Ultrafine Particles and Health: Reviewing the Evidence in the Current Policy Context

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21. ETH Conference on Combustion Generated Nanoparticles
Health Session (6A)
Zürich, June 21\textsuperscript{th} 2017 13:00
Ultrafine particles and health

KNOWN

• UFP have many toxic features that affect health
• Primary UFP are already subject to ambitious regulations of emissions

BUT:

• What are the long-term health effects under real-life conditions?
• What is the added value of ambient UFP standards?

→ Need assessment of epidemiological evidence and integration into current policy context
Air pollution – a symphonic issue

- Air pollution is an orchestra of complex pollutants caused by many sources and factors
- Health effects are orchestrated by hundreds of pathways
- Host reactions are orchestrated by multiple modifying factors
- Air quality management is an orchestrated set of various strategies and policies

→ Added value of regulating ONE «string?"
• Epidemiological evidence for health effects of UFP
• Policy context
Current state of UFP literature reviews

• HEI Report 2013
• U.S. EPA works on Integrated Science Assessment (ISA) for Particulate Matter (including UFP) → release of draft early 2018
• Will be relevant input for update of WHO Air Quality Guidelines (2016-2019+)
• German Environmental Agency mandated a “lean review” to University of Düsseldorf (Prof. Barbara Hoffmann) with Swiss TPH (LUDOK Team: Ron Kappeler) as supporting partner
More to hear...
See you at the 22nd NPConference 2018!

Ron Kappeler
LUDOK Team
Swiss TPH

Disclaimer: my presentation is NOT a «systematic» review...
Examples on **ACUTE EFFECTS**

(effect of «yesterdays UFP» on «todays» health)

in populations

UFP = Ultrafine particles
5-day average quasi-Ultrafine particles are associated with systemic inflammation

Delfino et al, Env H Perspect 2010) - 60 elderly subjects

Example of IL-6

(very similar findings for TNF-alpha)

- Associations with Primary Organic Aerosol
- No association with Secondary Organic Aerosols
Effects of home-outdoor 5-day mean concentrations in elderly (Delfino et al, Epidemiology 2010)
Inflammatory and Cardiovascular acute effects of source specific fractions of PM

Wu et al, Env Sci Technol 2014, Panel study in 40 healthy students

<table>
<thead>
<tr>
<th>Source Fraction</th>
<th>Mass (μg/m³)</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total PM$_{2.5}$</td>
<td>82.0</td>
<td>Null findings</td>
</tr>
<tr>
<td>PMF S1: traffic emissions</td>
<td>5.1</td>
<td>TNFα; Bloodpressure</td>
</tr>
<tr>
<td>PMF S2: coal combustion</td>
<td>10.7</td>
<td>TNFα; Peak-flow</td>
</tr>
<tr>
<td>PMF S3: secondary sulfate/nitrate</td>
<td>34.2</td>
<td>Null findings</td>
</tr>
<tr>
<td>PMF S4: metallurgical emission</td>
<td>0.6</td>
<td>Null findings</td>
</tr>
<tr>
<td>PMF S5: dust/soil</td>
<td>12.4</td>
<td>Null findings</td>
</tr>
<tr>
<td>PMF S6: industry</td>
<td>4.9</td>
<td>Bloodpressure, Peakflow</td>
</tr>
<tr>
<td>PMF S7: secondary organic aerosol</td>
<td>7.1</td>
<td>Null findings</td>
</tr>
<tr>
<td>Unknown</td>
<td>7.0</td>
<td>Null findings</td>
</tr>
</tbody>
</table>

**BUT...** Rich et al, Env Sci Technol 2013; 47:

«The triggering of myocardial infarction by fine particles is enhanced when particles are enriched in secondary species»
Association Between Short-term Exposure to Ultrafine Particles and Mortality in Eight European Urban Areas

Massimo Stafoggia, a,b Alexandra Schneider, c Josef Cyrys, c,d Evangelia Samoli, c Zorana Jovanovic Andersen, f Epidemiology, 2017

- UFP are not significantly associated with mortality
- UFP estimates were sensitive to adjustment for PM or NO₂

% increase of mortality
per 10’000 particles/cm³
As air pollution increases, hospital admissions of young children increase (Hanoi, Vietnam)

Nhung Nguyen Thi Trang, et al, (submitted 2017) (PhD student @ Swiss TPH) – do not cite nor quote

Diamond: warm (April-October),
Triangle: cold (November – March),
Bar: 95% confidence intervals

NO2 remained stable in all 2-pollutant models!
Examples on
LONG-TERM (chronic) EFFECTS
(effect of «life-time» exposure to UFP on long-term health)
Needs for long-term effect studies

- Spatial distributions of long-term exposure to UFP
- Spatial distributions of long-term exposure to co-pollutants → spatial correlations between UFP and other markers of pollution
Understanding the Health Effects of Ambient Ultrafine Particles

HEI Review Panel on Ultrafine Particles

**Epidemiologic Studies**

- **Studies of long-term exposure to ambient UFPs.** The kinds of data that have provided broad support for epidemiologic investigations of the public health implications of long-term exposure to PM$_{2.5}$ and PM$_{10}$ — multiple years of monitoring data, using consistent methods, in major urban areas representing millions of people — have simply not existed for UFPs.
Spatial determinants of UFP (Land-Use Regressions)

Amsterdam, NL (Hoek et al, EnvSciTechnol 2010)
Traffic intensity and distance; household density (300m); port (3000m)

Girona, Spain (Rivera et al, Atmos Env 2012)
High density population (1000m); distance to road intersection; household density (100m)

Montreal, Canada (Weichenthal et al, Env Res 2016)
Temp, Wind speed, park space, open space, local roads, length of rail, annual NO2, population density (LUR)

4 SAPALDIA regions, Switzerland (Eeftens et al, Env Health 2016)
Traffic load (250m); road length (100m); major road (100m)

Rome, Italy (Cattani et al, Atmos Env 2017)
Traffic intensity / distance – ratio; population density; green space in 500m

Augsburg, Germany (Wolf et al, Atmos Env 2017)
Traffic load (50m); industry (300m); semi-natural area (100m); green space (500m); building density

For Boston: see next talk by D. Brugge
Land Use Regression Models for Ultrafine Particles in Six European Areas

Erik van Nunn, Roel Vermeulen, Ming-Yi Tsai, Nicole Probst-Hensch, Alex Ineichen, Medea Imboden, Regina Ducret-Stich, Alessio Naccarati, Daniela Raffaele, Andrea Ranzi, Cristiana Ivaldi, Claudia Galassi, M. David Donaire-Gonzalez, Marta Cirach, Lec Kees Meliefste, Daan Buijtenhuijs, Bert Brunekreef, and Gerard Hoek

A) Basel

Map of Europe highlighting study areas.

<table>
<thead>
<tr>
<th>Intercept</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT Traffic intensity on nearest road</td>
</tr>
<tr>
<td>NT Road length of all major roads in a buffer of 50m</td>
</tr>
<tr>
<td>NT Sum of low and high density residential land in a buffer of 500m</td>
</tr>
<tr>
<td>PP Sum of low and high density residential land in a buffer of 1000m</td>
</tr>
<tr>
<td>PP Number of restaurants in a RE buffer of 100m</td>
</tr>
<tr>
<td>PP Number of restaurants in a RE buffer of 1000m</td>
</tr>
</tbody>
</table>

More to hear from EXPOSOMICS at NPC 2018!
Spatial land-use regression model for benzene, Tehran (Iran), 2015
PhD Thesis Heresh Amini, Swiss TPH; AQCC Tehran; Sharif University (Vahid Hosseini)

Annual mean benzene (µg/m3)
- 1.9 - 3.5
- 3.6 - 4.3
- 4.4 - 5.0
- 5.1 - 5.5
- 5.6 - 6.0
- 6.1 - 6.5
- 6.6 - 6.9
- 7.0 - 7.4
- 7.5 - 7.8
- 7.9 - 8.1
- 8.2 - 8.6
- 8.7 - 9.1
- 9.2 - 9.8
- 9.9 - 11
- 12 - 29

No «magic bullet»!
Living along traffic corridors does not only result in very high exposure to UFP.... - a complex mixture of traffic-related pollutants follows the same spatial distribution (e.g.: BC, organic material, organic aerosol markers, particle number concentration, CO, CO2)

All scales normalized to «background levels»

background = 1

Daten: Paul Scherrer Institut (PSI)
From 4 cities of the Swiss SAPALDIA study; 67 measurement sites
Eeftens et al, 2016

<table>
<thead>
<tr>
<th>Substance</th>
<th>( R^2 )</th>
<th>Range of the 4 within-city ( R^2 ) between PNC annual mean and...:</th>
<th>Rome (Cattani et al)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO2</td>
<td>0.81</td>
<td>0.47-0.82</td>
<td>0.38</td>
</tr>
<tr>
<td>PM2.5</td>
<td>0.41</td>
<td>0.10-0.43</td>
<td>0.37</td>
</tr>
<tr>
<td>PM2.5 absorbance</td>
<td>0.74</td>
<td>0.07-0.86</td>
<td>0.44</td>
</tr>
<tr>
<td>PM10</td>
<td>0.62</td>
<td>0.10-0.72</td>
<td>0.34</td>
</tr>
<tr>
<td>PM coarse</td>
<td>0.42</td>
<td>0.02-0.33</td>
<td>0.34</td>
</tr>
<tr>
<td>Lung depos. surface area</td>
<td>0.90</td>
<td>0.63-0.98</td>
<td>--</td>
</tr>
</tbody>
</table>
Traffic related PM from Highway 405 caused atherosclerosis in mice
Araujo et al, Circul Res 2008
Carotid intima-media thickness (CIMT) is associated with home-outdoor levels of pollutants in the Swiss SAPALDIA study –
(4 sites; 1500 subjects age >50)
Aguilera et al – Env H Perspect 2016
(so far the only CIMT study with UFP)

PM10 (per 10ug/m3) 2.33% (0.28, 4.38)
PM2.5 (per 5.6ug/m3) 2.63% (0.5, 4.77)
Vehicular source PM2.5 (per IQR) 1.67% (-0.13, 3.48)
Particle Number Conc (12k = IQR) 2.06% (0.03, 4.10)

BUT:
PNC, adjusted for PM2.5 0.63% (-3.60, 4.86)
... and Pearson correlation home outdoor PM vrs PNC very high (~0.9)
Post-menopausal breast cancer was associated with home outdoor NO2 but not with UFP.

Case-control study, Montreal; Goldberg et al, Env Res 2017

(no two-pollutant models)
Home outdoor ultrafine PM are associated with prostate cancer; case-control study (Montreal)
Weichenthal et al, Env Res 2017
Ischemic Heart Disease mortality in the Californian Teacher’s Study
Ostro et al; Env H Perspect 2015

**Association (risk ratio), per Inter-Quartile Range of exposure**

PM2.5 mass conc. \( \lor 1.18 \, (1.08-1.30) \)

UFP mass conc. \( \lor 1.10 \, (1.02-1.18) \)

Anthropogenic Sec Organic Aerosols (UFP) \( \lor 1.25 \, (1.13-1.39) \)

**Two-pollutant model:**

UFP mass conc. \( \lor 1.03 \, (0.94-1.12) \)

Anthropogenic Sec Organic Aerosols (UFP) \( \lor 1.19 \, (1.08-1.31) \)
• Epidemiological evidence of health effects of UFP
• Policy context
**Policy needs**

1. Enforce «highest possible fuel quality»
2. Enforce *existing* EMISSION Standards (Euro VI/6)
3. Set & enforce *existing* science based ambient AIR QUALITY STANDARDS as proposed by WHO
4. Put rigorous measures of control and sanctions in place

→ under above conditions no urgency for new air quality standards for e.g. UFP

Gerrit Kadijk:
“Most effective way: vehicle emissions must be as low as possible”
Trends in ambient concentrations of NO2
Swiss NABEL Network (1986-2015)
Strong reduction in soot despite not having an ambient air quality standard for soot / EC / BC (Payern, Switzerland)
We need Globalized air quality standards

Int J Pub Health 2017: Kutlar Joss et al (open access)

Public health oriented air quality standards

<table>
<thead>
<tr>
<th>WHO Guidelines</th>
<th>Afghanistan, Cameroon, Iceland, Iran, Switzerland (Australia)</th>
<th>State of California</th>
<th>U.S.A. Federal Mexico</th>
<th>Norway</th>
<th>E.U.</th>
<th>India</th>
<th>China and many others</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PM\textsubscript{10} Annual Mean</strong></td>
<td>20 µg/m\textsuperscript{3}</td>
<td><strong>20</strong> (AUST: 8 for PM2.5 !)</td>
<td>20</td>
<td>-- but PM2.5 of 12</td>
<td>25</td>
<td>40</td>
<td>60</td>
</tr>
</tbody>
</table>

«standards» do not protect health!

% of countries with standards for ≥ 1 pollutant

<table>
<thead>
<tr>
<th>Region</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Region</td>
<td>94%</td>
</tr>
<tr>
<td>South-East Asia</td>
<td>64%</td>
</tr>
<tr>
<td>Region of Americas</td>
<td>57%</td>
</tr>
<tr>
<td>Eastern Mediterranean Region</td>
<td>52%</td>
</tr>
<tr>
<td>Western Pacific</td>
<td>44%</td>
</tr>
<tr>
<td>African Region</td>
<td>36%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>60%</strong></td>
</tr>
</tbody>
</table>
Set and enforce science based targets as proposed by WHO to protect health!

EU limits are NOT SCIENCE BASE and do NOT protect people’s health

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>EU limit</th>
<th>% citizens Exceeding EU limit</th>
<th>Science based Guidelines of WHO</th>
<th>% citizens Exceeding WHO limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM10</td>
<td>50 µg/m³ in 24 h</td>
<td>16</td>
<td>20 µg/m³ a year</td>
<td>50</td>
</tr>
<tr>
<td>PM2.5</td>
<td>25 µg/m³ a year</td>
<td>8</td>
<td>10 µg/m³ a year</td>
<td>85</td>
</tr>
<tr>
<td>BaP</td>
<td>1 µg/m³ a year</td>
<td>20</td>
<td>0.12 ng/m³ a year</td>
<td>88</td>
</tr>
<tr>
<td>NO₂</td>
<td>40 µg/m³ a year</td>
<td>8</td>
<td>40 µg/m³ a year</td>
<td>8</td>
</tr>
<tr>
<td>SO₂</td>
<td>125 µg/m³ in 24 h</td>
<td>&lt;1</td>
<td>20 µg/m³ in 24 h</td>
<td>38</td>
</tr>
<tr>
<td>O₃</td>
<td>120 µg/m³ in 8 h</td>
<td>8</td>
<td>100 µg/m³ in 8 h</td>
<td>96</td>
</tr>
</tbody>
</table>
Stronge governance needed

Call for globalized standards in

- Fuel quality
- Emissions
- Ambient concentrations

Needed to abate the ever increasing global inequity in air quality and related health burden caused by the poor environmental governance (abused by globalized industries)

Time to harmonize national ambient air quality standards

Meltem Kuntar Joss1,2 · Marloes Eeftens1,2 · Emily Glintowt1,2 · Ron Kappeler1,2 · Nino Kümli1,2
Western countries outsource pollution to other countries!
Nature, April 2017

Transboundary health impacts of transported global air pollution and international trade
Qiang Zhang\textsuperscript{1*}, Xujia Jiang\textsuperscript{1,2*}, Dan Tong\textsuperscript{1*}, Steven J. Davis\textsuperscript{1,3}, Hongyan Zhao\textsuperscript{1}, Guannan Geng\textsuperscript{1}, Tong Feng\textsuperscript{1}, Bo Zheng\textsuperscript{2}, Zifeng Lu\textsuperscript{4}, David G. Streets\textsuperscript{4}, Ruijing Ni\textsuperscript{5}, Michael Brauer\textsuperscript{6}, Aaron van Donkelaar\textsuperscript{7}, Randall V. Martin\textsuperscript{7,8}, Hong Huo\textsuperscript{9}, Zhu Liu\textsuperscript{10}, Da Pan\textsuperscript{11}, Haidong Kan\textsuperscript{12}, Yingying Yan\textsuperscript{5}, Jintai Lin\textsuperscript{5}, Kebin He\textsuperscript{1,2,13} & Dabo Guan\textsuperscript{1,14}

- **Western Europe & USA:** the only regions causing (substantially) higher air pollution (\(=\) death & diseases) in OTHER COUNTRIES (than at home) to accommodate their own CONSUMPTION

- **China, India, Asia:** take the highest share of air pollution (\(=\) death & diseases) for the production of goods CONSUMED IN OTHER COUNTRIES
Costs of air pollution related health impacts are very large

See World Bank Report 2016 on costs of air pollution
Rigorous measures of control and sanctions needed

Nature 2017

Impacts and mitigation of excess diesel-related NO\textsubscript{x} emissions in 11 major vehicle markets

Susan C. Anenberg\textsuperscript{1*}, Joshua Miller\textsuperscript{2*}, Ray Minjares\textsuperscript{2}, Li Du\textsuperscript{2}, Daven K. Henze\textsuperscript{3}, Forrest Lacey\textsuperscript{3†}, Christopher S. Malley\textsuperscript{4}, Lisa Emberson\textsuperscript{4}, Vicente Franco\textsuperscript{2†}, Zbigniew Klimont\textsuperscript{5} & Chris Heyes\textsuperscript{5}

Global consequences of VW (et al) Directors’ decision to manipulate software:

~38’000 premature death /yr globally caused by the excess NO2 (via the NOx driven formation of PM and O3)
Consequences of unequal standard setting: «African quality» diesel

An investigation of PublicEye (Swiss NGO)

National Standards for permitted Sulphur-content of diesel
Sulphur levels as measured in «African Quality» diesel samples (ppm)

- Swiss traders are responsible for 61% of these sells (...and its consequences on death and diseases)
- Blending objective: sell the «poorest (legally) possible quality»

**Analysed samples contained up to 630 times more sulphur than diesel sold in Europe... !**
In sum...

• UFP are toxic (as are many of the 100’s of pollutants in air pollution)
• Long-term health effects unclear
• Systematic review of health effects of UFP and its independence from other regulated pollutants needed
• Added value of air quality standards for UFP at this stage not yet clear
• **BUT**: available technology and policies could lead to substantial improvements and compliance with WHO Guideline values if governments do their job to regulate...
Welcome on the SwissTPH LUDOK-Data base with the air pollution and health literature

http://ludok.swisstph.ch/fmi/iwp/cgi?-db=ludok_web&-loadframes

Thank you
Nino.Kuenzli@SwissTPH.ch