Effetti sanitari della biomassa legnosa

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ERS-Position paper

Health Impacts of Anthropogenic Biomass Burning in the Developed World

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Outline

• Why?
• Level of exposure
• Health effects
  o Epidemiological studies
  o Intervention studies
  o Toxicological studies
• Conclusions and perspectives
Biomass burning in the industrialized world

Across Europe, a shift towards renewable energy sources increases biomass incineration. As a response to fuel poverty, biomass burning is seen as a cheap form of fuel & households are now the main source of fine particulate matter emissions in the EU.
Sector contributions to primary PM$_{2.5}$ emissions in the EU15

2000

- Homes developing countries: PM$_{10}$=300 - 5000 ug/m$^3$
- Homes industrialised countries: PM$_{10}$=100-500 ug/m$^3$ in case of exclusive wood for heating
- Outdoor: Dk & Sw: PM from wood burning in rural areas = PM from traffic in major cities

2020

- Mobile sources 34%
- Power generation 5%
- Industrial processes 20%
- Agriculture 4%
- Domestic, wood stoves 25%
Release from biomass into the atmosphere

- Instantaneous combustion → gases and particles:
  - carbon dioxide (CO$_2$),
  - carbon monoxide (CO),
  - nitrogen oxides (NOx),
  - sulfur dioxide (SO$_2$),
  - methane,
  - non-methane hydrocarbons,
  - nitric oxide,
  - methyl chloride,
  - methyl bromine,
  - (HAPs)
  - lead, mercury
  - various particulate matter (PM)
Respiratory system: PM penetration

Oberdorster, 2005 (modified)
Deposition of Biomass Combustion Aerosol Particles

- The size-dependent DF varies depending on particle diameter and hygroscopicity.
- The respiratory-tract deposition of particles emitted from biomass combustion is approximately 20%.
- Traffic exhaust particles are generally both smaller in size and more hydrophobic than biomass combustion particles, which will lead to a higher deposition.

Löndahl et al. Inhalation Toxicology, 2008
Health effects of Biomass burning in the industrialized world

• Clinical studies
• Epidemiological studies
• Toxicological studies
• Intervention studies
Mixed dust pneumoconiosis occurring in an unusual setting.
Vallurupalli S & al, BMJ case report 2012;

Domestic wood smoke exposure is a cause of pneumoconiosis in women from developing countries, but is rarely seen in the USA.

An elderly female non-smoker, who immigrated to the USA from Pakistan 10 years previously, presented with a worsening non-productive cough and dyspnoea on exertion. She did not have any occupational or environmental exposures other than utilising firewood for cooking while living in Pakistan.

(A) CT of the chest soft tissue windows showing mediastinal and hilar lymph node enlargement;
(B) CT of the chest lung windows showing multiple nodules, most of them peripheral in location close to the pleura
Epidemiological studies

Wood smoke and related PM associated with:

• Developing countries
  o Respiratory infections in childhood, respiratory symptoms (congestion (cough, phlegm) and diseases (asthma, COPD), lung cancer...

• Industrialized countries
  o Low birth weight, respiratory symptoms (congestion, wheeze) and bronchiolitis in young children, increased medication use, decreases in lung function, asthma and COPD emergency room visits and hospitalizations, cardiovascular (myocardial infarction, heart rate variability but not ischemic heart disease) hospital admissions, thrombosis.

• Wildfires
  o Respiratory symptoms, asthma medication use, outpatient physician visits, emergency room visits, hospital admissions, and mortality
2-3 million ALRI Deaths in Children Under 5

- Poor case-management: 50%
- Underweight: 40%
- Lack of breastfeeding: 10%
- Diarrhea: 20%
- Measles: 10%
- Zn Deficiency: 15%
- Lack of vaccines: 25-50%
- Genetic Susceptibility?: 50%
- Poor Housing?: 40%
- Outdoor air pollution?:
- Lack of chimneys?: 20%
- Household solid-fuel burning?:

Attributable Fractions do not add to 100%

Rough estimates only
<table>
<thead>
<tr>
<th>Outcome</th>
<th>Exposure window</th>
<th>N (n cases)</th>
<th>Design</th>
<th>Mean Days exposed [IQR]</th>
<th>Adjusted() OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGA birth</td>
<td>All pregnancy</td>
<td>70,249 (6,939)</td>
<td>Cohort</td>
<td>65</td>
<td>1.00 (0.91 - 1.09)</td>
</tr>
<tr>
<td></td>
<td>Exposed 30% of pregnancy</td>
<td></td>
<td></td>
<td></td>
<td>1.05 (0.98 - 1.12)</td>
</tr>
<tr>
<td>Bronchiolitis</td>
<td>2 – 12 months</td>
<td>86,337 (10,485)</td>
<td>Nested C-C*</td>
<td>54</td>
<td>1.08 (1.04 - 1.11)</td>
</tr>
<tr>
<td>Otitis Med</td>
<td>1 month pre-diagnosis</td>
<td>45,513 (19,115)</td>
<td>Cohort</td>
<td>15</td>
<td>1.32 (1.27 - 1.36)</td>
</tr>
<tr>
<td>Asthma</td>
<td>All pregn 0-12 months</td>
<td>37,401 (3,482)</td>
<td>Nested C-C**</td>
<td>60 89</td>
<td>1.00 (0.94 - 1.07)</td>
</tr>
</tbody>
</table>

\* per IQR increase, adjusted for covariates: Infant sex (SGA, B, OM) First Nations Status (SGA, B, OM), Parity (SGA, B, A), Maternal age (SGA, B, OM), Maternal smoking during pregnancy (SGA, B, OM), Month-year of birth (SGA), maternal initiation of breastfeeding at birth (B, OM, A), Income (SGA, B, OM, A), Maternal education (SGA, B, OM, A), older siblings (OM), birth season (OM), birthweight (OM, A), gestational duration (OM, A). *incidence-density matching (up to 1:10) on date of birth **matched 1:5 by sex, month-yr of birth

Karr et al., AJRCCM 2009; MacIntyre et al., Epidemiology 2011; Clark et al., EHP 2010
## Health effects of biomass burning

<table>
<thead>
<tr>
<th>Country</th>
<th>Study 1st author</th>
<th>Exposure</th>
<th>Outcome</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Zealand</td>
<td>McGowan (2002)</td>
<td>Outdoor PM$_{10}$ rise of 15µg</td>
<td>CVD admissions</td>
<td>+</td>
</tr>
<tr>
<td>New Zealand</td>
<td>Barnett (2006)</td>
<td>Outdoor PM$_{10}$ IQR rise (?)</td>
<td>Cardiac admissions</td>
<td>-</td>
</tr>
<tr>
<td>Chile</td>
<td>Sanhueza (2009)</td>
<td>Outdoor PM$_{10}$ 100µg rise</td>
<td>CVD admissions CVD mortality</td>
<td>+</td>
</tr>
<tr>
<td>Canada</td>
<td>Allen (2011)</td>
<td>Indoor PM$_{2.5}$ intervention study</td>
<td>Markers of inflam &amp; endothelial function</td>
<td>+</td>
</tr>
<tr>
<td>India</td>
<td>Ray (2006)</td>
<td>Biomass vs non biomass fuel use</td>
<td>Markers of thrombosis risk</td>
<td>+</td>
</tr>
<tr>
<td>Turkey</td>
<td>Emiroglu (2010)</td>
<td>Biomass vs non biomass fuel users</td>
<td>Ventricular dysfunction</td>
<td>+</td>
</tr>
</tbody>
</table>
Public health dimension

• A conservative estimate of the current contribution of biomass smoke to premature mortality in Europe would amount to at least 40,000 deaths per year.
  o This is based on a contribution of biomass smoke to population exposure of 10%, and recent estimates of the total mortality burden due to PM exposure in Europe (EU28) of over 400,000 premature deaths each year.

• A recent WHO report estimated that ambient PM from residential heating with wood and coal is responsible for 61,000 premature deaths per year in the EU28.
  o This latter estimate is dominated by wood smoke.
**Évaluation à minima du coût de la pollution atmosphérique pour le système de soin français**

**Résumé.** Les évaluations réalisées en matière de coûts de la pollution de l’air se fondent le plus souvent sur une approche socio-économique et sur les coûts intangibles (valeur de la vie ou de la souffrance par exemple). Ce type d’évaluations est un sujet de controverses tant il est délicat de fixer ces valeurs en dehors d’un sujet de recherche.

<table>
<thead>
<tr>
<th>Nature de la pathologie</th>
<th>Nombre annuel de nouveaux cas attribuables à l’environnement</th>
<th>Coût annuel pour le système de soin des nouveaux cas attribuables à l’environnement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Valorisation basse</td>
<td>Valorisation haute</td>
</tr>
<tr>
<td>Broncho-pneumopathie chronique obstructive (BPCO)</td>
<td>26 800</td>
<td>40 200</td>
</tr>
<tr>
<td>Bronchite chronique (BC)</td>
<td>134 000 cas</td>
<td></td>
</tr>
<tr>
<td>Bronchite aiguë (BA)</td>
<td>Enfants 450 218 / Adultes 500 000</td>
<td></td>
</tr>
<tr>
<td>Asthme (As)</td>
<td>400 000 cas</td>
<td>1 400 000 cas</td>
</tr>
<tr>
<td>Cancers</td>
<td>Voies respiratoires basses</td>
<td>1 608</td>
</tr>
<tr>
<td></td>
<td>Voies respiratoires hautes</td>
<td>76</td>
</tr>
<tr>
<td>Hospitalisations</td>
<td>Causes respiratoires</td>
<td>13 796</td>
</tr>
<tr>
<td></td>
<td>Causes cardiovasculaires</td>
<td>19 761</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>1 milliard €</td>
<td>2 milliards €</td>
</tr>
</tbody>
</table>
The radioactivity recorded over the liver and bladder expressed as a percentage of the initial lung radioactivity.

Ultrafine carbon black particles labeled with Technetium-99 were detected in the blood of human volunteers within 5 – 20 minutes after inhalation.
Other type of information

Quasi experiments

Intervention studies
Launceston, Tasmania, showing reduced visibility associated with smoke from domestic wood heaters.

1994

2008

Fay H Johnston et al. BMJ 2013;346:bmj.e8446
Launceston Tasmania

Antecedent events
1980-1994
80’s: Increasing popularity of domestic wood heaters and increasing community perception of worsening air quality
91-94: An Expert Working Party was formed to provide the first detailed assessments of air quality and health, establishing the basis for subsequent monitoring and public education campaigns

Study period
1994-2008
1994-2001: Period of poor air quality
   Initial responses:
   94-01: Detailed research projects on particular air pollution in the area
   94-08: Tasmania wide marketing campaign to promote electric heating
   97-08: Winter air quality forecasts issued by the Bureau of Meteorology
   00-01: Distribution of educational leaflets
2001-2008: Period of improved air quality
   Coordinated interventions:
   01-04: Wood heater replacement programme
   01-03: The Airwatch education programme in schools, universities, and mass media
   02-05: Smoke patrols, targeted education, and issuance of infringement notices to households with excessively smoking chimneys
Percentage change* in all cause, cardiovascular, and respiratory mortality in Launceston and Hobart, Tasmania, between 2001-07 corresponding with period of improved air quality after series of coordinated interventions in Launceston

*Adjusted for age structure, meteorological conditions, and secular mortality trends in Tasmania.

<table>
<thead>
<tr>
<th>Launceston (intervention)</th>
<th>Hobart (control)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All year—males and females combined</td>
<td>All year—males and females combined</td>
</tr>
<tr>
<td>All cause mortality</td>
<td>−2.7 (−8.7 to 3.7)</td>
</tr>
<tr>
<td>Cardiovascular mortality</td>
<td>−4.9 (−15.5 to 7.0)</td>
</tr>
<tr>
<td>Respiratory mortality</td>
<td>−8.5 (−23.2 to 9.0)</td>
</tr>
<tr>
<td>All year—males</td>
<td>All year—males</td>
</tr>
<tr>
<td>All cause mortality</td>
<td>−11.4 (−19.2 to −2.9)</td>
</tr>
<tr>
<td>Cardiovascular mortality</td>
<td>−17.9 (−30.6 to −2.8)</td>
</tr>
<tr>
<td>Respiratory mortality</td>
<td>−22.8 (−40.6 to 0.3)</td>
</tr>
<tr>
<td>All year—females</td>
<td>All year—females</td>
</tr>
<tr>
<td>All cause mortality</td>
<td>2.7 (−5.3 to 11.4)</td>
</tr>
<tr>
<td>Cardiovascular mortality</td>
<td>2.3 (−12.2 to 19.3)</td>
</tr>
<tr>
<td>Respiratory mortality</td>
<td>1.0 (−18.9 to 24.4)</td>
</tr>
<tr>
<td>Wintertime—males and females combined</td>
<td>Wintertime—males and females combined</td>
</tr>
<tr>
<td>All cause mortality</td>
<td>2.2 (−14.1 to 11.3)</td>
</tr>
<tr>
<td>Cardiovascular mortality</td>
<td>−19.6 (−36.3 to 1.5)</td>
</tr>
<tr>
<td>Respiratory mortality</td>
<td>−27.9 (−49.5 to 3.1)</td>
</tr>
</tbody>
</table>
Wood stove intervention effects on PM levels outdoors in developed countries

<table>
<thead>
<tr>
<th>Location</th>
<th>Estimated reduction in PM (µg/m³)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launceston, Tasmania, Australia</td>
<td>38% reduction in winter PM$_{10}$</td>
<td>Fuel switching: Replacement of wood heating appliances with electric heating appliances. The proportion of households burning wood was reduced from 66% to 30%.</td>
</tr>
<tr>
<td>British Colombia, Canada</td>
<td>22% reduction in winter PM$_{2.5}$</td>
<td>Introduction of improved technology stoves and targeting of open fireplaces: The proportion of homes using open fireplaces was reduced from 15% to 3%, and the proportion of homes with improved technology wood stoves increased from 25% to 41%. The community also had an overall increase in wood stove usage.</td>
</tr>
<tr>
<td>Missoula, Montana, US</td>
<td>45% reduction in PM$_{10}$</td>
<td>Legislative action and enforcement: Over a 10 year period, the proportion of households burning wood was reduced from 44% to 20% and the contribution of residential wood burning to PM10 was reduced from 47% to 11%.</td>
</tr>
<tr>
<td>Libby, Montana, US</td>
<td>.% reduction in winter PM$_{2.5}$</td>
<td>Introduction of improved technology stoves. Over 1,100 older model wood stoves replaced with improved technology stoves.</td>
</tr>
</tbody>
</table>
What if you remove the smoke?

- Portable HEPA filters 60% ↓ in indoor PM$_{2.5}$
- Increases in endothelial function and decreases in systemic inflammatory markers

Allen et al., AJRCCM 2011
Key features of human experimental studies

**Pro**
- Study mechanisms
- Perform complex/invasive measurements
- Precise characterization of subjects and exposures
- Include non-exposed, i.e. wash-out periods
- RCT ➔ Infer causality

**Con**
- Expensive
- Exposure: at best only close to real life
- They are short-term only
Biomass associated with lower lung function

Adverse effects on heart

- Decrement in maximal heart rate at 0 h post (Ghio)
- Increase in heart rate at 0-1 h (Unosson)
- Augmentation index, augmentation pressure and pulse wave velocity were all higher at 0 h (Unosson) i.e. arterial stiffness
- Heart rate variability decrease 0-1 h (Unosson)

- No effects on HRV (Bønløkke, Riddervold)
Take home messages

• **Population studies** from industrialized countries have showed consistently, that exposure to biomass particles is associated with a range of respiratory and cardiovascular hospital admissions and respiratory infections.

• Evaluation of the respiratory and cardiovascular **toxicity** of biomass emission PM is complex due to high heterogeneity in biomass PM characteristics and limited knowledge of physicochemical properties of ambient (real-life) biomass PM exposure.

  Short-term inhalation of wood responsible of
  - Symptoms
  - Mild early inflammatory reactions in lungs
  - Maybe cardiovascular effects & maybe through oxidative mechanisms

• **Intervention studies** have shown beneficial effects of phasing out biomass for heating (a beneficial effect was also seen after introduction of air filtering devices in the homes of the elderly (data not shown).
Discussion

• PM from wood burning must be considered part of the PM pollution contributing equally to cardio-respiratory health effects as other PM components of the total air pollution. Hence, the emissions should be kept at a minimum to protect public health.

• So far, we cannot conclude that exposure to biomass smoke is less harmful than exposure to combustion particles from fossil fuel combustion.

• Further health effects other than cardiorespiratory are expected.

• Unknown effects to be further explored in:
  - Children
  - Old people
  - Asthmatics
  - COPD patients
ERS-Position paper.

Perspectives

• Modern and more efficient biomass technologies are available and a further development and implementation of such systems are clearly motivated from an air pollution mitigation perspective.

• An important regulatory step would be the unconditional adoption of the PM$_{10}$ and PM$_{2.5}$ WHO annual mean Air Quality Guideline values to protect public health.

• Compliance with these science-based guideline values (annual mean PM$_{10}$ and PM$_{2.5}$ concentrations of 20 and 10 $\mu$g/m$^3$, respectively) would inevitably require the

• Development and implementation of clean air strategies and “best available technology” for biomass combustion, comparable to the EU control policies for vehicle emissions.
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Technical Solutions

• Better Ventilation
  o Windows
  o Chimneys
  o Hoods

• Better Stoves
  o Fuel efficiency
  o Combustion efficiency

• Better Fuels
  o Clean solids (?)
  o Gases and liquids

Short Term

Long Term
Deposition of Biomass Combustion Aerosol Particles

Löndahl et al. Inhalation Toxicology, 2008