

Household energy, indoor air pollution and child respiratory health in South Africa

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Abstract

Indoor air pollution due to the indoor burning of polluting fuels has been associated with Acute Lower Respiratory Infections (ALRI) amongst children less than five years old. This paper reviews evidence of the association between household energy, indoor air pollution and child ALRI in South Africa. Studies show evidence consistent with the international literature with the likelihood of ALRI between 2 and 4 amongst children living in households using polluting fuels compared to households using electricity. Indoor air pollution is responsible for the deaths of up to 1 400 children annually. Interventions have demonstrated 46 – 97% lower pollution concentrations compared to open fires. However, the sustainability of selected interventions has been questioned in certain contexts. The paper discusses the strengths and weaknesses of the evidence and highlights opportunities for further research.

Keywords: household energy, indoor air pollution, child ARI, interventions

Introduction

Over half the global population (3 billion people) are reliant on solid biomass fuels such as wood, coal, crop residues and animal dung for their domestic energy requirements (The World Resources Institute, 1998; Ezzati et al., 2004). When burned indoors in open fires or rudimentary appliances, the incomplete combustion of solid biomass fuels release high concentrations of toxic pollutants such as particulate matter (PM), carbon monoxide (CO), oxides of nitrogen, sulphur dioxide (SO₂) and volatile organic compounds into the living environment (Smith, 1987; Bruce et al., 2000). In addition to environmental concerns such as deforestation and greenhouse emissions, the high household reliance on solid biomass fuels has been associated with a number of health outcomes.

Exposure to indoor air pollution has been associated with chronic obstructive pulmonary disease, lung cancer, nasopharyngeal cancer, tuberculosis and diseases of the eye in adults; low birth weight and, of particular concern, acute lower respiratory infections (ALRI) such as pneumonia amongst children less than five (Bruce et al., 2000; Smith et al., 2000). ALRIs are the single leading cause of death amongst children less than 5 years old worldwide

(Murray and Lopez, 1997) and amongst the top 4 killers of South African children less than five years old (von Schirnding *et al.*, 1991b; Bradshaw *et al.*, 2003).

Young children are more susceptible to ALRI through indoor air pollution exposure for a number of reasons. The epithelial linings of children's lungs are not fully developed resulting in greater permeability of pollutants (Pande, 2000), their immune systems are not fully developed thereby limiting the body's defence against infection (Smith *et al.*, 2000), they have higher respiration rates and they have a larger lung surface area per kilogram of body weight thus breathing in approximately 50% more (polluted) air under normal breathing conditions compared to adults (Moya *et al.*, 2004). In addition, from an exposure perspective, children tend to follow their caregivers' around, for example, through carriage on their caregivers' backs (Mtango *et al.*, 1992).

Indoor air pollution exposure is a function of the complex interplay between household fuel patterns (Smith, 1987), appliances (Ezzati *et al.*, 2000), housing design (Bruce *et al.*, 2002) and human behaviour (Barnes, 2005). In addition, risk factors such as nutrition, crowding, family history of infection, poor vaccination history and exposure to environmental tobacco smoke (Kirkwood *et al.*, 1995; Victora *et al.*, 1994) may influence child susceptibility to ALRI. Even more challenging is the fact that indoor air pollution unravels against the backdrop of poverty that influence each of these factors.

In terms of global relevance, South Africa is particularly interesting for two reasons. Firstly, there have been a number of scientific studies (summarized in this paper) to understand the problem of indoor air pollution and child ALRI in South Africa. Secondly, there have been a number of post-apartheid policy developments – including the Clean Air Act (NEM 2004) and the Integrated National Electrification Programme (INEP) – that have been designed to address, amongst others, indoor air pollution. The problem, however, is that except for one review of the methodological quality of epidemiological studies (Wichmann & Voyi, 2005), the scientific evidence has yet to be integrated into a single review document.

The aim of this paper, therefore, is to review the scientific evidence of the association between household energy, indoor air pollution and child ALRI in South Africa. In terms of methodology, studies were sourced using the PubMed, Google Scholar and Electronic Theses and Dissertation (ETD) databases. Search terms included the following: South Africa, household energy, indoor air pollution, child ALRI, epidemiology, wood smoke, interventions and poverty. Overall, 68 works were sourced based on their relevance to the topic. Peer-reviewed journal articles, peer reviewed reports and

dissertations were prioritised for review, which means that (important) topics such as renewable energy and housing efficiency that are under represented from an indoor air pollution perspective in the published peer-reviewed literature receive limited attention. Before proceeding, it is important to understand the spatial and temporal patterns of household energy in South Africa.

Household energy patterns

The 'energy ladder' model has been used to categorise energy sources along a hierarchy according to their cost, ease of use, technological advancement and, importantly for this work, the concentrations of air pollution they produce (Smith *et al.*, 1994). At the bottom of the ladder are solid biomass fuels such as cow dung, crop residues and wood. Biomass fuels are followed by coal, charcoal and paraffin (often referred to as transition fuels). 'Modern fuels' such as liquid petroleum gas (LPG), natural gas and electricity occupy the higher rungs of the ladder. Electricity is situated at the top of the ladder and is considered to be the safest fuel in terms of indoor air quality. As fuels become more advanced and safer, however, they also increase in both direct (to use them) and indirect (to purchase appliances to use them) cost at the household level (Smith, 1987).

The South African government's household energy strategy has had a strong focus on household electrification (http://www.dme.gov.za/energy/elect_inep/stm). The INEP electrified over 2.5 million households between 1994 and 2000 at a rate of approximately 1 000 households per day. As a result, between 1994 and 1999, the proportion of households with access to electricity increased from a 36% to 63% (Department of Minerals and Energy, 2001). By the end of 2006, 73% of South African households had access to electricity (Department of Minerals and Energy, 2006).

Table 1 summarizes the main energy used for cooking and space heating derived from Statistics South Africa's 1996 and 2001 census as well as 2007 community survey data sets. Electricity was the main fuel used for cooking and heating followed by either paraffin or wood at each interception. It is encouraging to note that there was a marked increase in the proportion of households using electricity for cooking (+20%) and heating (+14%) between 1996 and 2007; gas remained relatively static; while there were decreases in paraffin (-7% for cooking and -1% for heating), wood (-7% for cooking and -8% for heating) and coal (-3% for cooking and -4% for heating) (Statistics South Africa, 1998, 2003 and 2007).

Movement up the energy ladder was particularly noticeable amongst the Black African¹ population group, which due to apartheid legislation was, and continues to be, the most underserved social group

Table 1: South African fuel use 1996-2007
 Source: Statistics South Africa (1998, 2003 & 2007)

Year	Main fuel used for cooking			Main fuel used for heating		
	1996	2001	2007	1996	2001	2007
Electricity	47	51	67	45	49	59
Gas	3	3	2	1	1	1
Paraffin	21	21	15	14	15	13
Wood	23	21	15	27	25	20
Coal	4	3	1	8	7	4
Animal dung	1	1	<1	<1	<1	<1

* Unspecified fuels not included

in terms of energy access. Electricity as the main fuel used increased by 8.9% for cooking and 9.3% (between 1996 and 2001) for heating amongst this group – possibly a function of improved access to electricity the INEP together with an improvement in household income to be able to afford that electricity.

While the Statistics South Africa datasets provide a useful overview of household energy patterns, the figures tend to mask the use of multiple fuels for cooking and heating purposes. The census data is derived from a question that focused on the main fuel used for cooking and heating. In reality, however, poorer households use multiple fuels to fulfil their domestic energy needs based largely, although not exclusively, on their ability to afford those fuels (Davis, 1998; Shackleton, Gambiza & Jones, 2007).

Figure 1 highlights access to electricity as well as solid biomass fuel use in South Africa. Data is disaggregated by rural-urban differences but also, importantly, by level of economic development (reported as wealth quintiles) (WEC & FAO, 1999). In urban contexts, access to electricity increases and biomass usage decreases with economic development. Put simply, wealthier urban households not only have better access to electricity but also use

that electricity for their domestic energy needs. In rural contexts, however, not only is electricity access poorer but fuel switching is more commonplace, that is, the combined use of electricity with other (usually) biomass fuels.

Multiple fuel use has been highlighted by a number of localised studies that have focused on household energy patterns. A study in the rural North West Province (Mathee et al., 2000), for example, found that after electrification, all households used electricity immediately for lighting (the cheapest function). Approximately 44% and 89% of households had never used electricity for cooking and heating respectively three years after being electrified. The effect of household economic development was also highlighted in a study of 1 000 households in Port Elizabeth (Thomas et al., 1999). Although most households were electrified, amongst the low quintile group only 19.3% of households were reliant on electricity for cooking purposes followed by the lower middle (36%), middle (83.6%) and upper middle (94.3%) quintile. Amongst the high wealth quintile, 99.5% of households were reliant on electricity for cooking. Paraffin was used as the secondary fuel with a small proportion of households reliant on LPG (<3%) in each category (Thomas et al., 1999).

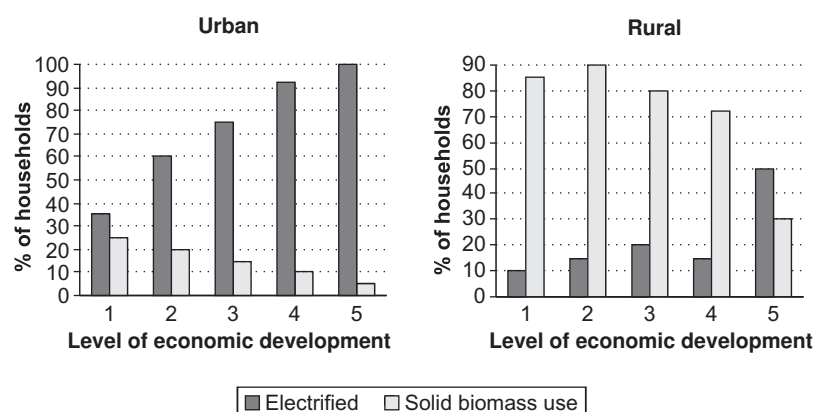


Figure 1: Household energy patterns by level of economic development in South Africa
 Source: WEC & FAO (1999)

Paraffin remains a major concern in poor urban environments not only from an indoor air quality perspective, but also because of its association with child poisoning and property damage (Matzopoulos, Jordaan & Carolissen, 2006). Paraffin dependence is supported by several studies in poor urban settlements. A study in Cato Manor (Durban), for example, found that 87% of households were reliant on paraffin for cooking (Muller et al., 2003), while a study in Alexandra (Johannesburg) found that 52% of households were reliant on paraffin for cooking (De Wet et al., 2001). A multi-site survey found a high reliance on paraffin even after electrification in Lady Grey (North Eastern Cape) (90% of households relied on paraffin), Benoni (Gauteng) (73%), Gugulethu (Western Cape) (73%) and Galashewe (Northern Cape) (56%) (Roberts & Wentzel, 2006).

Coal continues to be heavily used in high density urban settlements. Although household coal reliance is relatively low at the national level (3% for cooking and 7% for space heating in 2001), the problem is highly localised (Statistics South Africa 2003). For example, over 63% of households in informal settlements in the 'Vaal Triangle' areas of Sasolburg, Vereeniging and Vanderbijlpark are reliant on coal. Pollution from coal is not only a problem from indoor air pollution (particularly for adult health outcomes such as lung cancer) but also its contribution to community air pollution especially during winter.

In sum, although access to electricity has significantly increased from 1994, poorer communities continue to rely on polluting fuels as secondary energy sources. In rural areas wood is still widely used while in urban areas paraffin remains a popular choice. The high reliance on polluting fuels, particularly amongst poorer South African households, raises the question: what are the respiratory health effects of indoor air pollution exposure? To answer this question, we review the epidemiological evidence of the association between indoor air pollution and child ALRI.

Epidemiological evidence

Although epidemiological studies of the health effects of indoor air pollution exposure in South Africa are limited, several studies have highlighted cause for concern. As early as 1982, Kossove found that of 132 infants with severe lower respiratory tract disease treated in an outpatient clinic, 70% were exposed to daily levels of smoke from cooking and heating. In comparison only 33% of the 18 infants free of respiratory illness were exposed to smoke (Kossove, 1982) (OR=4.2).

Similarly, household reliance on solid fuels such as wood, coal and cow dung has been associated with child ARI morbidity. Amongst others, a failure to use electricity for cooking and heating was found

by von Schirnding et al., (1991a) (OR=2.5) and Dudley et al., (1997) (OR=2.37). In addition, one study found that chest illness amongst children (particularly boys) was strongly associated with non electricity fuel use (Zwi et al., 1990) (OR=1.88). Sanyal and Maduna (2000) showed a possible association between high levels of recurring respiratory symptoms amongst children and high levels of indoor air pollution (up to 12 times international guidelines) amongst poor communities living in the Eastern Cape province of South Africa.

One of the most comprehensive South African studies – the Vaal Triangle Air Pollution Study (VAPS) – highlighted, amongst others, high levels of air pollution in coal burning urban areas as well as the risk to upper and lower respiratory health associated with exposure (Terblanche et al., 1992; Terblanche et al., 1993). Amongst rural children, the VAPS study also highlighted a significantly elevated risk of developing ARI (OR=5) amongst children in wood and coal burning homes (Nel et al., 2003). Although in a positive direction (OR=1.3), a study by (Wesley & Loening, 1996), however, showed no significant association between fuel use on the severity of respiratory infections.

More recently, the work of Wichmann and Voyi focused on the association between polluting fuels and child ALRI derived from the 1998 South African Demographic and Health Survey (n =12 000 households). In terms of morbidity, children who lived in households that burned polluting fuels were 1.27 times more likely to have experienced an ALRI episode in the two weeks preceding the interview compared to children living in homes using clean fuels (defined as LPG or electricity) (Wichmann & Voyi, 2006a). The relative risk for mortality was 1.95 after adjusting for potential confounding (Wichmann & Voyi, 2006b). The associations (presented as odds ratio with 95% confidence intervals) found in the epidemiological studies considered in this paper are summarized in Figure 2.

A number of indoor air quality studies – that have not necessarily reported on child respiratory health – have highlighted cause for concern. A study of indoor air quality among 72 paraffin burning urban households revealed that 42% of households exceeded one hour guidelines for SO₂, 30% for CO and 9% for NO₂ (Bailie et al., 1999). Similarly, Sanyal and Maduna (2000) found that levels of CO, SO₂ and NO₂ often exceeded accepted guidelines in a peri-urban setting in the Eastern Cape. Monitoring of PM₁₀ amongst 100 household in the rural North West Province during winter showed that 68% of wood and cow dung burning households exceeded the US EPA (24 hour) guideline of 150µg/m³ for PM₁₀ (Barnes et al. 2006). The study also showed that children were in the kitchen 52-61% of the total time that a fire was burning during winter (Barnes et al., 2005).

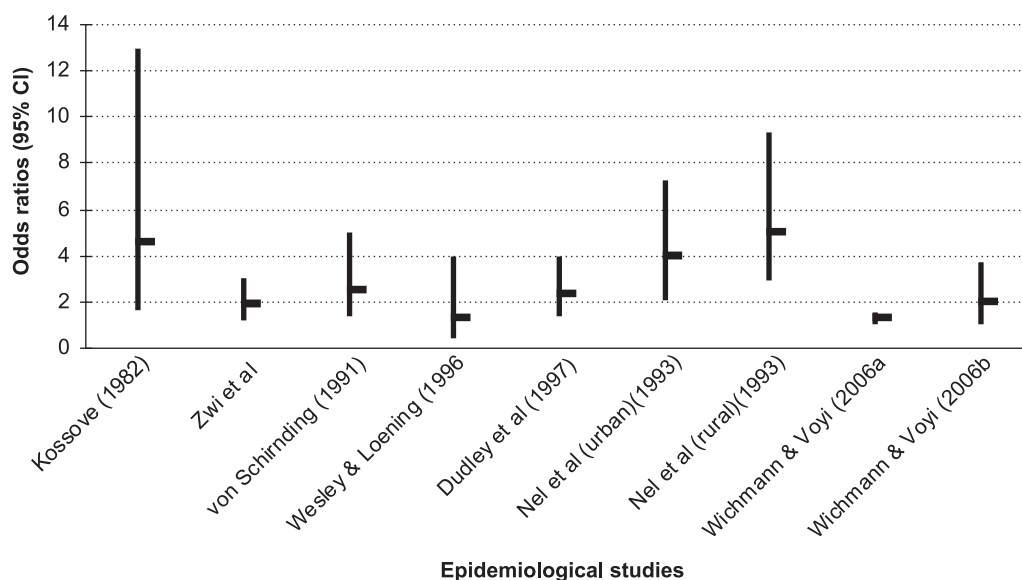


Figure 2: Risk of child ALRI and polluting fuels in South Africa

Air quality studies have also demonstrated a strong seasonal trend in indoor air pollution because of the increased reliance on solid fuels for space heating. The study by Sanyal and Maduna (2000) showed a strong seasonal trend with CO, SO₂ and NO₂ significantly lower in summer compared to winter. Amongst the low income group (mostly reliant on wood and low-grade coal), morning average hourly CO sampled in the cooking area increased by 63% while NO₂ increased by 130%. Compared to summer, a study in a coal burning township in the VAPS showed a 101% increase in children's (8 – 12 years old) total suspended particulate (TSP) exposure during summer (Terblanche *et al.*, 1993). Similarly, a comparison of two studies conducted in the same rural un-electrified villages and using the same sampling methodology – one in summer (Röllin *et al.*, 2004) and one in winter (Barnes *et al.*, 2006) – showed a difference of PM₁₀ measured in kitchens of over 200%.

Based on these and other studies, the World Health Organization (WHO) has recently estimated that 1000 people die annually from indoor air pollution exposure in South Africa. Of these, 450 children die of ALRI as a result of indoor air pollution exposure (World Health Organization, 2007). However, burden of disease estimates (BOD) done by the South African Medical Research Council suggests that indoor air pollution caused substantially more (2 489) deaths in South Africa that included 1 428 children less than five years old who died of ALRI because of indoor air pollution exposure (Norman *et al.*, 2007).

Given the strength of the associations between indoor air pollution exposure and child ALRI, it is important to understand the effectiveness of potential prevention activities. The following section

reviews studies of the effectiveness of indoor air pollution prevention.

Potential interventions

Globally, four intervention categories have been identified for their potential to reduce the impact of indoor air pollution on child ALRI: cleaner burning fuels, improved cook stoves, housing design and behavioural change (Ballard-Tremmer & Mathee, 2000; von Schirnding *et al.*, 2002). Six South African studies have highlighted the potential role of prevention interventions in reducing indoor air pollution.

In terms of cleaner burning fuel, a study by Röllin *et al.*, (2004) showed that, despite slow household progression up the energy ladder, rural electrified households showed 75% lower PM₁₀ (24 hour) concentrations than similar un-electrified households. One South African study monitored outdoor air pollution close to the living environment for 30 days before and after the introduction of household low-smoke fuels in an urban community. Air pollution was highest when low-grade coal was used in households during the first ten days of the experiment (mean daily PM₁₀ concentrations equalled 129 µg/m³), were lowest after low smoke fuels were introduced over the next ten days (mean equalled 70 µg/m³) (46% reduction) and increased again after residents used a combination of low grade coal and low smoke fuels over the final ten days (mean equalled 86 µg/m³). Although the study only measured outdoor air pollution, it highlighted the potential of low smoke coal in reducing indoor air pollution (Engelbrecht *et al.*, 2001).

Ballard-Tremmer & Jawurek (1996) compared the emissions of fuel/appliance combinations under controlled laboratory settings. The study showed

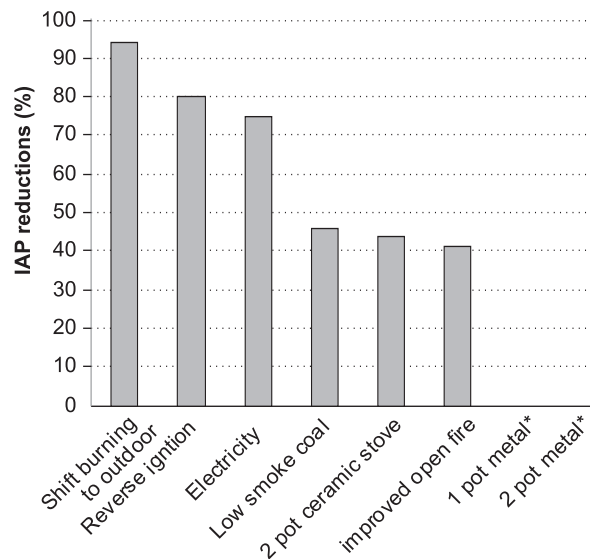
benefits from modern fuels such LPG and paraffin under controlled burning conditions. The simple act of raising a solid fire by placing it on a grate a few centimetres off the ground showed a 41% reduction in indoor air pollution while a 2-pot ceramic stove reduced emissions by 44% (Ballard-Tremeer & Jawurek, 1996). Importantly, the study showed that the 1-pot and 2-pot metal stoves emitted more pollution than the open fire highlighting and the fact that it is important to be cautious about assuming that improved technology will necessarily result in lower emissions.

A laboratory study by Surridge et al., (2005) focused on the impact of an alternative ignition process for coal fires on indoor air quality. The study reported that the upside-down ignition method in a commonly used burning appliance in urban South Africa (the brazier or 'mbawula') – where fires are ignited with coal at the bottom, paper/wood kindle above the coal and a small amount of coal on top (instead of the regular method of paper/wood kindle at the bottom and coal at the top) – reduced PM₁₀ by 80 – 90% in laboratory testing (indoor air pollution levels, however, were not reported), took a shorter time to cook with and less coal being used (Surridge et al., 2005). The 'Basa Njengo Magogo' (which, translated means 'make your fire like the old lady' is based on the idea was perfected by an old lady in a pilot phase) project has been included in South Africa's Integrated Household Clean Energy Strategy.

A before-intervention study in the rural North West Province promoted the health benefits of outdoor burning amongst poor rural (un-electrified) communities. When fires were brought indoors, the intervention promoted safer ventilation and child location practices. Based on two phases of formative research (Barnes et al., 2004b; Barnes et al., 2004a), the study showed that household shifts to outdoor burning was associated with significantly lower median levels of indoor air pollution (PM₁₀ by 94 – 96% and CO by 85 – 97%) and child personal exposure to CO (83 – 95%) compared to indoor burning. Behaviours in the indoor environment e.g. opening windows when fires were burning was associated with a 50% median reduction in pollutant concentrations (Barnes et al., 2006). Figure 3 summarizes pollutant reductions associated with the interventions described above.

Discussion

It is encouraging to note the progression of the South African population up the energy ladder between 1996 and 2007. Importantly, there was a higher than average increase amongst Black African households who used electricity as the main fuel used for cooking and heating. The use of electricity has been associated with a significant decrease in indoor air pollution (Röllin et al., 2004) and found



* Increased pollutant concentrations compared to open fires

Figure 3: Indoor air pollution reductions associated with interventions

to be significantly protective of respiratory health (von Schirnding et al., 1991a; Dudley et al., 1997; Wesley & Loening, 1996). Electricity access, however, does not necessarily imply a displacement of polluting fuels – particularly amongst the poor. The use of multiple fuels remains a concern after electricity (or other cleaner fuels) has been guaranteed.

Of particular concern is the continued dependence of paraffin in poor urban settlements. As much as 90% of poor households in informal settlements were reported to be dependant on paraffin as a secondary fuel after electricity has been guaranteed. Two studies (Bailie et al., 1999; Muller et al., 2003) have shown high levels of gaseous air pollution, which suggests that paraffin may not be as clean burning as previously thought (Mehta & Shahpar, 2004). More work is needed to understand the health effects of indoor air pollution from paraffin burning.

Although South African epidemiological indoor air pollution studies are few, they are relatively consistent with the international evidence. The epidemiological studies reviewed in this paper showed positive associations between indoor air pollution and child ALRI. The majority of studies reported Odds Ratios (ORs) between 2 and 4, which are comparable to other studies in developing countries (ORs 2 – 3) (Smith, 2002; Dehrani et al., 2008). The high levels of indoor air pollution measured in South African households contribute to this concern. However, the body of South African epidemiological evidence has a number of limitations.

First, relatively few epidemiological studies have actually focused on indoor air pollution and child ARI in South Africa. For example, only eight published epidemiological studies could be sourced for

this review. Second, very few studies have actually measured child indoor air pollution exposure or by the very least stationary indoor air concentrations. Instead, studies have mostly used proxies of exposure such as poor access to modern fuels, carriage on mothers' backs during cooking or estimates of the amount of time that children spend in the vicinity of fires to determine child indoor air pollution exposure (Ezzati & Kammen, 2002; Smith, 2002).

Third, many studies have not adequately dealt with the role of confounding factors (Bruce et al., 1998). It is important to note that indoor air pollution is not the only risk factor for child ALRI. The association between indoor air pollution and child ALRI is complex and a number of factors are thought to influence the association including low birth weight, under nutrition, crowding, environmental tobacco smoke and incomplete immunization history (Victora et al., 1999; Victora et al., 1994; Kirkwood et al., 1995).

Fourth, South African indoor air quality studies have focused on different pollutants (e.g. SO₂, NO₂, PM₁₀, CO and so forth) that have been measured over different time periods (1 hour, peak cooking times, 24 hours) using different sampling and analytic procedures (e.g. time weighted averages, passive diffusion sampling and/or continuous sampling), and have had different health outcome definitions (e.g. respiratory symptoms, incidence, severity and mortality). Despite the limitations, epidemiological studies and indoor air quality are supported by sophisticated air pollution studies in relation to outdoor pollution and exposure to environmental tobacco smoke (focusing on similar pollutants) conducted in developed countries (Schwartz, 2004).

South Africa is poised to address the indoor air pollution problem through a number of programmes such as the Integrated Household Clean Energy Strategy (IHCES) (Department of Minerals and Energy, 2004) and the ongoing Integrated National Electrification Programme (INEP) (Department of Minerals and Energy, 2001). In particular, the recently promulgated National Environmental Management: Clean Air Act No. 39 of 2004 (Statistics South Africa, 2004), under which indoor air pollution activities will be directed, calls for air quality management plans at the local, provincial and national levels to amongst others 'address the effects of emissions from the use of fossil fuels in residential applications' (NEM, 2004, 16 section (iv), p 20).

The effectiveness of a number of intervention strategies have been identified and tested in South Africa including electricity, low smoke fuels, improved cook stoves, reverse ignition and outdoor burning. Intervention studies suggest reductions of between 46 – 97% in the indoor environment typical of interventions documented in other develop-

ing countries (Ballard-Tremmer & Mathee, 2000; Budds et al., 2001). However, a comparison of these figures should be interpreted with caution. As mentioned above, studies have focused on different pollutants measured using different methodologies and conducted in a variety of settings (laboratory, field and so forth). In addition, the figures presented above reported percentage reductions compared to baseline values. This means that for some studies the baseline values to which reductions are compared are much higher than others. In addition, it is important to acknowledge the wide within-category variation of air pollution values documented in developing countries, which means, for example, that well tended and ventilated indoor fires may have lower emissions than some improved technologies such as metal stoves (Ballard-Tremmer & Jawurek, 1996).

When considering the effectiveness of interventions in reducing exposure, it is also important to be cautious about assuming that reductions will be of the magnitude to be statistically protective of child ALRI. As mentioned above, the relationship between child ALRI and indoor air pollution is complex and there are a number of reasons why there may be a positive yet relatively modest impact of exposure reductions on child ALRI. First, even though indoor air pollution is often significantly reduced, interventions often do not completely remove air pollution in the indoor environment. In some studies, residual indoor air pollution concentrations after intervention were still evident. The effectiveness of one intervention such as electricity may also be compromised by the use of one or more polluting fuels such as paraffin or solid fuels during winter. It is important, therefore, to acknowledge that interventions do not result in 'air pollution free' living environments and that even low levels of exposure together with other risk factors could still contribute negatively to child ALRI.

Second, as noted above, it is important to remember that the relationship between indoor air pollution and child ALRI is complex and a number of risk factors are thought to influence the relationship. Indeed, some of these factors are thought to play a much stronger role in child ALRI than indoor air pollution in certain contexts (Kirkwood et al., 1995). In South Africa, like elsewhere, indoor air pollution affects the poor where additional risk factors are particularly prevalent. While indoor air pollution may be significantly reduced, the magnitude of additional risk factors may serve to undermine any potential respiratory health gains.

Third, understanding the impact of interventions on child ALRI is also based on the assumption that the uptake and use of those interventions is sustained. Unfortunately, however, many factors serve to impede the uptake and sustainability of interventions in resource-poor settings. The successful dis-

semination and uptake of interventions at the household level is generally context specific and is linked to a number of factors including the design of the intervention e.g. stove (to meet household domestic energy needs such as cooking and space heating), marketing strategies, subsidization, commercialization processes (including local job creation), user perceptions, community participation as well as local energy policies (Goldemberg, 2004; Barnes et al., 1994; Budds et al., 2001). In addition, the financial inability of poor households to afford the uptake and maintenance of the intervention remains a key concern.

Interventions cannot be selected based on pollution reducing effectiveness alone but also on the potential sustainability of those interventions suited to individual contexts. For example, in poor rural communities where fuels are collected free of charge and close to the living environment (the labour burden for fuel collection is low), it is highly unlikely that more expensive technologies such as electricity will be used in the short term. It is worthwhile considering a behavioural intervention approach in such contexts until households are able to afford such technologies. Similarly, in poor urban contexts, technologies to replace or improve paraffin stoves will need to fulfil a number of criteria including cost and convenience as well as addressing accessibility, local distribution and marketing. It is equally erroneous to assume that a single motivation – cost, convenience or improved health – is sufficient for the adoption of a given intervention. Factors that influence household energy choices are complex and what motivates households in one context to adopt an intervention may not be of value in another context. It is important, therefore, to have a thorough understanding of context specific factors that may influence not only effectiveness but also the uptake and sustainability of interventions.

A number of research gaps are evident in relation to household energy, indoor air pollution and health in South Africa. In particular, there is a need for larger more detailed studies to explore the association between interventions, indoor air pollution and, importantly, health impacts. Future studies need to monitor indoor air pollution and exposure for longer periods of time and in much more detail than previous studies (possibly continuously over the study period), need large enough sample sizes to be able to detect impacts on indoor air pollution as well as child ALRI, a clear case definition and robust methodology for diagnosing ALRI, and adjust for the myriad of confounding variables that may influence the impact of exposure reduction on child ALRI. If cases are to be measured at health-care facilities, studies need to pay careful attention to care seeking behaviours, the accuracy and consistency of diagnosis as well as the quality of the

records. There is also a need for harmonized methodologies to facilitate comparison of studies.

Conclusion

Indoor air pollution remains a major environmental health hazard for South African children. Despite the relatively small scale nature of the epidemiological evidence, South African studies have highlighted strong and relatively consistent associations between indoor air pollution and child ALRI. Children living in households that are reliant on polluting fuels are 2 – 4 times more likely to suffer from an ALRI compared to children living in homes reliant on electricity resulting in as many as 1 400 under fives death annually.

Interventions look promising in terms of reducing exposure. In particular, there is evidence of the progression up the energy ladder towards the exclusive use of electricity. There are contexts, however, where there may be a considerable delay in the uptake of electricity. Practitioners need to identify effective yet appropriate interventions to fill the gap until electricity is accessible and affordable.

Note

1. We use the term Black African to reflect a social category stipulated by apartheid legislation. In no way do we support the use of these racial categories except to highlight shifts in access to basic environmental health services from 1994 onwards (post apartheid era).

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