted in London (Guite et al., Public Health 2006) mental well-being affected by:
  - Neighbour noise (but not traffic noise)
  - Crowded apartment, lack of green spaces and community facilities, unsafe environment

- Severe depression associated with cardiovascular diseases
Role of urban green spaces II

- Possibilities to decrease exposure at residences next to busy roads?
  - Most important for larger particles?
- How to take into account air pollution and noise when planning green spaces?
  - Efficient reduction of exposure – tolerance of vegetation
- Reduction of annoyance due to noise (without reduction of noise levels)
  - Living areas, noise barriers
- Protection of sensitive targets
  - Hospital, elderly homes, schools, day care centers
- Importance of quiet areas acknowledged (EU Environmental noise directive)
  - Criteria not established, not yet evidence on beneficial effects