Research program health risks ultrafine particles around Schiphol Airport

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TNO study (2014):

Schiphol Airport important source of UFP concentrations in the range of 10-20 nm; finding elevated levels at 7 km distance (Keuken et al. Atm Env, 2015)

➢ RIVM exploratory study
RIVM exploratory research

2015:
1. Literature review
2. Measurements of UFP
   - Confirmation of TNO study
   - No health studies published in relation to UFP from air traffic

2016:
1. Exploratory study into mortality
2. Advice about the feasibility and design of possible follow-up studies
   - 5 year research program (2017-2021)
Aim:
To gain understanding into the potential adverse health effects of UFP around Schiphol airport

Module 1: Measurements & Modelling
Research question: What are the long-term concentrations of UFP from air traffic in the vicinity of Schiphol airport?

Report (mid 2019)

Module II: Long term effects
Research question: What are the health effects of long-term exposure to UFP from air traffic?

Report (2021)

Module IVa: Integration
Integrated final report (2021)

Conclusion report M1:
The adjusted model (Stacks+) is well able to determine average concentrations over a longer period. Locations with lower and higher concentrations are well distinguished, making the model suitable for research into the health effects of long-term exposure to ultrafine particles originating from air traffic at Schiphol.

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Aim:
To gain understanding into the potential adverse health effects of UFP around Schiphol airport

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Research questions

1. What are the health effects of short-term exposure to UFP in general and of UFP from aviation in particular?
2. How do these effects compare to effects of UFP from other sources (mainly road traffic)?

3 studies with varying designs:

1. Panel study with primary school children in residential areas near Schiphol (at real-life concentrations))
2. Volunteer study with healthy adults directly next to Schiphol (experimental research at high concentrations)
3. Toxicological study with lung cells (in-vitro)
Panel studie
- 161 children from 3 schools situated in Badhoevedorp (S1) and Aalsmeer (S2+S3) (school panel)
- 30 children with asthma from the wider area around Schiphol (asthma panel).

Volunteer study
- 21 young healthy adults exposed in a mobile lab next to the airport (V)

Toxicological study
- Lung cells, exposed to UFP collected at the site of the volunteer study and directly from the exhaust of a turbine engine.
# Overview of the different studies

<table>
<thead>
<tr>
<th></th>
<th>Panel study</th>
<th>Volunteer study</th>
<th>Toxicological study</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design</strong></td>
<td>Observational study</td>
<td>Experimental field study</td>
<td>Experimental laboratory study</td>
</tr>
<tr>
<td><strong>Population/model</strong></td>
<td>Primary school children - School panel - Asthma panel</td>
<td>Healthy adults</td>
<td>Model for respiratory epithelial cell barrier (Calu-3 cells)</td>
</tr>
<tr>
<td><strong>Location of exposure</strong></td>
<td>Living environment</td>
<td>In a mobile lab next to the airport</td>
<td>In the lab to UFP sampled: 1) next to Schiphol at different wind directions; 2) Directly from the exhaust of a jet engine</td>
</tr>
<tr>
<td><strong>Exposure metrics</strong></td>
<td>Total and size-specific particle number measured at school. Modelled particle number from aviation at home</td>
<td>Total and size-specific particle number measured on site</td>
<td>Particle mass (dose µg/cm²) and mean particle size distribution (measured in particle suspensions)</td>
</tr>
<tr>
<td><strong>Duration of exposure</strong></td>
<td>Continuous (real-life residential area concentrations)</td>
<td>5 hours (low to high concentrations)</td>
<td>24 hour; 4 different doses</td>
</tr>
<tr>
<td><strong>Co-pollutants</strong></td>
<td>BC (measured at school) NO₂, PM2.5 (from national monitoring network)</td>
<td>BC, NO₂, CO, O₃, PM2.5 measured on site</td>
<td>None</td>
</tr>
<tr>
<td><strong>Health endpoints - respiratory</strong></td>
<td>All children: Daily spirometry and symptom recording at home School panel: weekly exhaled NO and supervised spirometry at school</td>
<td>Spirometry Exhaled NO</td>
<td>Cytotoxicity (cell viability and cell damage) Pro-inflammation (cytokines IL-6 and IL-8)</td>
</tr>
<tr>
<td><strong>Health endpoints - other</strong></td>
<td>No</td>
<td>ECG (including heart rate), Oxygen saturation, Blood pressure, Urine²</td>
<td>No</td>
</tr>
</tbody>
</table>
Panel study (schoolyard measurements)
• Investigated whether changes in UFP concentration were associated with changes in respiratory health.

• For UFP of the same day, the previous day, and two days before the health measurement, as well as the average of the 3 days before the measurement.

• For total UFP, for UFP mainly from air traffic (PNC20) and for UFP mainly from road traffic (PNC50_100)

• Expressed as the difference between a health measurement after a period with high UFP and a health measurement after a period with low UFP (p5-p95 increment).
Respiratory symptoms and medication use

- Significant associations between exposure to UFP and an increase in daily respiratory symptoms and bronchodilator use.
- Both for total UFP, for UFP mainly from aviation and for UFP mainly from road traffic.
- Strongest associations for wheeze and bronchodilator use

Lung function and exhaled NO

- No consistent associations between variations in UFP and weekly lung function measurements at school or daily lung function in the evening (at home)
- Significant association between exposure to UFP from road traffic and reduced lung function in the morning (at home)
- No consistent associations with exhaled NO (indicator for pulmonary inflammation)
• 21 healthy volunteers exposed for 5 hours in a mobile lab next to the airport

• 2-5 exposure per person; 32 exposure days (total 86 exposures)
  ➢ Large variation in UFP (10.000-170.000 #/cm³)

• Measurements of UFP and other air pollutants during the exposure

• Health measurements before and after the exposure (lung function, exhaled NO, ECG, blood pressure, oxygen saturation)
Results volunteer study

• Short-term (5 hour) increased exposure to UFP, as occurs right next to Schiphol, was associated with direct changes:
  - A decline in lung function (FVC)
  - A prolongation of the QTc interval (ECG)

• This applied to both total UFP and UFP mainly from air traffic

• UFP from road traffic was significantly associated with an increase in systolic blood pressure.

• For other lung and cardiac function parameters, exhaled NO and oxygen saturation, no statistically significant associations with UFP were observed
UFP sampling:

- Location volunteer study (5x):
  - Classified as ‘airport’ (2x) and ‘non-airport’ (3) based on wind direction
  - Directly from the exhaust of a turbine engine (2x)
  - Turbine-1: taxiing and idling
  - Turbine-2: full thrust

- Standard reference material for diesel (NIST)
Exposure of lung cells to UFP leads to cell damage and release of pro-inflammatory markers

No significant differences in reactivity between the different sources of UFP (overlap black lines)
## Summary of the 3 studies

<table>
<thead>
<tr>
<th>Health parameter</th>
<th>Location</th>
<th>Population/model</th>
<th>Associations for UFP from aviation</th>
<th>Associations for UFP from road traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel study (children)</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Daily symptoms</strong></td>
<td>At home</td>
<td>Combined school and asthma panel</td>
<td>Yes, especially for wheeze and phlegm</td>
<td>Yes, especially for wheeze and shortness of breath during rest</td>
</tr>
<tr>
<td><strong>Bronchodilator use</strong></td>
<td>At home</td>
<td>Combined school and asthma panel</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Daily lung function</strong></td>
<td>At home</td>
<td>Combined school and asthma panel</td>
<td>No</td>
<td>Yes, in the morning</td>
</tr>
<tr>
<td><strong>Lung function, supervised, weekly</strong></td>
<td>School</td>
<td>School panel</td>
<td>No, not consistent over multiple parameters</td>
<td>No, no consistent over multiple parameters</td>
</tr>
<tr>
<td><strong>Exhaled NO (weekly)</strong></td>
<td>School</td>
<td>School panel</td>
<td>No, not consistent for children with and without asthma</td>
<td>No, not consistent for children with and without asthma</td>
</tr>
<tr>
<td><strong>Volunteer study</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Lung function</strong></td>
<td>Next to Schiphol</td>
<td>Healthy adults</td>
<td>Yes, for FVC</td>
<td>No</td>
</tr>
<tr>
<td><strong>Exhaled NO ; oxygen saturation</strong></td>
<td>Next to Schiphol</td>
<td>Healthy adults</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Heart function</strong></td>
<td>Next to Schiphol</td>
<td>Healthy adults</td>
<td>Yes, for QTc</td>
<td>No, not consistent</td>
</tr>
<tr>
<td><strong>Blood pressure</strong></td>
<td>Next to Schiphol</td>
<td>Healthy adults</td>
<td>Nee</td>
<td>Ja</td>
</tr>
<tr>
<td><strong>Toxicological study</strong></td>
<td></td>
<td></td>
<td></td>
<td>Reactivity</td>
</tr>
<tr>
<td><strong>Cell damage and pro-inflammatory markers</strong></td>
<td>Next to Schiphol and from the source</td>
<td>Lung cells (in vitro)</td>
<td>Yes. No significant differences in reactivity between UFP sampled during difference wind directions (airport vs non-airport) and directly from a turbine engine</td>
<td></td>
</tr>
</tbody>
</table>
• Together these studies show that short-term increased exposure to UFP, as occurs around Schiphol, is associated with acute health effects.

• This applies to both total UFP (from all sources) and UFP mainly from air traffic

• No indications that effects of UFP from aviation are substantially different from those of UFP from road traffic
• The increase in daily respiratory symptoms and medication use among children in the vicinity of Schiphol is health-relevant

• Although the observed short-term changes in lung (children & adults) and heart function (adults) are relatively small based on a group average, they may be greater for sensitive individuals.

• It is not yet clear what this means in the long term. This is investigated in Module II of this research program (Research into the effects of long-term exposure to ultrafine particles from aviation)

• Results of Module II are expected in 2021.