How low does HAP (PM$_{2.5}$) need to be to achieve health benefits?

Recommendations of new WHO guidelines

DFID/WHO conference, 1$^{st}$ May 2014

Dr Nigel Bruce, Consultant

Public Health, Environmental & Social Determinants of Health (WHO/PHE)
Overview of presentation

• Why does this question matter?
• Existing WHO air quality guidelines:
  – A foundation for the new guidelines
• Key questions for the new Guidelines
• Evidence reviewed:
  – Focus on 3 reviews most relevant to our question
• Main recommendations
• Implementation and evaluation plans
Why does this question about HAP levels matter?

- 2.8 billion use solid fuels
- High HAP (>> AQGs)
- 4.3 (2.9, 4.9) million premature deaths (2012)
- World’s poorest people; majority rural, facing multiple challenges.
- Experience - sustained use of ‘effective’ interventions challenging
- Hence ... question of whether moderate ↓ in HAP would → ‘useful’ health benefit
Existing WHO air quality guidelines
## WHO Air Quality Guidelines: PM$_{2.5}$ and carbon monoxide (CO)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Guideline or target</th>
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Scope and key questions

Scope:
• Global, with focus on LMIC; all uses - cooking, heating and lighting

4 key questions for guidelines:
• Practical means of assessing performance: what emission rates are required to meet:
  – The annual average AQG and IT-1 for PM$_{2.5}$, and
  – The 24-hr average AQG for CO?
• In light of challenges in securing sustained use of low emission devices/fuels, what approach should be taken during this transition?
• Should coal be used as a household fuel?
• Should kerosene be used as a household fuel?

Additional issues:
• Safety; Health and climate synergies
Evidence reviews
1. **Fuel use, emissions and pollution levels:**
   - Global patterns of household fuel use
   - Emissions of health-damaging pollutants
   - **Model linking emission rates with air quality**
   - Population levels of household air pollution

2. **Health impacts:**
   - Health risks from HAP, including exposure-risk
   - Specific risks from household use of coal
   - Risks of burns, scalds and poisoning

3. **Implementation - interventions and policy:**
   - Impacts of interventions in daily use on \( \text{PM}_{2.5} \) and CO
   - Factors enabling and limiting adoption
   - Interventions costs and financing options
1: Model linking emissions to air quality

**Inputs:**
- Emission rates:
  - PM2.5
  - CO
- Kitchen volume
- Air exchange rate
- Duration of use (hours per day)

**Outputs:**
- Predicted average concentrations of:
  - PM2.5
  - CO

- Uses ranges of inputs and Monte Carlo simulation
- Assumes uniform mixing of pollutants and air in kitchen
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  - CO
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- Predicted average concentrations of:
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  - CO

- Uses ranges of inputs and Monte Carlo simulation
- Assumes uniform mixing of pollutants and air in kitchen
## 2: Health risks from exposure to HAP from solid fuels

<table>
<thead>
<tr>
<th>Strong evidence</th>
<th>Tentative evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Child pneumonia</td>
<td>• Stillbirth</td>
</tr>
<tr>
<td>• Low birth weight</td>
<td>• Pre-term birth</td>
</tr>
<tr>
<td>• Chronic obstructive pulmonary disease (COPD)</td>
<td>• Stunting</td>
</tr>
<tr>
<td>• Lung cancer (coal)</td>
<td>• Cognitive development</td>
</tr>
<tr>
<td>• Lung cancer (biomass)</td>
<td>• Asthma</td>
</tr>
<tr>
<td>• Cataract</td>
<td>• Other cancers (naso-pharynx, uterine cervix)</td>
</tr>
<tr>
<td>• [Cardiovascular disease]</td>
<td>• Tuberculosis</td>
</tr>
</tbody>
</table>

Also: health risks from kerosene and gas
IER function*: PM$_{2.5}$ and child ALRI risk

- Household air pollution (red)
- Second-hand smoking (blue)
- Outdoor air pollution (green)

*Burnett et al EHP 2014
IER function for PM$_{2.5}$ and child ALRI risk (linear scale)

WHO IT-1 (35 µg/m$^3$ PM$_{2.5}$)
## IER functions included

<table>
<thead>
<tr>
<th>Disease outcome</th>
<th>HAP data available for IER</th>
<th>Exposure measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child acute lower respiratory infection (ALRI)</td>
<td>Yes</td>
<td>Direct</td>
</tr>
<tr>
<td>Ischaemic heart disease</td>
<td>No</td>
<td>-</td>
</tr>
<tr>
<td>Stroke</td>
<td>No</td>
<td>-</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease (COPD)</td>
<td>Yes</td>
<td>Estimated</td>
</tr>
<tr>
<td>Lung cancer</td>
<td>Yes</td>
<td>Estimated</td>
</tr>
</tbody>
</table>
IER function: lung cancer

- OAP
- SHS
- HAP
- AS

Graph showing the relationship between the IER function and lung cancer.
### 3: Impacts of interventions - daily use (PM$_{2.5}$)

<table>
<thead>
<tr>
<th>Device and fuel type</th>
<th>Number of studies (estimates)</th>
<th>Kitchen PM$_{2.5}$ ($\mu g/m^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre-intervention mean</td>
</tr>
<tr>
<td>Solid fuel unvented</td>
<td>4 (7)</td>
<td>780</td>
</tr>
<tr>
<td>Solid fuel vented</td>
<td>18 (23)</td>
<td>1030</td>
</tr>
<tr>
<td>Advanced solid</td>
<td>1 (3)</td>
<td>650</td>
</tr>
<tr>
<td>Ethanol</td>
<td>4 (4)</td>
<td>720</td>
</tr>
<tr>
<td>Gas</td>
<td>1 (2)</td>
<td>890</td>
</tr>
<tr>
<td>Electricity</td>
<td>1 (1)</td>
<td>160</td>
</tr>
</tbody>
</table>

WHO annual AQG = 10 $\mu g/m^3$
3: Impacts of interventions - daily use (PM$_{2.5}$)

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<th>Number of studies (estimates)</th>
<th>Kitchen PM$_{2.5}$ ($\mu$g/m$^3$)</th>
<th>Pre-intervention mean</th>
<th>Post-intervention mean</th>
<th>Summary % reduction (95% CI) in mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid fuel unvented</td>
<td>4 (7)</td>
<td></td>
<td>780</td>
<td>410</td>
<td>-48% (-34, -54)</td>
</tr>
<tr>
<td>Solid fuel vented</td>
<td>18 (23)</td>
<td></td>
<td>1030</td>
<td>370</td>
<td>-63% (+14, -89)</td>
</tr>
<tr>
<td>Advanced solid</td>
<td>1 (3)</td>
<td></td>
<td>650</td>
<td>380</td>
<td>-41% (-29, -50)</td>
</tr>
<tr>
<td>Ethanol</td>
<td>4 (4)</td>
<td></td>
<td>720</td>
<td>120</td>
<td>-83% (-63, -94)</td>
</tr>
<tr>
<td>Gas</td>
<td>1 (2)</td>
<td></td>
<td>890</td>
<td>280</td>
<td>-64% (-48, -80)</td>
</tr>
<tr>
<td>Electricity</td>
<td>1 (1)</td>
<td></td>
<td>160</td>
<td>80</td>
<td>-50% (N/A)</td>
</tr>
</tbody>
</table>

For CO – similar story with important difference that most groups at/below 24-hr AQG
Recommendations
Focus on emissions reductions – why?

• Indoor ↔ outdoor
• Evidence base stronger than for other approaches
• Implementation practicality – via design, production, standards, etc.
• Some options (clean fuels), are relatively independent of user behaviour.
**Recommendation**

For 90% of homes to meet the WHO AQGs for PM$_{2.5}$, emission rates should not exceed the emission rate targets (ERTs) set out below.

<table>
<thead>
<tr>
<th>Emissions rate targets (ERT)</th>
<th>Emission rate (mg/min)</th>
<th>Percentage of kitchens meeting AQG (10 µg/m$^3$)</th>
<th>Percentage of kitchens meeting AQG IT-1 (35 µg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unvented</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.75</td>
<td>9%</td>
<td>60%</td>
</tr>
<tr>
<td>Final</td>
<td>0.23</td>
<td>90%</td>
<td>100%</td>
</tr>
<tr>
<td><strong>Vented</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>7.15</td>
<td>4%</td>
<td>60%</td>
</tr>
<tr>
<td>Final</td>
<td>0.80</td>
<td>90%</td>
<td>100%</td>
</tr>
</tbody>
</table>
For 90% of homes to meet the WHO AQG for CO, emission rates should not exceed the emission rate targets (ERTs) set out below.

<table>
<thead>
<tr>
<th>Emissions rate targets (ERT)</th>
<th>Emission rate (mg/min)</th>
<th>Percentage of kitchens meeting AQG (7 mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unvented</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>0.35</td>
<td>60%</td>
</tr>
<tr>
<td>Final</td>
<td>0.16</td>
<td>90%</td>
</tr>
<tr>
<td>Vented</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>1.45</td>
<td>60%</td>
</tr>
<tr>
<td>Final</td>
<td>0.59</td>
<td>90%</td>
</tr>
</tbody>
</table>
Recommendation 2: Policy during transition

**Recommendation:**
- For many, it will take time to meet AQGs (especially PM$_{2.5}$), so intermediate steps (solid fuel stoves) may be required
- Policy should promote clean fuel where and when possible
- Solid fuels: test emissions (ref Recommendation #1), use best possible options
- Monitor use and air pollution (not just laboratory)

**Rationale:**
- Health evidence: need low levels for major health benefits (ALRI)
- In practice, solid fuel stoves not achieving low levels (some vented wood stoves 35-70 µg/m$^3$)
- Even clean fuel users well above IT-1 (other sources)
- Based on evidence, requires (near) exclusive use of clean fuels to achieve AQG (PM$_{2.5}$).
**Household energy transition**

- **Urban and peri-urban**
  - 2015 to 2030

- **Rural better-off**
  - 2015 to 2030

- **Rural poor**
  - 2015 to 2030

- **Fuel types**
  - Traditional biomass
  - Low emission biomass
  - Clean fuel

**World Health Organization**
Household energy transition

Urban and peri-urban

Rural better-off

Rural poor

2015 → 2020 → 2025 → 2030

To ensure ‘best possible’
• Testing
• Standards
• Certification

Traditional biomass
Low emission biomass
Clean fuel
Rec. 3: Household use of coal

**Recommendation:**
Unprocessed coal should not be used as a household fuel

**Rationale:**
- It is very difficult to burn coal cleanly in home
- IARC Monograph: emissions from household use of coal are a Group 1 carcinogen
- Coal often contains toxins (fluorine, arsenic, mercury, etc.) which are not destroyed on combustion.

- There should be further assessment of so-called ‘clean’ and ‘smokeless’ coal
Rec. 4: Use of kerosene

**Recommendation:**
Household combustion of kerosene is discouraged while further research into its health impacts is conducted.

**Rationale:**
- High levels of emissions of PM and other health-damaging emissions.
- Epidemiologic studies suggest links to cancer, respiratory disease, adverse birth outcomes, etc., but are not of adequate consistency/quality.
- Kerosene use carries substantial risks of burns and poisoning.
Implementation and evaluation plans
Outline of implementation strategy

• **IAQ Guidelines:**
  – Outline of strategy in published volume
  – Website: guidance and tools (will evolve)

• **All countries:**
  – WHO region/country offices → Ministries
  – Dissemination through regional workshops
  – Evaluation

• **Work with selected countries and partners:**
  – 4 to 5 countries over 3 years (initially)
  – Defining health sector role; link to policy
  – Arrangements for multi-sectoral working
  – Support development and implementation of action plans
  – Evaluation → revise guidance

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<tr>
<th>Timing</th>
<th>Activity</th>
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<tr>
<td>Mid-2014</td>
<td>Publish IAQG with web pages</td>
</tr>
<tr>
<td>2014-15</td>
<td>Regional workshops</td>
</tr>
<tr>
<td>2014-17</td>
<td>Work with 4-5 countries</td>
</tr>
<tr>
<td>2016</td>
<td>Evaluation of IAQG implementation</td>
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<tr>
<td>2016-17</td>
<td>Revisions to guidance and tools</td>
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Supporting implementation in countries

COUNTRY

ACTION PLAN

Multisectoral ‘task group’

- Needs assessment and mapping
- HAPIT tool
- Survey and AQ measurement tools
- M&E strategy, capacity and resources
- Intervention options assessment
- Emissions model
- Standards, testing and certification
- Policy (finance, market, &c.) for adoption and sustained use
- Adoption tool
Thanks!

[Image of two women cooking in a traditional kitchen]
1. The home does not exist in isolation:
   - Emissions from household combustion contribute outdoor air pollution, some of which re-enters homes
   - Outdoor air pollution from any source (including neighbours’ houses) enters homes

2. Household fuel combustion devices/fuels linked to increased risks for burns, scalds, fires, and poisoning

3. Policy for achieving sustained adoption vital if guidelines are to be implemented – especially for poorer, rural homes.

4. Growing evidence on synergies between health and climate impacts
Existing WHO Air Quality Guidelines (AQG)

- Global update (ambient) 2005:
  - PM$_{2.5}$, PM$_{10}$
  - Chapter on IAP
- Indoor AQG:
  - Dampness and Mould: 2009
  - Selected pollutants: 2010
  - Household fuel combustion: this project
General considerations

- **Household emissions**: escape and re-enter homes and lower IAQ; so total emissions should be minimised.
- **Local ambient air quality** outdoor emissions (from homes and other sources) affect indoor air quality: implications for community-wide action and control of other sources.
- **Homes have multiple energy needs** (cooking, heating, lighting, etc.): use and emissions from all sources should be considered.
- **Safety**: Safety of interventions for ↓ HAP emissions should not be assumed: approaches to minimize exposure to emissions should be taken in a way that incorporates safety concerns.
Best-practice recommendation

Recommendation:
In view of the close synergy between health and climate impacts of household fuel combustion, climate mitigation policy addressing household energy should include health assessment.

• Rationale:
  – Inefficient combustion of biomass (higher emissions) in settings with non-sustainable harvesting contributes to net CO₂ emissions.
  – Incomplete combustion leads to emissions of (shorter-lived) pollutants that are both health damaging and exert positive radiative forcing.