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Clean fuels for resource-poor settings: A systematic review of barriers and enablers to adoption and sustained use

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ABSTRACT

Background: Access to, and sustained adoption of, clean household fuels at scale remains an aspirational goal to achieve sufficient reductions in household air pollution (HAP) in order to impact on the substantial global health burden caused by reliance on solid fuels.
Aim and objectives: To systematically appraise the current evidence base to identify: (i) which factors enable or limit adoption and sustained use of clean fuels (namely liquefied petroleum gas (LPG), biogas, solar cooking and alcohol fuels) in low- and middle-income countries; (ii) lessons learnt concerning equitable scaling-up of programmes of cleaner cooking fuels in relation to poverty, urban–rural settings and gender.
Methods: A mixed-methods systematic review was conducted using established review methodology and extensive searches of published and grey literature sources. Data extraction and quality appraisal of quantitative, qualitative and case studies meeting inclusion criteria were conducted using standardised methods with reliability checking.
Findings: Forty-four studies from Africa, Asia and Latin America met the inclusion criteria (17 on biogas, 12 on LPG, 9 on solar, 6 on alcohol fuels). A broad range of inter-related enabling and limiting factors were identified for all four types of intervention, operating across seven pre-specified domains (i.e. fuel and technology characteristics, household and setting characteristics, knowledge and perceptions, financial, tax and subsidy aspects, market development, regulation, legislation and standards, and programme and policy mechanisms) and multiple levels (i.e. household, community, national). All domains matter and the majority of factors are common to all clean fuels interventions reviewed although some are fuel and technology-specific. All factors should therefore be taken into account and carefully assessed during planning and implementation of any small- and large-scale initiative aiming at promoting clean fuels for household cooking.
Conclusions: Despite limitations in quantity and quality of the evidence this systematic review provides a useful starting point for the design, delivery and evaluation of programmes to ensure more effective adoption and use of LPG, biogas, alcohol fuels and solar cooking.
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1. Introduction

Approximately 2.8 billion people used solid fuels for cooking (wood, animal dung, agricultural wastes, charcoal and coal) in 2012 (WHO, 2014) and this has changed little since 1980 (Rehfuess et al., 2006; Bonjour et al., 2013). Combustion of these solid fuels leads to high levels of health-damaging household air pollution (HAP) including particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO_2) and polycyclic aromatic hydrocarbons (PAHs) (Naeher et al., 2007). Studies consistently show very high HAP levels in households using solid fuels with $PM_{2.5}$ being at least 10 to 50 times in excess of the World Health Organisation (WHO) Air Quality Guideline (AQG) safe levels (Saksena et al., 2003; WHO, 2006).

Globally, HAP from solid fuels was estimated to account for 4.3 million premature deaths in 2012 (WHO, 2014). This HAP-related mortality arises from four disease outcomes: chronic

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obstructive pulmonary disease (COPD) (22%), cardiovascular disease (60%) and lung cancer (6%) in adults and acute lower respiratory infections (ALRI) (12%) in children less than 5 years (WHO, 2014). In addition, cataracts among women contributed significant years lived with disability (YLD) (Smith et al., 2014). A range of other conditions have been linked to HAP exposure, including adverse pregnancy outcomes and other cancers, but the evidence was not strong enough to include these in current global burden of disease calculations (Smith et al., 2014; Pope et al., 2012).

Until very recently, most intervention research has focussed on behaviour change and the adoption and sustained use of improved solid fuel stoves (IS). Thes have, however, been shown to have variable but generally limited effects on levels of HAP; despite often achieving reductions of 50% or more, mean post-intervention levels of $PM_{2.5}$ and CO have been found to be still considerably above the WHO-AQG levels (WHO, 2014). Even the most promising low-emission advanced combustion biomass cookstoves (e.g. semi-gasifiers), for which initial laboratory emission tests have reported 90% reductions in CO and $PM_{2.5}$ emissions (Jetter et al., 2012), have not so far been shown to reach WHO-AQG values for $PM_{2.5}$ in everyday use (WHO, 2014; Sambandam et al., 2014). The reasons for these findings include sub-optimal design for everyday cooking and other household energy requirements leading to only partial adoption and intermittent use (also known as fuel/stove 'stacking'), and the contributions from other sources of combustion within the home (e.g. kerosene lighting), as well as other sources outside the home (e.g. from neighbours, waste burning, etc.) (WHO, 2014).

Recently published evidence on the relationships between exposure to $PM_{2.5}$ and disease risk for five important disease outcomes (child ALRI, ischaemic heart disease, stroke, COPD and lung cancer) – termed integrated exposure response functions (Burnett et al., 2014), indicates that for the first four of these, exposure needs to be reduced to low levels at or below the WHO intermediate target (IT)-1 for $PM_{2.5}$ (35 $\mu g/m^3$) in order to prevent the majority of attributable cases (Burnett et al., 2014). The function for lung cancer is more or less linear, implying a more proportionate reduction in risk as exposure is reduced, but current estimates show that the attributable burden from this disease is the smallest among the five disease outcomes (Smith et al., 2014). Given this evidence, and the limitations of current improved and advanced solid fuel stoves, switching from polluting fuels (biomass or coal) to clean fuels – liquefied petroleum gas (LPG), electricity, biogas, alcohol fuels or solar cooking – can be expected to bring about the largest reductions in HAP and hence secure the greatest health benefits, provided these fuels/energy sources are used for the majority of cooking and other household energy tasks. Understanding the factors that enable and constrain the adoption and sustained use of clean fuels is therefore critical to achieving substantial health gains from reduced HAP exposure.

The objective of this systematic review was to synthesise the available evidence on adoption and sustained use of four clean cooking fuels – i.e. LPG, biogas, alcohol fuels and solar cooking – to identify factors that enable or limit their uptake at scale. Electricity was not included due to the complexity of and importance of generation, distribution and pricing strategies relatively to factors at the community and household level, and the fact that – over the historical period covered by available studies – it has not been a practical energy source for cooking in most Low and Middle Income Countries (LMICs) because of lack of and/or unreliable supply and cost. That said, electricity is an important and growing energy source for cooking in some countries, a trend being accelerated by availability of cheap high efficiency induction stoves (Smith and Sangar, 2014).

Specific questions of this systematic review were: (a) Which factors enable or limit adoption and sustained use of LPG, biogas, alcohol fuels and solar cooking in LMICs? (b) Can any specific lessons be derived with respect to scaling-up programmes of cleaner cooking fuels in equitable ways in relation to poverty, urban–rural location and gender?

2. Methods

2.1. Scope of systematic review

This review of the factors influencing adoption and use of clean fuels was part of a larger systematic review on household energy for cooking commissioned by the UK Department of International Development (Puzzolo et al., 2013). The broader review also covered adoption and use of improved solid fuel stoves published elsewhere (Rehfuess et al., 2014; Stanistreet et al., 2014). This paper focuses on findings for clean fuels, and uses the same methodological and conceptual approach. The full review was registered with the Evidence for Policy and Practice Information and Co-ordinating (EPPI) Centre, where a detailed, peer-reviewed protocol was published (Puzzolo et al., 2011).

This review was restricted to LMICs and included both rural and urban settings. Eligible studies were concerned with households reliant on biomass or kerosene for cooking who switched to any of the following: LPG, biogas, solar cooking and alcohol fuels (ethanol or methanol) (Table 1). Outcomes were barriers and enablers to (i) adoption and (ii) sustained use of these cleaner fuel options. Adoption was defined as initial technology acquisition and use for less than one year from acquisition. Sustained use reflected longer time periods, covering both medium-term (one to two years after acquisition) and long-term use (more than two years).

The review used mixed-methods to synthesise evidence on clean fuel interventions in the context of projects, programmes or other relevant initiatives undertaken at scale, combing quantitative, qualitative and case studies that provided empirical data.

2.2. Search strategy

We used five steps to identify relevant literature:

(1) Systematic searches of multiple bibliographic databases (including MEDLINE, EMBASE, Web of Knowledge, Global Health, PsycINFO and LILACS);
(2) Searches in dissertation and thesis portals (including Proquest Dissertations & Theses, EThOS, NDLTD);
(3) Searches of 'grey literature' through Google, Google Scholar and portals of key stakeholder organisations such as Development Institutions and Non-Governmental Organisations promoting clean fuels;
(4) Hand searches of the references of included studies;
(5) Consultations with experts in the field of HAP.

The search terms are listed in Table 2; we piloted these and adapted them as necessary to meet databases requirement. Searches covered the period of 1980 to 2012. Full details are available in the protocol (Puzzolo et al., 2011) and in the published report (Puzzolo et al., 2013).

2.3. Eligibility criteria

Reflecting the mixed methods, we determined that qualitative, quantitative and policy/case studies were all eligible, provided these (i) reported experience with one of the four clean fuel options, (ii) included empirically-derived information on determinants of uptake of any of the included fuels, and (iii) did not