A BEHAVIOURAL INTERVENTION TO REDUCE THE IMPACT OF INDOOR AIR POLLUTION ON CHILD RESPIRATORY HEALTH: IDENTIFYING TARGET BEHAVIOURS

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Abstract

Indoor air pollution has been causally linked to Acute Lower Respiratory Infections in children less than 5 years old and accounts for a significant proportion of death and illness in developing countries. The aim of this study was to identify the target behaviours for a behavioural intervention to reduce the impact of indoor air pollution on child respiratory health by answering 2 research questions. What are the behavioural determinants of Acute Lower Respiratory Infections in young children in this context? What behaviours do caregivers recommend to reduce the impact of indoor air pollution on their children's health? Study participants were 67 caregiver-child combinations living in poor, un-electrified areas in rural South Africa. Of these, 40 households (divided into 20 high and 20 low Acute Lower Respiratory Infection households) participated in the observations and personal interviews while the remaining 27 were involved in focus group interviews. Based on quantitative analyses of household behavioural patterns as well as qualitative analyses of caregivers' recommendations, it is suggested that four behaviours be considered as the core behaviours for the intervention. These are 1) to improve stove maintenance practices 2) improve the quality of ventilation practices 3) reduce the time that children spend close to burning fires and 4) reduce the duration of burning. The behaviours are recommended not only because of their potential to be effective, but also because they are relatively easy to perform and can be implemented at low cost.

It is estimated that indoor air pollution is responsible for between 2.7 and 2.8 million deaths annually (Bruce, Perez-Padilla & Albalak, 2000). In many developing countries, indoor air pollution accounts for 4-6 percent of the burden of disease, placing it above environmental tobacco smoking, sexually transmitted diseases, alcohol and homicides as a leading causes of ill health and death (Smith, 1999). Two recent reviews of published epidemiological studies have identified Acute Lower Respiratory Infections (ALRI) such as pneumonia amongst children under 5 years of age in developing countries as one of the key health outcomes of exposure to indoor air pollution [i] (Smith, Samet, Romieu & Bruce, 2000, Bruce *et al*, 2000).

At the level of prevention, behaviour change has been identified (amongst others) as a possible intervention strategy to reduce the impact of indoor air pollution on child health. Behaviours such as moving children out of the room while a fire is burning, using pot lids while cooking and improving the quality of ventilation practices when burning have all been identified for their potential to reduce the impact of indoor air pollution on human health (cf. von Schirnding, Bruce, Ballard-Tremmer, Ezzati & Lvovsky, 2002). Yet published research studies have yet to systematically focus on these and other behavioural determinants of exposure to indoor air pollution or the effect of behaviour change strategies in reducing the impact of indoor air pollution (Ezzati & Kammen, 2002, Barnes & Mathee, 2002 & Favin, Yacoob & Bendahmane, 1999).

The broad aim of this work, therefore, is to evaluate the effectiveness of a behaviour change intervention in reducing the impact of indoor air pollution on child respiratory health. The goal of this phase of research was to identify the target behaviours for the intervention by answering 2 research questions. What are the behavioural determinants of child ALRI in this context? What behaviours do caregivers recommend to reduce the impact of indoor air pollution on their children's health?

There were two reasons for the selection of the research questions. Firstly, informed by an evidence-based approach to designing interventions (Raphael, 2001), information was needed to determine which behaviours are the determinants of child ALRI in this context. Secondly, it is acknowledged that it is equally, if not more, important to include the recommendations and opinions of community members, thereby developing a process for their involvement from the beginning of the intervention.

The determinants of indoor air pollution and health in developing countries

Indoor air pollution in developing countries mostly arises from the indoor burning of solid fuels such wood, animal dung and crop residues in open fires or poorly functioning stoves. The incomplete combustion of these fuels releases pollutants such as particulate matter (PM), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and other organic compounds (Smith, 1987). It is estimated that at least two-thirds of all households in developing countries are still primarily dependent on biomass fuels and coal, affecting approximately 2 to 3.5 billion people worldwide(The World Resources Institute, 1998).

Research is increasingly demonstrating that exposure to indoor air pollution occurs as a result of the complex interplay of a number of factors. The type of fuel that is burned, for example, is an important determinant of levels of air quality. Controlled studies have shown that fuels can be ranked according to the levels of emissions they produce when burned in similar conditions (particularly those associated with respiratory health such as PM and CO). Biomass fuels such as animal dung, crop residues and wood produce the highest levels of these pollutants thus posing the greatest danger to respiratory health. Moving up the ‘energy ladder’ (according to decreasing levels of emissions and increasing levels of safety), biomass fuels are followed by solid fuels such as coal and charcoal, liquid fuels such as kerosene and Liquid Petroleum Gas (LPG) with electricity being the safest at the top of the energy ladder (Smith, 1987).

In addition to fuel, the type of stove used to burn fuels (or lack thereof) is an important determinant of indoor air quality. The fuel-stove interface is a significant factor determining the emissions produced and their impact on respiratory health. Improved stoves have been associated with improved levels of indoor air quality and respiratory health compared to open fires or poorly maintained stoves using the same fuels (see for example Ezzati & Kammen, 2002a, Albalak, Bruce, McCracken, Smith & De Gallardo, 2001 & Wafula, Kinyanjui, Nyabola & Tenambergen, 2000).

Ventilation is also an important determinant of levels of indoor air quality. For example, cross draft from improved windows and raised roof eaves (Nystrom, 1994 in Ballard-Tremeer & Mathee, 2000, Gitonga, 2001) have been associated with improved air quality levels. In addition, cooking practices such as the use of pot lids and adding fuel to the burning fire have been associated with peaks in emissions from cooking fires within the cooking micro-environment

(Ezzati, Saleh & Kammen, 2000). While air quality is important, the health effect of indoor air pollution is also determined by the amount of time a person spends breathing the polluted air i.e. exposure. Studies have shown that people in developing countries spend between 3 and 7 hours a day in the burning environment (Bruce *et al*, 2000). Because of their domestic responsibilities in and around the burning room, women are typically exposed to indoor air pollution far more than their male counterparts (Engel, Hurtado & Ruel, 1998). In addition, women usually have the added responsibility of caring for children. As a result children tend to be close to their carers - either carried on their caregivers backs or within eyesight – thus also exposing them to high levels of indoor air pollution on a daily basis.

It is not the intention of this paper to portray the body of evidence on indoor air pollution and health as complete or unanimous in its findings. Indeed, as Ezzati and Kammen (2002b) point out, there exist many research gaps and needs that need to be addressed to understand more fully, amongst other things, the determinants of indoor air pollution. The point being made is that the relationship between human behaviours and exposure to indoor air pollution is one such knowledge gap that has been neglected by research studies. Apart from a few studies that have focused on cooking practices and time-activity budgets of women and young children, the study of the behavioural determinants of exposure to indoor air pollution has been largely neglected by research in the field. Moreover, to date, no published studies have evaluated the effect of changing high-risk behaviours in reducing the impact of indoor air pollution (Favin et al, 1999).

Methodology

Study Design

Exploratory study in which observations were used to identify the behavioural determinants of child ALRI, while post-observation interviews and focus group interviews were used to identify caregivers' recommendations.

Setting

Research participants were residents of two poor, rural villages in the North West Province of South Africa. The villages were selected primarily because preliminary investigations showed that there was a high reliance on solid fuels for cooking and heating (particularly during the cold winter months), child respiratory health was a concern expressed by both caregivers and health care workers, and there appeared to be an absence of ambient air pollution from industry or motor vehicle pollution to bias the presence of child ALRI.

Research participants

Overall 67 caregiver-child combinations were involved in the study. Of these, 40 participated in the observations and personal interviews while the remaining 27 were involved in focus group interviews. The 40 observation households were divided into 20 households that care for a child with a history of severe ALRI (hereafter high ALRI) and 20 that care for a child with a history of minimal ALRI (hereafter low ALRI).

The ages of the observation children ranged from 2 to 60 months with the mean age of 22.6 months (1year and 8 months old). Where possible, the ages of the high and low ALRI children were matched. Because of their particular susceptibility to indoor air pollution, a greater proportion of younger children were selected for inclusion in both groups. For example, 37.5% (n=15) of the sample was less than 12 months of age and 67.5% (n=27) of the sample was less than 24 months of age.

Table 1

Age distribution of study children who participated in the observations

	Number of children	
Age category	High ALRI	Low ALRI
Child age: 0-12 months	7	8
Child age: 13-24 months	5	7
Child age: 25-36 months	5	4
Child age: 37-48 months	2	1
Child age: 49-54 months	0	1

The 2 groups were also matched according to background environmental conditions that could influence ALRI status.

Table 2

Background conditions of households that participated in the observations

Condition	ALRI status	
	High ALRI	Low ALRI
Average number of people sleeping in the home	5	6
Study child shares a bed with another individual	100%	100%
Dampness/mould is reported to be a problem in the home	45%	50%
Dust is reported to be a problem in the home	95%	85%
Had received all scheduled vaccinations	100%	100%
One or more people regularly smoke at home	60%	55%
One or more people smoke >20 cigarettes per day at home	70%	80%
Average size of burning room (m^2)	10	10
Average number of rooms in house	3	4
Average number of windows in the room used for burning	2	2
Average number of doors (leading to the outside) in the room used for burning	1	1

Sampling procedure

The study employed a purposive intensive sampling strategy (Patton, 1990) to identify research participants. To do this, a standardised ALRI questionnaire (using WHO criteria for the diagnosis of pneumonia) was administered to, and information gathered from all 150 dwellings that had a child less than five years of age in both villages. Once identified, the 20 children with most severe cases were selected for inclusion in the high ALRI group and 20 with the least severe cases were selected for the low ALRI group. The 27 caregivers who participated in the focus group discussions were randomly selected from the remainder of the sampling frame.

Procedure

Trained research assistants observed household energy related behaviours for a one-day period from the first (approximately 06h30) to the last fuel use activity of the day (approximately 18h30) using a pre-structured observation sheet. Typically the research assistant would sit in a corner of the burning room out of the way of household members and complete the questionnaire as events unfolded. It is important to note that, to avoid bias in reporting, research assistants were not aware of the ALRI status of the study child but were randomly assigned to selected households each day.

Personal interviews were conducted with the caregiver directly after each observation using a semi-structured interview schedule. Each interview took between 10 and 30 minutes to complete. The interviews were tape-recorded and transcribed.

Focus group interviews were conducted approximately three weeks after the observations and post-observation interviews. Overall, four focus groups were conducted with each group consisting of between 6 and 10 participants. The discussions were facilitated by a trained focus group moderator and were held in a local crèche in one village and in a local church in the other. The length of the focus groups ranged from 45 minutes to 120 minutes. The focus group interviews were also tape-recorded and transcribed.

<u>Analysis</u>

Data from the observations were captured and analysed using the Statistics Package for the Social Sciences (SPSS) software package. To observe overall trends in the data, frequency distributions and measures of central tendency were used. To identify differences between the high and low ALRI groups, cross tabulations using the chi-square statistic (χ^2) were used for nominal data while the *t* test was employed for ordinal data. A binary logistic regression model was used to identify behavioural determinants at the multivariate level. The following variables (from the observations) were considered.

Table 3

Variables considered in the observations of household behavioural patterns

Variable description	Variable name
1. Type of polluting fuel used (solid, kerosene or both)	FUEL
2. Type of stove(s) used (wood stove only, kerosene stove only)	STOVE
3. Duration of solid fuel burning	SOLDUR
4. Duration of kerosene burning	KERDUR
5. Location of stove in relation to working ventilation (within 1 metre or further than 1 metre)	STOVELOC
6. Proportion of time that 2 ventilation sources were opened while a fire was burning	VENT
7. Proportion of time that children spent in relation to stove while a fire was burning (within 1 metre, further than 1 metre or elsewhere)	CHILOC

To identify the factors that influence observed practices, the transcribed (post-observation and focus group) interviews were analysed using a thematic analysis (Miles & Huberman, 1994).

Results

The behavioural determinants of child ALRI

Three household behaviours were found to be significantly associated with an increased risk of child ALRI. These are:

1. The lengths of time that 2 sources of ventilation were opened while a fire was burning.
2. The lengths of time that children spent within 1.5 metres of the stove during burning.
3. The location of indoor burning in relation to working ventilation.

The opening of at least 2 sources of ventilation (for cross ventilation) during indoor burning was found to be significantly associated with an increased risk of child ALRI. Not only were high ALRI households over-represented in the group that did not open at least 2 sources of ventilation (Pearson Chi-Square = 6.67, P = .01), but those who did, did so for significantly shorter periods of time (mean = 34.9 minutes) compared to low ALRI households (mean = 84.9 minutes) (t = -2.56, P = .042). Figure 1 highlights the fact that 80% (n = 16) of high ALRI households either did not open any ventilation or opened only 1 source of ventilation for short periods of time during burning. More importantly, figure 2 shows how the high ALRI households that did open two sources of ventilation, tended to do so for significantly shorter periods of time than low ALRI households. Typically, people in this category would open windows and doors during ignition and close them as soon as the visible smoke had disappeared.

Figure 1

Proportion of households that opened at least 2 sources of ventilation during burning

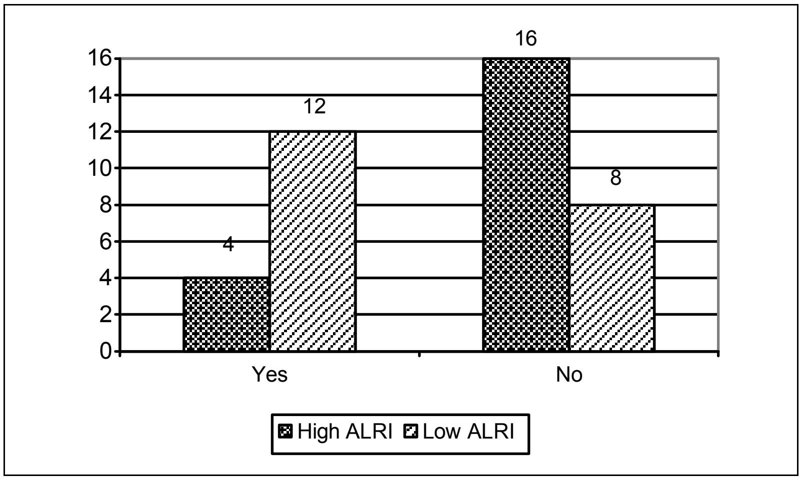
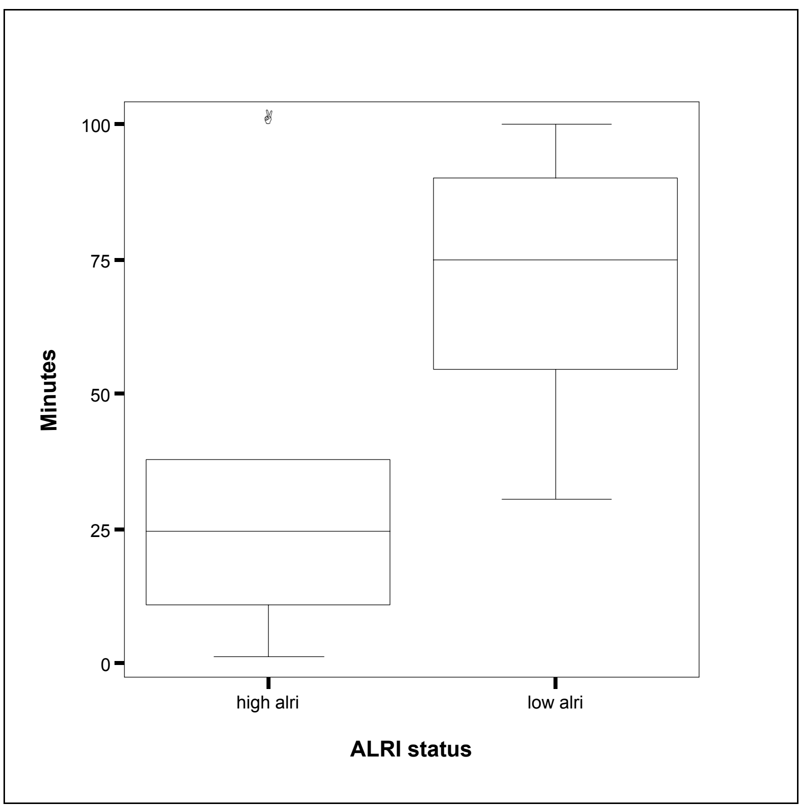


Figure 2

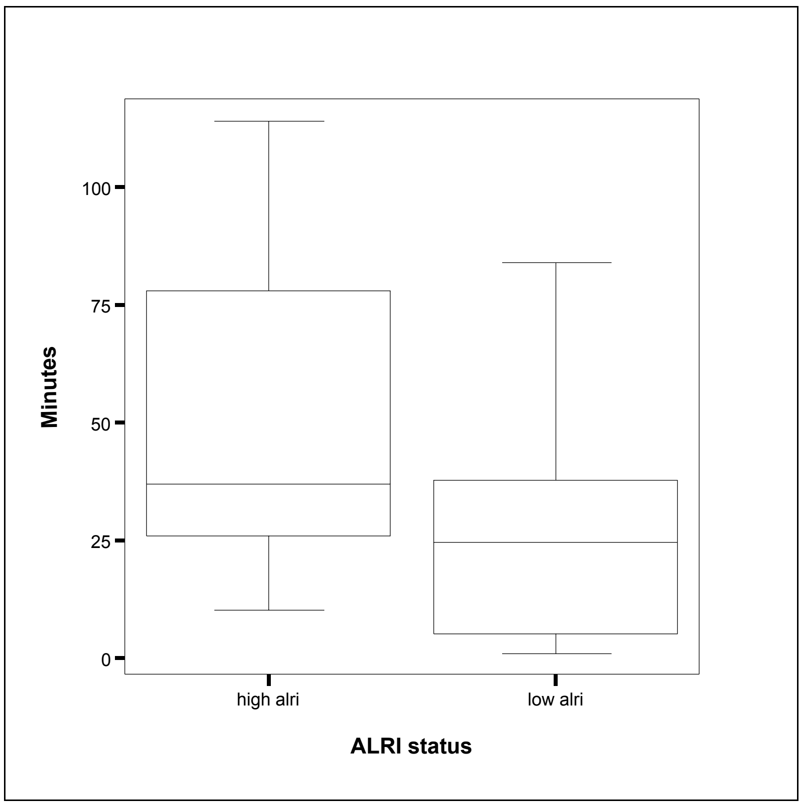
Length of time that at least 2 sources of ventilation were open during burning



The duration that children spent within 1.5 metres of the stove was found to be significantly associated with an increased risk of child ALRI. High ALRI children were more likely to spend longer periods (mean = 48 minutes) within 1.5 metres of the stove of time during burning than their low ALRI children (mean = 31 minutes)(t = 1.006, df = 38, P = 0.024) (see figure 3). Typically, older children would sit on a chair close to the stove to warm themselves while infants would either be carried on their caregivers' backs or left to sleep in a box or cot next to the stove.

Figure 3

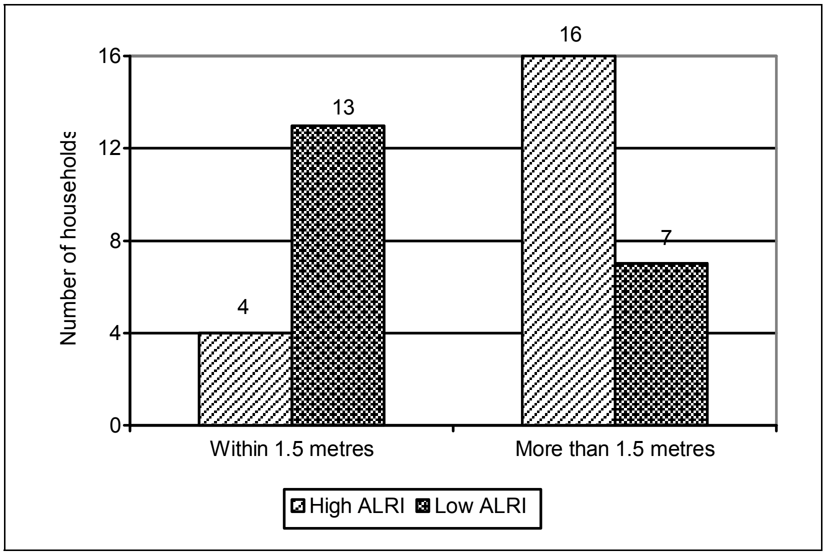
Length of time children spent within 1.5 metres of stove by ALRI status



The location of indoor burning away from ventilation sources was found to be associated with an increased risk of ALRI. In high ALRI households, burning was more likely to take place further than 1.5 metres away from one source of working ventilation (Pearson Chi-Square = 8.286, df = 1, P = .004). Wood stoves were normally permanently fixed in a corner of the room while kerosene stoves, being much smaller than wood stoves, are able to be moved but were usually permanently placed on a table or on the floor within the room. Figure 4 highlights how the burning appliances in 80% of high ALRI households were situated further than, while 65% of low ALRI households had their stoves within 1.5 metres of a ventilation source.

Figure 4

Location of burning in relation to working ventilation by ALRI status



It is important to note that no significant differences were found in the types of fuels used with 50% (n =10) of households in each group using solid fuels only (wood, animal dung and crop residues), 30% (n = 6) using kerosene only and 20% (n = 4) using a combination of solid fuels and kerosene. Solid fuels were burned in wood stoves and kerosene in kerosene stoves. Consequently, stoves that were used followed the same pattern as the fuels that were used.

In addition, no significant differences were found for the duration of burning for different fuels. Although not significant, high ALRI households tended to burn for slightly longer (mean = 289 minutes) compared to low ALRI households (mean = 282 minutes). When broken down by fuel type, high ALRI households tended to burn solid fuels (mean = 278 minutes) and kerosene (mean = 127 minutes) for slightly longer than low ALRI households (mean for solid fuels = 269 minutes, mean for kerosene = 100 minutes).

The results of a stepwise binary logistic analysis showed that the location of the stove in relation to working ventilation, the closing of ventilation while a fire was burning and the presence of children in front of the burning fire for long periods of time still remained significantly associated with high child ALRI at the multivariate level.

Table 4

Results of binary logistic regression model

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1	STOVELOC	-2.005	.730	7.555	1	.006	.135
	Constant	3.184	1.230	6.700	1	.010	24.143
Step 2	VENT	-1.686	.792	4.535	1	.033	.185
	STOVELOC	-1.912	.782	5.981	1	.014	.148
	Constant	5.758	1.931	8.887	1	.003	316.613
Step 3	CHILOC	-.032	.017	3.620	1	.057	.969
	VENT2	-1.873	.878	4.549	1	.033	.154
	STOVELOC	-1.904	.846	5.070	1	.024	.149
	Constant	7.214	2.361	9.340	1	.002	1358.765

a Variable entered on step 1: STOVELOC.

b Variable entered on step 2: VENT.

c Variable entered on step 3: CHIL0C.

d Variables not significant after step 3: FUEL, STOVE, SOLDUR, KERDUR.

Caregiver recommendations

Caregivers commonly cited 4 behaviours, which they believed, could reduce their children's exposure to indoor air pollution. These were:

1. To move their children out of the room while a fire was burning and if possible, get another adult to look after the children during this time.
2. To open ventilation for longer periods of time while a fire is burning.
3. To improve maintenance of wood stoves by using low cost materials and indigenous methods. Suggestions included blocking holes in the stove with putty or mud, covering broken stove doors with a wet cloth, unblocking chimneys and sealing leaky chimneys.
4. To reduce the duration of burning by extinguishing fires after cooking and heating by throwing water or leftover 'pap' (maize porridge) over the coals instead of allowing the fire to extinguish on its own.[ii]

The following extracts highlight these suggestions and are taken from personal and focus group interviews.

Extract 1

Interviewer:	*How can you protect your children from smoke?*
Respondent 1:	*You should keep them away from the stove when you are making a fire, take them to another room and close the door. You can get someone else to watch them there.*
Respondent 5:	*You can also make sure that the stove is closed properly so that the smoke cannot come out*
Respondent 4:	*You can do this by putting a wet cloth over the part that is leaking to decrease the amount of smoke coming out…*
Respondent 8:	*We can make sure that our doors and windows are open at all times.*

Extract2

Interviewer:	*What do you think as mothers you can do to solve the problems that you have with smoke especially where children are concerned?*
Respondent 3:	*We have to start opening our windows more.*
Interviewer:	*What else do you think we can do as mothers?*
Respondent 1:	*We can open the door.*
Respondent 5:	*We can make sure that children are not in the room when there is smoke.*

Extract 3

Respondent 6:	*… when we go to bed we would put leftover pap in the stove when we are finished cooking with it. There would be no smoke in the house. I still do that in my house, and there is no more smoke by the time we go to bed.*

Extract 4

Respondent :	*If we can fix chimneys for all of our stoves.*
Interviewer:	*How can you do this?*
Respondent:	*By tying an old cloth around the leaking part or sealing it with putty if you have the money.*

Discussion

Overall, 5 behaviours were identified that could reduce children's exposure to indoor air pollution. Results from the observations point toward three behaviours – ventilation practices, the lengths of time that children spend close to the burning fire and the location of the fire in relation to ventilation – as high risk for the development of child ALRI. Changing these behaviours could result in benefits to respiratory health. Recommendation from caregivers included a further two behaviours, improve stove maintenance behaviours (including chimneys) as well as reduce the duration of burning (particularly of solid fuels).

It is important to note that even though the types of fuels that people used in this context did not emerge as a determinant of indoor air pollution, the promotion of cleaner burning fuels such as Liquid Petroleum Gas or biogas were initially considered as possible interventions. In addition, they were not part of the recommendations from caregivers. Even though a fuel-switching component would have probably contributed to the effectiveness of the intervention, it was felt that the cost of such an intervention to the user would have been prohibitive. Even though people pay small amounts of money for wood and kerosene, cleaner fuels such as LPG, biogas and electricity are more expensive than those that are used in this context. A similar argument holds true for replacing existing stoves. The cost of replacing wood and kerosene stoves with improved stoves would be too high for the users and/or implementing agencies.

It is also the opinion of the authors that at least one of the five behaviours considered above, changing the location of burning, will not be feasible in this context. Wood stoves are large in size, heavy and are often fixed in one location within the kitchen. In addition, their chimneys protrude through a permanent hole in the roof. Moving the location of burning closer to ventilation will entail moving these large stoves and making a new hole in the roof of the house. Alternatively, this would involve leaving the stove where it is but breaking out part of the wall behind the stove to insert an additional window. We believe that the cost of this would be too high for most households. In addition, it is reported to be very difficult to move kerosene stoves closer to ventilation because air movements often extinguish the flame rendering the stove useless in the presence of air movements. This is the reason why many caregivers use their kerosene stoves in locations away from windows and doors.

It is recommended that the 4 remaining behaviours – improve stove maintenance, reduce the amount of time that children spend in close proximity to the fire, improve the quality of ventilation practices and reduce the duration of solid fuel burning – be considered as the target behaviours for the behavioural intervention. Given that most people in the study area use relatively sophisticated wood stoves i.e. stoves that have doors and a chimney, but which are in poor condition, we believe that part of the intervention should focus on improving the condition of these stoves instead of replacing them. This can include filling holes in stoves and chimneys, cleaning chimneys, fixing hinges on doors and replacing missing cooking plates. Maintaining stoves can be done occasionally, is relatively cheap yet can still have significant value. To be successful, part of the intervention should focus on making those materials available to community members, possibly through the local village store.

In light of the fact that most (85%) of observation households had someone else present during burning, but only 30% of these people took an active role in caring for the child, part of the intervention could focus on getting someone else to look after the child in a location away from the stove while it is burning. This aspect will have to focus on ways of keeping the child warm and occupied in those locations for long periods of time. This may be particularly effective, given that low ALRI children were less likely to be closer to the stove and more likely to have someone look after them in another location during burning than high ALRI children were.

Results from observations also showed an association between the quality of ventilation practices and child ALRI. Because people are already opening windows and doors, part of the intervention could focus not only on opening two sources of ventilation (for cross ventilation) but also increasing the duration that ventilation is opened during burning. The study found that people burned solid fuels for extended periods of time even after cooking was done and the house appeared to be adequately heated. Caregivers often allowed the fire to burn out instead of extinguishing it. Part of the intervention could focus on reducing the amount of time people burn solid fuels particularly after cooking and heating requirements have been fulfilled.

A number of barriers might serve to inhibit the performance of the above behaviours. For stove maintenance, even though the cost of materials such as putty is relatively low, this may still be too much for over burdened household budgets. In addition, many people may not have the skills to fix up their stoves. They would therefore have to pay someone to do this and this could also act as a barrier to this practice. In area where winter minimum temperatures often drop below 0^{o}C, the comforting warmth generated by fires during the cold winter months could possibly serve as a barrier to both moving children out of the room, improving ventilation practices as well as reducing the duration of burning, all of which appear to be determined, in part, by the need for warmth during winter. Over 15% of households observed did not have another adult to look after the child. The absence of an adult to look after children away from the burning fire may serve as a barrier to this practice.

It is important that the intervention takes into account and guards against unintended consequences. For example, asking caregivers to keep their children away from the burning fire may result in children being left unsupervised for extended periods of time. Leaving children without adult supervision could have a number of consequences, most notably, injuries, kerosene ingestion and burns - all of which are reportedly prevalent in these communities. Fixing up their stoves could also have the unintended consequence of people neglecting the other behaviours. For example, it might occur that ventilation quality might be reduced and young children might be allowed spend more time in front of stove thinking that it is safe. In all likelihood, stoves will still be emitting pollutants (albeit lower than before) but spending longer periods of time exposed to lower concentrations of pollutants might work against the intention of the intervention.

Conclusion

This study recommends the 4 behaviours not only because of their potential to be effective, but also because of their approximations to what caregivers are doing already. The behaviours are also easy to perform and can be implemented at relatively low cost compared to interventions such as replacing stoves, fuel switching or changing housing design. The study also took into account the valued opinions and recommendations of the caregivers of young children and developed a participatory tone that will hopefully remain through subsequent phases of research. Although using a relatively small sample size and using methods that can be criticised on a number of levels, it is hoped that this study can stimulate further debate about behaviours in relation to indoor air pollution.

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[i] Strong evidence shows that exposure to IAP is also associated with an increased risk of chronic obstructive lung disease (COLD) in adults and moderate to weak evidence exists for TB, adverse birth outcomes, eye problems and cardiovascular disease.

ii Two caregivers also reported throwing uncooked maize meal over burning embers to reduce the amount of smoke they produce but this was not suggested by anyone else.