Tackling the health burden from household air pollution (HAP): development and implementation of new WHO Guidelines

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Abstract

Household air pollution (HAP), arising mainly from the combustion of solid and other polluting fuels, is responsible for a very substantial public health burden, most recently estimated as causing 3.5 million premature deaths in 2010. These patterns of household fuel use have also important negative impacts on safety, prospects for poverty reduction and the environment, including climate change. Building on previous air quality guidelines, the WHO is developing new guidelines focused on household fuel combustion, covering cooking, heating and lighting, and although global, the key focus is low and middle income countries reflecting the distribution of disease burden. As discussed in this paper, currently in development, the guidelines will include reviews of a wide range of evidence including fuel use in homes, emissions from stoves and lighting, household air pollution and exposure levels experienced by populations, health risks, impacts of interventions on HAP and exposure, and also key factors influencing sustainable and equitable adoption of improved stoves and cleaner fuels. GRADE, the standard method used for guidelines evidence review may not be well suited to the variety and nature of evidence required for this project, and a modified approach is being developed and tested. Work on the guidelines is being carried out in close collaboration with the UN Foundation Global Alliance on Clean cookstoves, allowing alignment with specific tools including recently developed international voluntary standards for stoves, and the development of country action plans. Following publication, WHO plans to work closely with a number of countries to learn from implementation efforts, in order to further strengthen support and guidance. A case study on the situation and policy actions to date in Bhutan provide an illustration of the challenges and opportunities involved, and the timely importance of the new guidelines and associated research, evaluation and policy development agendas.

Keywords

Household air pollution, Air quality guidelines, Household fuel combustion, Exposure to household air pollution, Health risk from air pollution, household air pollution in Bhutan.

Introduction

Well into the second decade of the 21st Century, almost 3 billion people (around 6-700 million households) still rely on solid fuels (wood, animal dung, crop wastes, charcoal and coal) for their everyday cooking and heating needs. Combustion of household fuels is responsible for a very substantial global burden of disease, estimated at almost 2 million premature deaths for 2004 (WHO 2009). The most recent estimate of disease burden published by IHME for the year 2010 reported 3.5 million premature deaths, the main reason for the apparent increase being the addition of cardiovascular disease as an outcome (Lim *et al.* 2012). The incomplete combustion of solid fuels in traditional open fires and stoves leads to levels of household air pollution (HAP) which far exceed WHO air quality guidelines (WHO 2005), causing a wide range of respiratory diseases, adverse pregnancy outcomes and cancer affecting people across the whole life course. This burden occurs mainly in developing countries where solid fuels are used extensively for cooking, and also for heating (Figure 1).

Although the use of solid fuels for cooking has declined globally from around 60% of homes in 1980 to 41% in 2010, the world's growing population means that the number of people affected - some 2.8 billion – is the almost the same now as it was 30 years ago (WHO 2012) (Bonjour *et al.* 2012, accepted). At current rates of change, the total number of people using solid fuels is expected to increase to 2030 (IEA 2011).

This is not only a health risk in developing countries, however. Solid fuels are also used extensively for heating in more developed countries where poorer quality stoves, inadequate ventilation and maintenance contribute a smaller but largely unknown health burden (Noonan *et al.* 2007). Other household fuels used widely in both developing and developed countries, including kerosene (paraffin) and gas for both heating and lighting, also emit health damaging pollutants with exposure levels depending on the condition of the device and adequacy of ventilation. (Lam *et al*. 2012).

For the 1.3 billion people with no access to electricity (and many more with intermittent supply) (IEA 2011), lighting is most commonly obtained from simple kerosene lamps, which are an important source of HAP and an important risk for burns and fires (Lam *et al.* 2012). Children are also at risk of poisoning from drinking kerosene which is commonly purchased and stored in soft drink and water bottles (Yach 1994). The majority of households without electricity are the same homes as those habitually using solid fuels for cooking. They are among the world's poorest people, who face multiple other threats to health, including from unsafe water and sanitation, infectious diseases, and inadequate access to health services.

Until recently, progress with the implementation of policies and interventions for improving access to clean and safe household energy has been very slow at best in most affected countries. The launch in 2010 of the UN Foundation's Global Alliance for Clean Cookstoves (http://www.cleanccokstoves.org), and the ambitious UN-led initiative on Sustainable Energy for All (http://www.sustainableenergyforall.org/) are providing a renewed momentum to address this issue.

The new WHO indoor air quality guidelines on household fuel combustion will make an important contribution to these efforts through providing the scientific basis for selecting household energy interventions which can substantially improve the health of users, and ensuring that these benefits are realised as quickly and equitably as possible. Building on existing WHO ambient and indoor air quality guidelines (WHO 2005; WHO 2009; WHO 2010), this new volume will be global in scope but with a particular focus on developing countries, in recognition of the distribution of disease burden. All main applications of energy in the home will be addressed, principally cooking, heating, lighting. The guidelines work will be conducted in two phases. Phase I will see the development and publication of the Guidelines volume, with initial guidance on implementation. Phase II will be directed at supporting countries in implementation, evaluating the progress made, and developing further technical support based on this experience.

The aim of this paper is to describe the development of these new guidelines, the rationale for the areas of evidence reviewed, methods for assessing the strength of evidence available for making recommendations, and plans for supporting and evaluating country implementation. In order to illustrate the circumstances and policy challenges involved in developing countries seeking to address this issue, a case study from one country, Bhutan, where the authors of this paper investigate HAP at the moment, is reported.

Evolution of the new IAQG

These new Guidelines are the third in a series of WHO indoor air quality guidelines products. Following publication of the WHO ambient (outdoor) AQG Global Update in 2005 (WHO

2005), work began to develop indoor guidelines with three components: (i) Selected pollutants (WHO 2010), (ii) Dampness and Mould (WHO 2009), and (iii) Household Fuel Combustion - this project.

The 2005 Global update included particulate matter (PM_{10} and $PM_{2.5}$), and introduced for the first time the concept of 'intermediate targets', set at three levels (IT1 to 3) (Table 1). The purpose of these was to allow a staged approach towards meeting the actual guideline levels in settings where current levels are very high, and rapid compliance with the guideline would be seen as impractical. This is an important concept and strategy that is being carried through to the new Guidelines. The 2005 update also included a Chapter on household air pollution (Chapter 9), with a focus on the situation and challenges for developing countries. This discussed proposals that – alongside the conventional guideline levels of pollutants - technology and fuel-base guidelines would also be required. Thus, in the absence of actual measurements of HAP and exposure (which will not be available on a population basis), proxies based on survey information on fuels, technologies and household characteristics will need to be used. It was also argued that a limited number of ad hoc studies measuring HAP and exposure will still be required, to 'calibrate' such survey-based information to absolute concentrations.

Box 1: Chemicals included in WHO Guidelines on selected pollutants (WHO 2010)

1. Benzene*
2. Carbon monoxide*
3. Formaldehyde*
4. Napthalene*
5. Nitrogen dioxide*
6. Poly aromatic hydrocarbons (PAH)*
7. Radon
8. Trichlorethylene
9. Tetrachlorethylene

* Combustion related

The volume on Specific Pollutants reviewed the evidence for nine pollutants (see Box 1), six of which are combustion–related. Particulate matter was not included in this volume, as the available evidence and guideline levels already covered in the 2005 Update were stated to apply equally to the indoor environment. This volume also included a new 24-hr guideline for carbon monoxide of 7 mg/m^3, in response to growing evidence of health impacts from chronic exposure, in addition to the already well-recognised toxic effects from more acute exposures (Table 1).

Phase I: Development and publication of new Guidelines for household fuel combustion

The core of the new Guidelines is a set of systematic evidence reviews that will form the basis of recommendations. These are complemented by description of an emissions model, based on work designed to relate emission rates to predicted HAP concentrations in a standard box model (Johnson *et al.* 2011). The reviews cover a wide range of topics, from background material on household fuel use globally, through levels of emissions, household pollution and exposure to health impacts and the effectiveness of the different types of stoves and fuels available as interventions. In recognition of the challenges for adoption of interventions in low-income settings, the guidelines also include a review of enabling and limiting factors for adoption and sustained use of improved stoves and clean fuels (see Box 2).

The evidence on which these reviews draw is very diverse, including nationally-representative surveys, laboratory-based testing of stoves, quasi-experimental field studies of the impacts of stoves on HAP and exposure, and a range of epidemiological studies of health risks that include cross sectional studies, analytic observational studies, and a very few randomised trials. Bringing this varied body of evidence together presents a considerable challenge, and not least for applying the standard methods recommended by WHO for assessing the strength and quality of evidence used for making policy recommendations.

This methodology, known as GRADE (Grading of Recommendations Assessment, Development and Evaluation), was originally developed for the type of evidence available to medical interventions, and mainly RCTs[1]. In summary, GRADE is used to categorise bodies of evidence used for making recommendations into four levels, namely high, moderate, low and very low. (Balshem *et al.* 2011) Randomised trials enter the process as high, while all observational designs (including quasi-experimental) enter as low. This initial assessment can be downgraded according to five criteria, and upgraded according to three others (Table 2). Using this methodology, bodies of evidence that are

Box 2: Topics for evidence reviews

- Fuels and technologies used for cooking, heating, lighting and other uses.
- Emissions from a representative range of fuel/technology options.
- Modelling emissions to meet WHO air quality guidelines.
- Air pollution and exposure levels experienced by households.
- Health risks from HAP exposure from solid, liquid and gaseous fuels.
- Risks of burns and poisoning from household fuels
- Impacts of interventions on HAP and exposure in practice
- Key enabling and limiting factors for sustainable adoption at scale.
- Intervention costs, financing options (including climate finance) and economic evaluation.
- Key issues for emergency and humanitarian settings.

[1] See GRADE working group http://www.gradeworkinggroup.org/index.htm

dominated by observational evidence, as is common in environmental health due to the practical and ethical constraints on conducting randomised trials, tend to results in GRADE assessments which are low or very low.

Recent years have seen growing awareness of the limitations of this approach for application to the evidence use for policy on complex interventions common in public and environmental health work, although some argue that GRADE can work effectively for such evidence (Durrheim and Reingold 2010; Schunemann *et al.* 2010; Rehfuess *et al.* 2011).

Building on this debate and the undoubted value of GRADE, work is underway to apply a modified version in the new guidelines. The new approach recognises that the majority of evidence available contributes to a set of steps in a causal chain (from intervention to emissions, to household concentrations, to exposure and finally to health outcomes), and that few studies provide evidence on the overall impacts on health of introducing a cleaner household energy intervention. Each of these steps (or combinations) for which there is a body of evidence can be assessed separately, prior to reviewing the coherence of all available evidence in the context of the causal chain model.

The approach to assessing evidence makes an important distinction between (i) the question of whether the association is causal, for which Bradford-Hill viewpoints are used, and (ii) the strength of evidence for the intervention effect size, for which the modified GRADE is being used. Thus, although there are common aspects to these two perspectives, it is possible to have good evidence that an association between HAP exposure and a specific disease outcome is causal (and by implication that reducing exposure will reduce the risk of that disease), but rather weaker evidence as to the precise size of the effect of an intervention to reduce exposure. The modified version of GRADE being applied to these guidelines will give more weight to quasi-experimental study designs, and also take into account two other factors. These are (i) consistency of effect across varied settings and study designs, and (ii) analogous evidence such as where effects on an outcome consistent with dose are also seen with other sources of combustion pollution including ambient air pollution, second-hand smoking and active smoking (Rehfuess *et al*. 2011).

Decisions on how strong a recommendation should be are informed not only by the strength of the available evidence, but also by other factors, including interventions costs, values and preferences, the balance of benefits and harms, and economic assessments of costs and benefits[2]. In the case of the new IAQG, these can have an important bearing on recommendations, and all are subject of reviews and discussion (Box 2).

The draft evidence review chapters were discussed in detail at a Guidelines Development Group (GDG) meeting, held in New Delhi, India, between 24 to 26 April 2012, where provisional recommendations were drafted. The meeting was hosted by the Indian Council of Medical Research and attended by around 30 international experts and ten Indian and international observers. Following external peer review and WHO clearance, the guidelines are expected to be published during 2013.

During the development of the guidelines, WHO is working closely with the UN Foundation's Global Alliance initiative on international standards for cookstoves. Established thus far as voluntary standards through an 'international workshop agreement' overseen by the International Organisation on Standardisation (ISO), these set tiers of performance across four dimensions (fuel efficiency, total emissions, indoor emissions, safety)[3]. The health impacts, based on levels of emissions, relate to existing WHO air quality guidelines for $PM_{2.5}$ and carbon monoxide, and future refinement of the levels used for the tiers will be informed by the evidence compiled in the new WHO Guidelines.

Phase II: Implementation and evaluation

Following publication of the guidelines, WHO will provide technical support to all countries to assist with implementation of the guideline recommendations. The WHO recognises, however, that – particularly for low income countries - there are a number of significant challenges in bringing about a rapid transition to clean, safe and efficient household energy for all segments of society, including:

- The people worst affected by HAP exposure and burns from traditional household fuel use are also the poorest. They are viewed by investors and markets as having low purchasing power and representing high risk, and hence in current market conditions cannot easily access improved energy technologies and fuels.

[2] See guidance from WHO GRC: http://www.who.int/kms/guidelines_review_committee/en/index.html
[3] See http://www.iso.org/iso/catalogue_detail?csnumber=61975

- Unlike the wider (urban) environment, the home cannot easily be subjected to regulation, so that mitigation must look to a wider range of policy instruments , including education, market development, and innovations in finance and other measures to strengthen both supply and demand for cleaner solid fuel technologies and clean fuels. (Bruce *et al.* 2006)
- Regulation has a place however, including around product standards referred to above, and in respect of pollution of the outdoor environment to which household fuel combustion makes a surprisingly large contribution (some 16% globally, substantially more in some regions) (Lim *et al.* 2012), and policy will need to take advantage of these opportunities.
- Those responsible for implementing mitigation policies do not have to hand routinely available data on air pollution in homes. In order to monitor progress, it will be necessary - in addition to some targeted household air pollution assessment – to develop more sophisticated survey instruments that will provide the necessary data on stove and type and use, ventilation and other factors, which can be linked to information in the WHO Guidelines (and new evidence as this becomes available) on how these relate to actual levels of household air pollution and health risk.

By way of example for this last point, current routinely used survey instruments, e.g. for the DHS, do not distinguish between a traditional solid fuel stoves and advanced combustion devices with, for example, fans which have been shown to have much superior performance at least in laboratory tests (Jetter *et al.* 2012). As a consequence, all solid fuel homes are currently allocated the same (high) level of risk. New sets of questions are required to provide more nuanced assessments of all energy uses in the home (e.g. cooking, heating and lighting), and will complement existing and new field studies reporting actual levels of HAP and exposure achieved, and evidence on the related levels of health risk as is being compiled in the new WHO guidelines.

An initial 3-year implementation and evaluation phase is proposed, during which WHO plans to work closely with a number of countries, while developing guidance and tools that can be used more widely. The specific objectives of Phase II will be to (a) provide technical support in preparing an Action Plan and (b) evaluate experience within the countries in developing and starting to implement policy in order to revise and update implementation guidance. Action plans, which are being developed in collaboration with the UN Foundation Alliance, will include tools for situation assessment, methods for evaluation of alternative interventions prior to implementation, opportunities for regulation and application of the evolving ISO standards, awareness raising and market development, financing options, and strategy for monitoring and evaluation. Updating will involve incorporation of new evidence relevant to the guidelines, in particular on field-base testing and evaluation of the performance, acceptability and adoption of cleaner technologies and fuels, and associated programmatic experience.

How will implementation work in practice in developing countries: the example of Bhutan.

Bhutan is a small eastern Himalayan nation, landlocked and bordered by India and China. Some 70% of Bhutan's population of 634,982 live in rural areas (RGoB 2006) and the rural population primarily consists of subsistence farmers. Around 70% of Bhutan's total land area is under forest cover (RGoB 2010). People live in traditional houses made of wood, stone and mud, and cooking takes place either in kitchens attached to the outer wall of the house, or in enclosed separate kitchens.

The government of Bhutan has plans to electrify all rural houses by 2013. A record maintained with the Bhutan Electricity Authority showed that as of December 2010, a total of 68,590 rural households of the total 88,642 have been electrified (Personal Communication). However, except for lighting where electricity has become the primary source, multiple fuels are still used for cooking in rural areas. While rice is generally cooked in an electric rice cooker, curry for example, is still usually cooked over traditional stoves using wood. In general, wood is used for all the intensive cooking purposes as well as for heating. Thus the primary energy source for most Bhutanese households remains biomass, which includes firewood, woodchips and animal dung (DoE 2009). Figure 3 shows the percentage of households relying on different energy sources for lighting and cooking in Bhutan and (DoE, 2005).

It is important to note that the electrified rural households were found to consume only about 25% less fuel wood than un-electrified houses, with per capita wood consumption of 10.4 and 7.8 tonnes per annum respectively for rural un-electrified and electrified houses (DoE 2005). This is because many household activities (in addition to cooking food) such as preparation of animal fodder, brewing and distilling local liquor, which are energy and time intensive, require fuel wood. There is a significant difference in energy usage patterns between urban and rural areas and while urban households mostly rely on electricity and petroleum products, rural areas consume significant amount of wood, the latter accounting for 96% of the total fuel wood consumption (DoE 2005). Bhutan consumed a total of about 725,000 tonnes of firewood in 2005, accounting for 57.7% of the total primary energy supply mix. Per capita wise this has been rated as the highest consumption in the world (DoE 2009).

Cooking using biomass is normally done only on traditional mud ovens, (Figure 4) and even in the houses which are electrified, this type of stove is still used for cooking some dishes (e.g. curry), or just to lower the costs of cooking since wood is widely available and free. Without a chimney (which is the case for a large fraction of households), all of the emissions are released directly into the indoor environment. The thermal efficiency of traditional ovens was found to range from 8 to 18% (DoE 2005). During winter months the use of metal stoves, where wood is burnt for space heating, locally known as *bukhari* (Figure 5) is becoming increasingly common in both urban and rural areas. Although these stoves all have chimneys, during initial lighting, the door of the combustion chamber is left open to allow sufficient air for wood to catch fire. Usually, a small amount of kerosene is used for initial lighting of the wood. This normally generates a lot of smoke, which disperses within the indoor space. Also, strong winds outside can force smoke back through the chimney into the indoor environment. It should be added that the presence of a chimney does not completely resolve the HAP problem: while it certainly improves indoor air quality in houses where biomass combustion takes place, it leads to outdoor air pollution, and hence penetration of the combustion products back to the indoor environment. The higher the density of the houses, which is the case for larger villages or towns, the greater this problem becomes.

An effort to reduce household air pollution and pressure on forests by promoting ‘improved’ stoves was initiated by a number of organisations in the early 1980s. The National Women’s Association of Bhutan was one of the first organizations to disseminate this program with financial and technical assistance from UNICEF and the government. In the early 1990s, this program became a national project. An estimated 14,000 to 15,000 improved stoves were installed, all free of cost in different parts of the country (Palit and Garud 2010). The latest initiative of improved stove dissemination in some of the rural areas is being carried out by a local NGO called the Tarayana Foundation in collaboration with the ALSTOM Foundation (Pindirica 2011).

A number of qualitative reviews have been carried out to assess the benefits of the new stoves following dissemination. In two of the projects funded by the UNDP, users reported that wood consumption was reduced by about 50%, and fuel collection time lowered significantly (Ugyen and Giri 2004). Further, this report also mentions perceived health benefits reported by the people with less smoke exposure. However, several factors have limited sustained use of improved stoves. Over time, stoves became non-functional and people eventually switched back to traditional ovens. The major drawback perceived by the users was that stoves had limited heat radiation capacity for space heating and prolonged cooking hours (Ugyen and Giri 2004; Palit and Garud 2010). Thus, users ended up modifying the pothole dimensions in order to increase the heat output, causing structural damage to the stoves. Further, chimneys were simply removed as some users perceived fire hazards and also because traditionally rural people use smoke to dry chilli and grain in the kitchen.

To date, there has been no quantitative, empirical evidence available on indoor pollution levels in Bhutan, nor on levels of human exposure. However, it is clear that, given the fuels used for cooking and space heating, these can be expected to result in very poor indoor air quality, even among the urban and peri-urban households. Furthermore, the extent to which the new stoves disseminated so far are actually improved remains unknown, and recent experience from India shows that limitations of technology and user acceptance may result in no discernible impact on exposure or health (Hanna *et al.* 2012). Against this background, Bhutan's Health Ministry has ranked respiratory diseases among the top ten most common diseases in the country (MoH 2007). While there is well established evidence of significant contribution to the global burden of disease; however, effective interventions to prevent this occurring in Bhutan, like in many other developing countries, are yet to be developed.

What are the research questions when conducting research on HAP in a developing country like Bhutan affected by household fuel combustion, and how, in the context of this, would the new WHO guidelines be implemented?

A team of academics from QUT, Brisbane, UK, Poland and Bhutan (including all the authors of this paper), aims to address this very important topic and to identify the pollution levels, their sources, drivers, the trends of personal exposure and establish effectiveness of selected interventions. Based on the knowledge built by studies conducted in many developing countries, including Lao PDR lead by one of us (LM) (Morawska *et al.* 2011, Mengersen *et al.* 2011, Mengersen *et al.* 2011) which established the existence of high exposures and related health effects, but not necessarily how to address it, we considered that following specific questions need to be addressed in a quantitative way:

1. What is the contribution of household fuel combustion to household air pollution (HAP) as well as ambient air pollution in rural Bhutan and what are its drivers?
2. How effective is control of indoor exposure to products of household combustion with exhausting them outdoors as a sole mitigation?
3. How does personal exposure vary between different age/gender groups and what drives it?
4. Can a set of appropriate interventions, shown to have low emissions in laboratory testing, be identified and their community acceptability, performance and affordability demonstrated?
5. What are the policy, technical and capacity issues that need to be addressed in implementing the new WHO Guidelines on Household Fuel combustion, and specifically in seeking to attain Guideline levels for $PM_{2.5}$ and CO?

This knowledge will allow for recommendations to combat HAP in Bhutan and contribute to global experience on the application of the new WHO Guidelines for Household Fuel Combustion.

Relevance of the WHO Guidelines on Household Fuel Combustion to developed countries?

Solid fuels, particularly wood are used in many countries of the developed world as a mean of heating or creating a ‘warm’ ambiance, including for example US, Canada or US, (e.g. Wilton *et al.* 2012, Cavanagh *et al.* 2012, Longley *et al.* 2012, Noonan *et al.* 2011), as well as Australia and New Zealand. Cities like Launceston (Luhar *et al.* 2000) in Tasmania, or Christchurch and other cities in New Zealand are notoriously blanketed by smoke from indoor wood combustion during cold winter months when low wind speeds and temperature inversion worsen the situation; with ambient PM_{10} level frequently exceeding the national standards (which is 50 µg m^{-3} as a 24-hour mean; the WHO guidelines in addition specify annual average of 20 µg m^{-3}). While measures have been taken to address the situation by in particular replacement the old inefficient stoves with more modern, lower emission devices

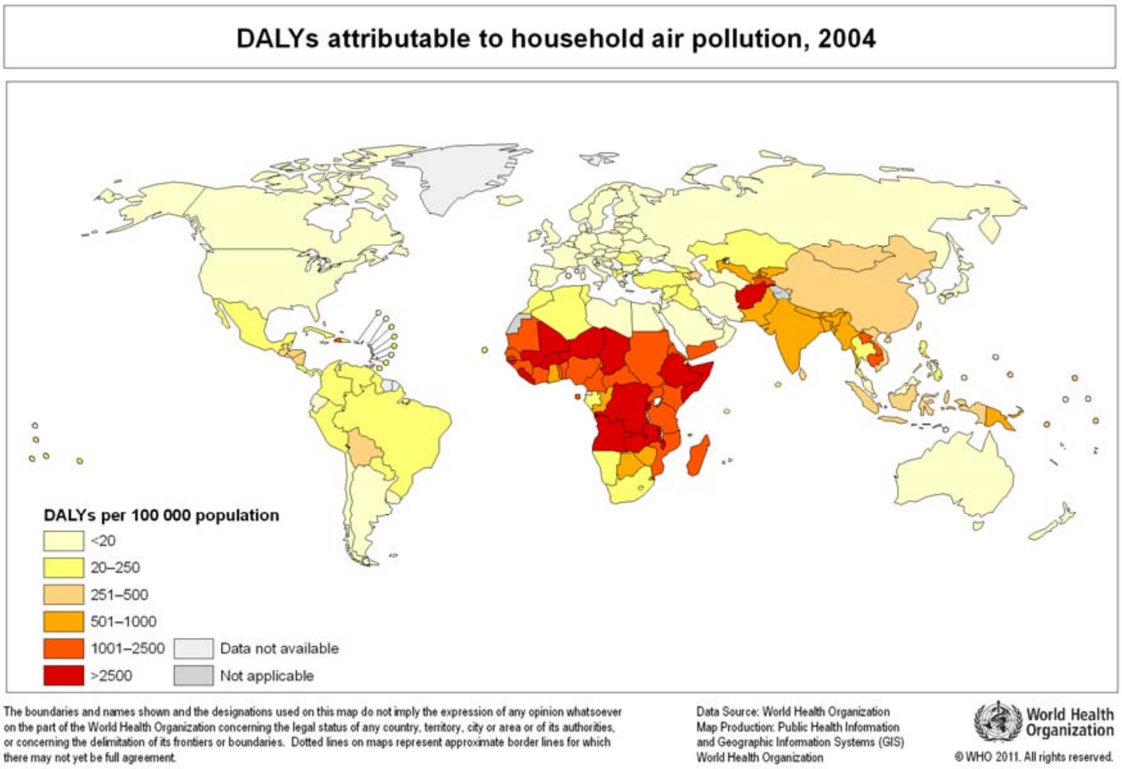
(O'Connell *et al.* 2010), there is still much to be done to reach acceptable ambient are quality. There is much less quantitative information on indoor air quality and the effect the heaters have on it, and as stated by Longley *et al.* 2012: *Studies on the impact of wood-burner replacement interventions are rare, especially on in terms of impact on indoor air quality and exposure,* or by (Wilton *et al.* 2012): *…less is understood about the impact of these burners on indoor air quality.* However, Noonan *et al.* have reported time trends in household and outdoor air pollution associated with replacement of woodstoves in Libby, Montana *(*Noonan *et al.* 2011).

There is no doubt that the types of the wood-burners used in developed countries, particular those modern and more efficient, generate far less household air pollution than for example the stoves used in Bhutan and depicted in Figures 3 and 4, and therefore interventions to improve the situation will be different. It is likely that in developing countries the interventions will initially enable to achieve one of the intermediate targets (WHO 2005), although – for all populations - it remains to be seen whether solid fuel combustion in homes is compatible with the WHO guideline levels for PM2.5 or whether only clean fuels can achieve this. The new WHO Guidelines on Household Fuel Combustion will be an important tool for decision-makers in setting new regulations and policy, and will focus the attention of regulatory as well as the research communities on the need for comprehensive characterisation of air quality affected by solid fuel combustion as well as of human exposure.

Conclusions

Household fuel combustion remains a major public health priority well into 21st Century, as a result of air pollution, safety, and impacts on development and climate. This is primarily an issue for developing countries, but it also presents risks for developed countries. The new WHO Guidelines will provide evidence-based information on stove/fuel performance and associated health risks for decision-making in this challenging policy area, and in helping to ensure equitable access to clean and safe household energy technologies and services. To support this, guidance on implementation, based on evidence of key enabling factors and barriers for adoption and sustained use, will also be included. Following publication of the guidelines during 2013, WHO plans to work closely with a number of countries and international partners to support and evaluate implementation, and use this experience to update guidance as countries and stakeholders get to grips with the challenges and opportunities.

Figure 1: Burden of disease, expressed as DALYs (disability-adjusted life years), attributable to household air pollution from cooking with solid fuels, for the year 2004.



Source: WHO Global Health Observatory (2012)

Figure 2. Primary energy sources for cooking and lighting in Bhutan (RGoB, 2006).

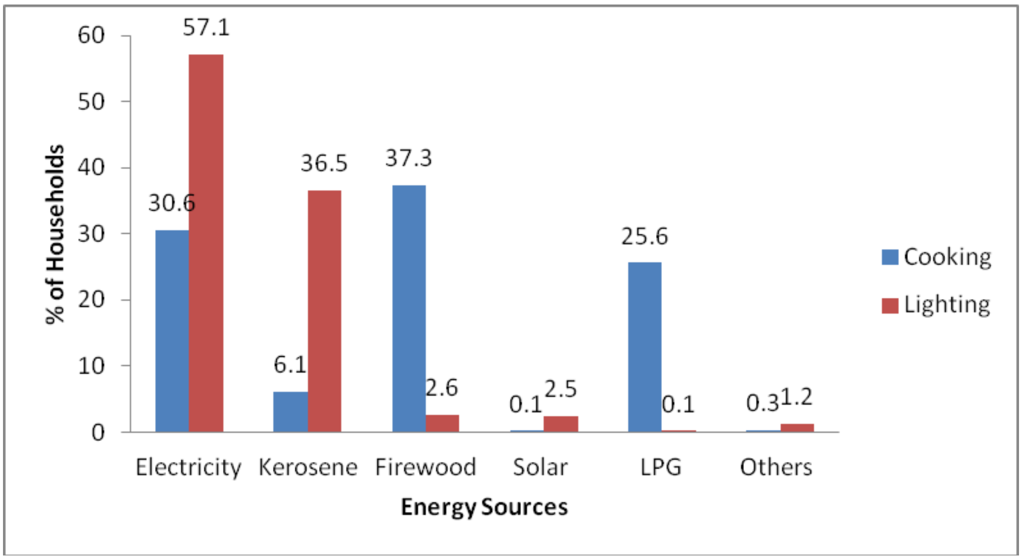


Figure 3: Stoves A traditional mud stove: The stove consists of one or two openings through which fuel wood is fed and ash is removed, and two or three potholes, with raised lumps where pots can rest.

Figure 4: A *bukhari* used for space heating, made of metal and with a chimney (it can also be seen an evident fuel stacking taking place in this house).

Table 1: Guidelines for $PM_{2.5}$ from the WHO Global update (2005) and for Carbon Monoxide from Selected Pollutants (2010).

Pollutant	Guideline or target	Exposure period	Level ($\mu g/m^3$)
$PM_{2.5}$	Guideline	Annual average	10
	IT-3		15
	IT-2		25
	IT-1		35
Carbon monoxide	Guideline	8-hour	10
	Guideline	24-hour	7

Source: WHO

Table 2: The GRADE table used for assessing the quality of bodies of evidence used for making recommendations

Study design	Initial score	Reduce score for these factors	Increase score for these factors	Quality of evidence
Randomized trials	High	Risk of bias: -1 (serious) -2 (very serious)	Large effect: +1 (Large) +2 (Very large)	High (++++) Moderate (+++)
		Inconsistency: -1 (serious) -2 (very serious)	Dose response: +1 (Evidence of a gradient)	Low (++)
Observational studies	Low	Indirectness: -1 (serious) -2 (very serious)	All plausible residual confounding: +1 (would reduce a demonstrated effect) +1 (would suggest a spurious effect if not effect was observed)	Very low (+)
		Imprecision: -1 (serious) -2 (very serious)		
		Publication bias: -1 Likely -2 Very likely		

Source: (Balshem *et al.* 2011)

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