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WHO indoor air quality guidelines on household fuel combustion: Strategy implications of new evidence on interventions and exposure–risk functions

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HIGHLIGHTS

- New WHO air quality guidelines will address household air pollution (HAP).
- Action on HAP could lower risk of multiple child and adult diseases by 20–50%.
- New evidence shows levels at or below 35 μg/m^3 $PM_{2.5}$ (WHO IT-1) are needed.
- Most improved solid fuel stoves result in $PM_{2.5}$ levels well above IT-1.
- Intervention strategy must shift towards accelerating access to clean fuels.

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ABSTRACT

Background: 2.8 billion people use solid fuels as their primary cooking fuel; the resulting high levels of household air pollution (HAP) were estimated to cause more than 4 million premature deaths in 2012. The people most affected are among the world's poorest, and past experience has shown that securing adoption and sustained use of effective, low-emission stove technologies and fuels in such populations is not easy. Among the questions raised by these challenges are (i) to what levels does HAP exposure need to be reduced in order to ensure that substantial health benefits are achieved, and (ii) what intervention technologies and fuels can achieve the required levels of HAP in practice? New WHO air quality guidelines are being developed to address these issues. **Aims**: To address the above questions drawing on evidence from new evidence reviews conducted for the WHO guidelines. **Methods**: Discussion of key findings from reviews covering (i) systematic reviews of health risks from HAP exposure, (ii) newly developed exposure–response functions which combine combustion pollution risk evidence from ambient air pollution, second-hand smoke, HAP and active smoking, and (iii) a systematic review of the impacts of solid fuel and clean fuel interventions on kitchen levels of, and personal exposure to, $PM_{2.5}$ and carbon monoxide (CO). **Findings**: Evidence on health risks from HAP suggest that controlling this exposure could reduce the risk of multiple child and adult health outcomes by 20–50%. The new integrated exposure–response functions (IERs) indicate that in order to secure these benefits, HAP levels require to be reduced to the WHO IT-1 annual average level (35 μg/m^3 $PM_{2.5}$), or below. The second review found that, in practice, solid fuel 'improved stoves' led to large percentage and absolute reductions, but post-intervention kitchen levels were still very high, at several hundreds of μg/m^3 of $PM_{2.5}$, although most solid fuel stove types met the WHO 24-hr average guideline for CO of 7 mg/m^3. Clean fuel user studies were few, but also did not meet IT-1 for $PM_{2.5}$, likely due to a combination of continuing multiple stove and fuel use, other sources in the home (e.g. kerosene lamps), and pollution from neighbours and other outdoor sources. **Conclusions**: Together, this evidence implies there needs to be a strategic shift towards more rapid and widespread promotion of clean fuels, along with efforts to

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encourage more exclusive use and control other sources in and around the home. For households continuing to rely on solid fuels, the best possible low-emission solid fuel stoves should be promoted, backed up by testing and in-field evaluation.

1. Introduction

Household air pollution (HAP)[1] from the combustion of solid and other polluting fuels, is responsible for a very substantial public health burden, impacting primarily on homes in low and middle-income countries (LMIC).[2] In the 2010 Global Burden of Disease study (GBD-2010), cooking with solid fuels (wood, dung, crop wastes, charcoal and coal), was estimated to cause 3.5 (uncertainty interval: 2.7, 4.5) million premature deaths in 2010, with a further 0.5 million outdoor air pollution deaths being attributed to emissions from household cooking (Lim et al., 2012; Smith et al., 2014), and HAP was responsible for the largest global environmental burden among the risk factors studied. New WHO estimates for 2012 using similar methods but updated solid fuel use and mortality data, report 4.3 million premature deaths (WHO, 2014).

Recognising the extent of this problem, and in addition to efforts within countries, a number of international initiatives have recently been launched to accelerate access to cleaner household energy, including UN[3] Sustainable energy for all (UN, 2014) and the UN Foundation Global Alliance for Clean Cookstoves (UNF, 2014). Whatever approach is taken by these various initiatives, planning must take into account the fact that the 2.8 billion people relying on solid fuels are also the world's poorest people, and furthermore that experience has shown that securing adoption and lasting use of clean and efficient stoves and fuels can be very challenging, for reasons that involve a wide range of factors (Rehfuess et al., 2014). In respect of this strategic challenge, two questions arise:

1. To what levels does HAP exposure need to be reduced in order to ensure that substantial health benefits are achieved.
2. What intervention technologies and fuels can achieve the required levels of HAP in practice?

New WHO indoor air quality guidelines (AQG)[4] for household fuel combustion are being developed to help address these questions and thereby guide countries in effectively reducing this public health burden (Bruce et al., 2013a). The new guidelines build on existing WHO AQGs for ambient air pollution (WHO, 2006), and the 2010 volume of indoor AQG for selected pollutants (WHO, 2010).

Key to the new guidelines is a set of evidence reviews which inform both the recommendations and plans for supporting implementation in countries. The aim of this paper is to address the two questions set out above, drawing on key findings from two of these reviews, and to consider the implications for intervention strategy.

2. Material and methods

The development of WHO guidelines follows well-defined procedures (WHO, 2012), the application of which to the current guidelines have been described (Bruce et al., 2013a), emphasizing the central role of thorough evaluation of evidence in formulating recommendations. The new guidelines include a wide range of evidence relevant to the scientific and policy issues involved and cover: households fuel use, pollutant emissions, levels of HAP and exposure, health and safety (i.e. burns, poisoning) risks, intervention impacts, and factors relating to adoption, intervention costs and financing (Table 1). Two of the reviews (#5 and #7 in Table 1) are especially relevant to the questions set out in Section 1, and addressed (i) health risks of exposure to HAP, and (ii) impacts of interventions on HAP and exposure. The methods used for these are now described.

2.1. Health risks of exposure to HAP

This review sought to answer two questions:

1. What child and adult disease outcomes are linked to solid fuel HAP exposure, and what are the estimated risks and strength of causal evidence?
2. What information is available on the relationships between exposure level and risk of important disease outcomes, and what are the shapes of these relationships?

For Question 1, the review draws on recently conducted systematic reviews and meta-analyses, many of which were carried out for the GBD-2010 study comparative risk assessment for HAP (Lim et al., 2012), the methods for which have been described elsewhere (Smith et al., 2014). The strength of evidence for causation was assessed by reference to the Bradford Hill viewpoints (Hill, 1965), and strength of evidence for intervention effect estimates using a revised version of GRADE (Balshem et al., 2011), which was modified to increase relevance to environmental health interventions (Bruce et al., 2013a, 2013b; Rehfuess et al., 2011; Schunemann et al., 2010).

For Question 2, the review first identified the very few epidemiologic studies which have reported exposure and risk data, and then drew on 'integrated exposure response functions' (IERs)[5] which were recently developed for the GBD-2010 study (Burnett et al., 2014). Drawing on prior work by Pope et al. (2009, 2011) and commentary on the relevance to HAP (Smith and Peel, 2010), these functions model risk estimates for $PM_{2.5}$[6] from studies of four sources of combustion-derived pollution: outdoor air, second-hand smoke, HAP and active smoking (Burnett et al., 2014).

2.2. Impacts of interventions on HAP and exposure

The second review addressed the question of whether improved solid fuel stove and cleaner fuel interventions in everyday use are effective in reducing average concentrations of, or exposure to, particulate matter (PM) and carbon monoxide (CO)[7] among households in LMIC. As this systematic review is currently being prepared separately for publication in full, an overview of the

[1] HAP: Household air pollution.
[2] LMIC: Low and middle income countries.
[3] UN: United Nations.
[4] AQG: Air quality guideline.
[5] IER: Integrated exposure–response function.
[6] $PM_{2.5}$: Particulate matter of aerodynamic diameter 2.5 microns and less.
[7] CO: Carbon monoxide.