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The impact of health behaviour change intervention on indoor air pollution indicators in the rural North West Province, South Africa

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Abstract
Indoor air pollution has been associated with a number of health outcomes including child lower respiratory infections such as pneumonia. Behavioural change has been promoted as a potential intervention strategy but very little evidence exists of the impact of such strategies on actual indoor air pollution indicators particularly in poor rural contexts. The aim of this study was to evaluate a community counselling intervention on stationary levels of PM10 and carbon monoxide (CO) as well as CO measured on children younger than five. Using a quasi-experimental design, baseline data was collected in an intervention (n=36) and a control (n=38) community; the intervention was implemented in the intervention community only; and follow-up data was collected one year later amongst the same households. Despite the fact that indoor air pollution was reduced in both communities, the intervention group performed significantly better than the control group when stratified by burning location. The net median reductions associated with the intervention were: PM10=57%, CO=31% and CO (child)=33% amongst households that burned indoor fires. The study provides tentative evidence that a health behaviour change is associated with reductions in child indoor air pollution exposure. The intervention is relatively inexpensive and easy to replicate. However, more powerful epidemiological studies are needed to determine the impact on health outcomes.

Keywords: indoor air pollution, health behaviour, child respiratory health, North West Province, South Africa

Indoor air pollution and child respiratory health

Exposure to indoor air pollution – caused by the indoor burning of solid fuels such as wood, cow dung and crop residues – has been causally linked to a number of health outcomes including Acute Lower Respiratory Infections (ALRI) such as pneumonia amongst children less than five (Bruce et al., 2000). Indoor air pollution is associated with the excess mortality of 1.6 million people each year and is the fourth largest global disease risk factor accounting for 3.6% of attributable disability adjusted life years (DALYs) in high mortality developing countries(Ezzati et al., 2002). In South Africa, as many as 1 400 child deaths annually have been associated with indoor air pollution exposure (Norman et al., 2007). Indoor air pollution is particularly problematic in South African rural areas where clean energy sources are less accessible (Barnes et al., 2009).

By the late 1990s enough epidemiological evidence of the probable link between indoor air pollution and child ALRI existed to call for evaluation studies of the health benefits of indoor air pollution interventions(von Schirnding et al., 2002). Four intervention categories were highlighted for their potential to reduce indoor air pollution exposure: cleaner burning fuels, improved cook stoves (ICS), dwelling modification and, importantly for this work, behavioural change (von Schirnding et al., 2002; Ballard-Tremmer and Mathee, 2000).

The intervention field turned towards the first two – cleaner burning fuel and ICS interventions – based on evidence of their potential effectiveness to reduce indoor air pollution. However, despite sig-

nificant development efforts and evidence of their effectiveness, the costs to governments, donor agencies and households associated with technical intervention efforts were prohibitive for many poor rural contexts in developing countries. This was particularly true in poor rural contexts where people collect fuel free of charge and in relatively close proximity to their living environment (Goldemberg, 2004).

Behavioural change has been promoted as a relatively cost-effective strategy to reduce child indoor air pollution in poor rural contexts requiring very little monetary or technical investment (Barnes, 2005). Behaviour(s) may account for the wide range of exposure estimates documented from households with similar energy patterns and ventilation characteristics. Put differently, what people actually *do* (that is, their behaviours) within the burning micro-environment – for example, where they burn fires (indoors versus outdoors) (Albalak *et al.,* 1999a); how fuels are prepared and fires are kindled (Bussman and Visser, 1983 cited in Manibog, 1984); how they use ventilation (Still and MacCarty, 2006); how appliances are maintained (Reid et al., 1986); and where children and adults are located in relation to indoor fires (Ezzati et al., 2000b) – may affect indoor air pollution exposure. However, comparatively little evidence exists on the role of behavioural change and the information that *does* exist is largely based on cross-sectional studies (many of them laboratory-based), which tells us very little about *how* to change behaviours in actual field settings.

To date, just one study in rural Tibet has evaluated a behavioural intervention on ARI using a before-after design. The study monitored ARI incidence for six months in 331 children under five years old in an intervention and 338 children in a control community in Yangdon, Tibet (Tun et al. 2005). Baseline data on maternal knowledge, attitudes and indoor air pollution practices were collected once before and once six months after the intervention. The key messages are not well described in the article but the intervention reportedly focused on 'the causes and prevention of ARI with special emphasis on the avoidance of indoor air pollution' (p.31).

Mothers were visited once to explain the intervention and were offered pamphlets. Wall posters were placed in the market place, tea shops and local authority offices (Tun et al., 2005). The study found at follow-up that although caregivers knowledge of indoor air pollution was significantly increased amongst the intervention group (compared to the control group), there were no significant differences between the two groups in location of cooking (in living room, kitchen or outside), type of fuel used or mosquito deterrent behaviours (use of scented sticks and/or coils). There was also no impact on ARI incidence, which increased in both groups following the intervention (Tun *et al.,* 2005).

The trial had a number of shortcomings including the fact that indoor air pollution was not measured, the intervention was relatively superficial (only one visit by a midwife), ARI was measured using mothers' recall, the study was of a short duration (the effects might have only been apparent after a longer time period) and the comparability of the intervention and control group was not assessed beforehand. Importantly, the study had limited generalisability to a rural African context

In response to the paucity of behavioural intervention studies in this field together with the need for interventions designed specifically for rural Africa, the aim of this study was to evaluate a low-cost behavioural intervention to reduce indoor air pollution in a poor rural context of South Africa. This paper reports on the impact of indoor air pollution indicators and forms part of a broader study on the role of behavioural change and indoor air pollution.

Methods

Study design

The study employed a quasi-experimental before-after study design with a control group. Baseline data was collected during winter (year 1) in both the intervention (n=36) and control group (n=38). The intervention was implemented immediately after baseline data collection amongst the intervention group and not in the control group. Follow-up data was collected from both groups 12 months later (year 2). The study design is summarized in Figure 1.

Study group	*Quantitative evaluation*				
Intervention	**o**	→	**x**	→	**o**
Control	**o**	→	→	→	**o**
	July year 1	August year 1		July year 2	

Legend:
o Quantitative cross sectional assessment
x Behavioural intervention implemented

Figure 1: Study design

Study setting

The study took place in two poor rural villages, *Madibe Makgabane* and *Tsunyane,* in the North West Province of South Africa. The village of *Tsunynane* was selected as the control group. Household data from the 2001 census (Statistics South Africa, 2003) suggested that the two villages were similar in terms of socio-demographic status (for example, household income, employment and

occupancy). The villages were situated far enough from major urban centres and polluting industry (Mafikeng[1] is situated approximately 40 kilometres from both villages) for outdoor air pollution to influence indoor air pollution measurements. Winter temperatures were low enough to expect that households would bring fires indoors for space heating, which could lead to high exposures. In addition, the two villages were approximately 35 kilometres from each other with relatively little social contact between them to minimise message contamination.

Homesteads usually had two structures relevant to burning. The *segotlo* was an outside burning area surrounded by a wall of interwoven dried sticks (approximately 160 centimetres in height) that served to protect the fire and occupants from windy conditions prevalent in the area. The *segotlo* served as an outside kitchen where most of the cooking and water heating was done during the day. During summer, when the need for space heating was minimal, cooking and water heating was undertaken exclusively in the *segotlo*. During winter, however, fires are burned in the *segotlo* during the warmer parts of the day but moved indoors into the *inkwe* (indoor burning room where most of the exposure occurred) during colder parts of the day. Approximately 30% of households, however, did not bring a fire indoors and burned exclusively outdoors. Children less than five often followed their caregivers around and were found to spend between 52% and 61% of the total time that indoor fires were burning in the *inkwe* (Barnes et al., 2005).

Figure 2: Children exposed to indoor air pollution in this study

Participants

The sampling frame consisted of 324 households in the intervention (n=149) and control groups (n=175) respectively. Eligibility was defined as a household in which one or more children five years old or less lived during the sampling exercise. The unit of analysis was defined as the household. Fifty households (this number was subsequently reduced due to loss to follow-up between year one and year two – explained in more detail) in each village were randomly selected for air quality sampling of particulate matter of 10 microns or less (PM_{10}) and carbon monoxide measured in the burning room (CO) over a 24 hour period. CO was also measured on the youngest (index) child ($CO_{[child]}$) of the households selected for indoor air pollution sampling over the same 24 hour period.

The participant information and informed consent procedures were approved by the Wits University Ethics Committee for Research on Human Subjects (Clearance Number: M03-05-43). If the caregivers agreed to participate, the primary caregiver completed an informed consent form and was assigned a unique study identification number. The study achieved a participation rate of 98 and 99% in the intervention and control groups respectively.

Materials and methods

Baseline data collection

Socio demographic variables (caregiver age, caregiver education, child age, child sex, and dwelling characteristics) as well as burning location were measured using an interview questionnaire. Trained researchers visited study households and interviewed the primary caregiver. The interview took between 30 and 45 minutes to complete. The indoor air pollution monitoring commenced immediately after the interview. The monitoring of respirable particulates (PM_{10}) in a sample of households was done using portable, constant flow, battery powered Gilian pumps with Dorr-Oliver cyclones as pre-separator with 37mm (0.8 micron) mixed cellulose ester filters in line. Based on standardized analytical procedures (Harrison, 1999), filters were dehydrated for 24 hours and pre-weighed using a microbalance under controlled temperature and humidity conditions in the National Institute of Occupational Health (NIOH) laboratory in Johannesburg. Each filter was assigned a unique identification number and weighed three consecutive times. The pre-weight measurement represented the mean of three weights. Each filter's pre-weight was electronically captured next to its identification number. The filter was immediately placed into a sealed cassette and stored in a cool location under controlled temperatures. The cassettes containing the filters were packed carefully to minimise disruption and transported in an air conditioned vehicle to the study sites

Once in the field, the cassette (containing the filter) was inserted into the cyclone pre-separator and attached to the Gilian pump. Pumps with cyclones were located at a standard height (breathing height of adults) and distance (approximately 1.5 metres) from where study participants reported to burn their

indoor fires. Sampling was undertaken at a flow rate of 1.7 litres per minute, as specified for Dorr-Oliver cyclones. One field blank was used for every 10 households to determine whether particulates were coming from sources other than indoor fires, for example, dust. The time(s) that the pump was switched on and switched off 24 hours later was noted. Each Gilian pump was serviced before each phase of data collection and calibrated to achieve a flow rate of 1.7 litres per minute before each sampling using a two litre cyclone calibration jar, electronic bubble metre and wet cell Sensodyne Gilibrator. Pumps were run for one minute to warm up before calibration, calibrated to as close to 1.7 litres per minute as possible and the pre-sampling flow rate was noted. After each sampling, the flow rate was measured using the same calibration mechanism and noted. The mean of the two (pre-sampling and post-sampling) flow rates were used as the average flow rate.

The filter cassettes (containing the filter) were resealed immediately after sampling and stored in a cool, stable place (to not disturb the particles captured on the filters) until they could be transported to the laboratory in Johannesburg. The cassettes containing the filters were dehydrated for 24 hours and weighed three times. The post-weight measurement of the filter represented the mean of the three weights. The difference between the pre-weight and post weight of the individual filter and the volume of the air sampled (a function of the flow rate by the duration of sampling) was used to calculate the time weighted average of PM_{10} expressed in micrograms of respirable particles per cubic meter of air ($\mu g/m^3$) over the 24 hour collection period. Ten random control filter samples (not attached to a Gilian pump or pre-separator) representing 10% of the samples were collected to determine whether factors other than respirable particulates were influencing readings. In this way, standard methods conforming to standardized NIOSH protocols were applied throughout the PM_{10} monitoring (National Institute for Occupational Safety and Health, 1994).

The Dorr-Oliver cyclones conform to the ACGIH standard for respirable particulates and are designed to separate the respirable fraction of airborne dust (RSP) from the non-respirable fraction i.e. airborne particles with an aerodynamic diameter of between 0.2 and 10 microns (μm). Separation achieved by the cyclone samplers follows the convention for separation of respirable particles as specified by ACGIH (American Conference of Government Industrial Hygienists) (www.ACGIH.org) and 100% of 10 micron particles and 50% of 4 micron particles are removed by the cyclone. This corresponds with 0% of 10 micron particles and 50% of 4 micron particles that penetrate the lower lung.

CO was measured using Dräger passive diffusion (colour stain) tubes, with a range of measurement up to 600 (ppm x h). CO tubes were placed in the burning room (inkwe) at the same position as the cyclone, and attached to the clothing of the youngest child or in close proximity when the child is sleeping, being bathed or changed. The CO tubes were read immediately on site after the 24 hour monitoring period, capped and read blind by another member of the research team on the same day. CO levels were expressed in parts per million (ppm) over a 24 hour period.

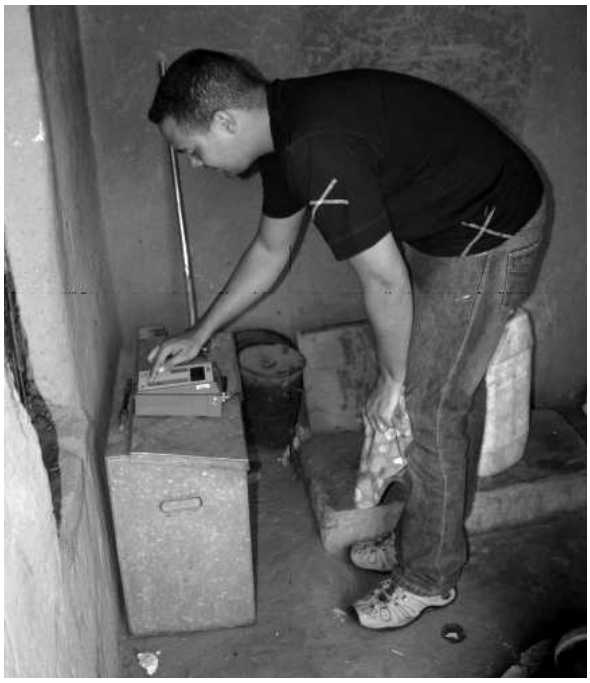

Figure 3: Setting up stationary particulate monitoring equipment in the vicinity of indoor fires

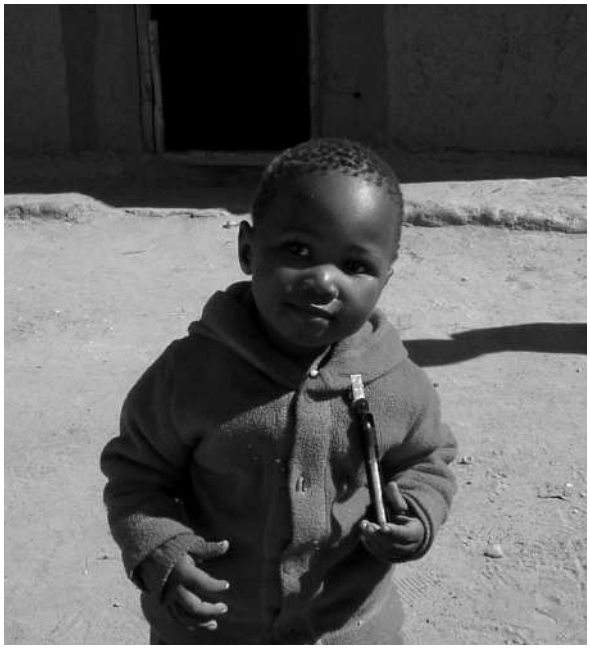

Figure 4: Study child with attached carbon monoxide diffusion tube

The intervention

The intervention was implemented immediately after the baseline data collection *in the intervention group only*. Based on the two phases of formative research (Barnes *et al.,* 2004 a&b), the following behaviours were promoted:

1. Burn outdoors when possible (for example, when it is warm enough to do so).
2. If fires are burned indoors, open at least two sources of ventilation during peak emission times (for example, during ignition and when fuels are added to fires).
3. Reduce the amounts of time that children spend in the *inkwe* while fires are burning.

The intervention commenced with a presentation at a special community meeting held at the chief's homestead. The objectives of this meeting were twofold; a) obtain community acceptance of the project and b) enhance the diffusion of the key messages beyond the target households with young children into the wider community. Approximately 50 households were represented at this meeting. A key outcome of this meeting was that the traditional community leadership structure agreed to include indoor air pollution as a standing item on their agenda throughout that winter and beyond if they believed the need existed.

The main thrust of the intervention involved door to door visits to each household in the intervention group after the baseline assessment. Two once-a-week visits were conducted with each caregiver and other family members present in the selected households by trained health communicators. The communication strategy was based on a Trials of Improved Practices (TIPs) methodology (Dicken and Griffiths, 1997). During the first visit, hereafter referred to as the counselling visit, trained communicators discussed the health effects of indoor air pollution exposure with the primary caregivers and others present. The counselling visit began with the communicators sharing knowledge of the biomedical link between indoor air pollution and child respiratory health including the pollutants contained in smoke, why children were particularly vulnerable to the health effects, how the pollutants affect children's lungs and health outcomes associated with exposure.

Following the information sharing session, communicators discussed current behaviours and possible modifications to those behaviours. Communicators based the discussions on individual household data obtained from the baseline data collection conducted a week before. Households that reported to burn outdoors regularly during winter were encouraged to continue to do so. Households who ignited fire outdoors but brought them indoors were encouraged to open windows at strategic times and to keep children away from fires. No recommendations were forced upon families. Instead, communicators assisted each family (usually the primary caregiver and whoever was available at the time), through a process of negotiation, with identifying the behaviours that participants felt would be feasible while still effective. For example, in some instances families felt that, from the outset, outdoor burning would be too difficult to perform and communicators discussed the two other alternatives with them.

Once household members agreed to what they would try and to what degree, researchers then facilitated a discussion of *how* they would perform those behaviours(Dicken and Griffiths, 1997). Household members were asked questions such as: who is going to take responsibility for looking after the child while the primary caregiver is in the *inkwe* during winter? Do you have enough clothes to keep the child warm if you burn outdoors during winter? If the caregiver looks after the child away from the fire, can someone else do her chores? Who is going to take responsibility for opening and closing windows? What if a window is broken? Are you able to fix it? What will happen if others do not want you to burn outdoors, what will you do? In so doing, household members were encouraged to think through the actual implementation of the behaviours and possible barriers that they were likely to encounter. The counselling visit took between 60 and 90 minutes to complete. A time and date was agreed upon for communicators to conduct a follow-up visit one week later.

Each household was visited one week later (reminder visit) to determine how household members were coping with the agreed behaviours and encourage them to continue. Communicators used the opportunity to consolidate the previous week's discussions, to answer participants' questions or clarify things and to encourage them to continue with the agreed behaviours. The reminder visits took between 30 and 60 minutes to complete.

Follow-up data collection

Households were visited 12 months later to collect follow-up data. The same data collection procedure was applied in both year one and year two. However, 14 and 12 households were lost due to follow-up in the intervention and control group respectively. Anecdotal evidence suggested that families had mostly migrated for employment reasons and, as such, could not be found at follow-up. There were no systematic differences between those lost to follow-up and those households that remained. Households lost to follow-up were, therefore, excluded from the analysis leaving a final sample size of 36 in the intervention and 38 in the control group.

Analysis

Data for each year was captured into the STATA version 9 software package. The data was double entered, cleaned and analysed for consistency. Each household, and eligible child living within that household, was assigned a unique identification number. Descriptive statistics were employed to describe the univariate characteristics of each variable by group and by year. The distribution(s) of the data for each of the air pollution indicators were analysed. Univariate analyses included graphical representations such as box and whisker plots, histograms and measures of central tendency. Distributions of indoor air pollution distributions in both groups violated assumptions of normality. Consequently, the non parametric Mann-Whitney U Test was employed to test between-group differences for each year. The non parametric Wilcoxon Signed Ranks Test was used to test before-after shifts in values within each group.

Results

Background characteristics of the study sample are summarised in Table 1. Socio demographic, child, household and burning characteristics were remarkably similar in both the intervention and control groups at baseline. Importantly, background characteristics remained constant between baseline and follow-up.

In terms of burning characteristics at baseline, *all* households had an outdoor cooking area (*segotlo*) available and burned wood, cow dung or a combination of the two. However, over two thirds of households made an indoor fire during colder parts of the day. A very small proportion (less than 2%) of households in both groups reportedly used kerosene to compliment solid fuels. Kerosene was burned indoors for very short periods of time (to, for example, make tea or warm up leftover food) and only when enough money was available to purchase it.

Both groups reduced indoor air pollution indicators between baseline and follow-up. In the intervention group, the median before-after reduction in PM_{10} equalled 17% ($p<.01$), CO equalled 11% ($p=.15$) and CO (child) equalled 47% ($p=.02$). In the control group, the median reduction in PM_{10} equalled 28% ($p=.01$), CO equalled 21% ($p=.46$) and CO (child) equalled 57% ($p=.09$). Table 2 summarizes within group differences at baseline and follow-up.

Given that the intervention focused on reducing *indoor* air pollution exposure, the data was further stratified by burning location (those who burned exclusively outdoors versus those who made a fire indoors in both year 1 and year 2). As expected households who burned outdoors only displayed extremely low indoor air pollution values with PM_{10} equalling 5 $\mu g/m^3$; CO= 10 ppm and CO (child)= 0.8 ppm hours with no significant differences between the intervention and control groups. However, the intervention group performed significantly better than the control group among the indoor burners (see Table 3).

Among the indoor burners, the median PM_{10} reduction was 85% in the intervention compared to 28% in the control group. The median CO reduction in the intervention group was 69% compared to 38% in the control group. Of particular importance was the fact that child CO exposure was

Table 1: Background characteristics at baseline

	Intervention	*Control*	*p value*
Child characteristics			
Child age	23; 15.3; 1-50	25; 14.6; 1-55	.33
Female (%)	48%	52%	.46
Caregiver characteristics			
Caregiver age	46; 16.3; 18-78	45; 15.8; 18-76	.49
No formal education (%)	40%	38%	.79
Household characteristics			
Household income <R1000 a month	87%	85%	.48
Informal dwelling	45%	43%	.78
Occupancy (people per dwelling)	5.35; 2.88; 1-21	4.86; 2.91; 1-21	.40
One or more people smoke (%)	46%	52%	.38
Ambient temperature			
Minimum temperature (degrees Celsius)	10.6; 2.6; 2.7-13.6	11; 2.8; 2.3-14	.62
Household energy patterns			
Proportion using solid fuels	100%	100%	
Proportion burning outdoors only	31%	33%	.76

* Ordinal values reported as mean, standard deviation and range

Table 2: Indoor air pollution indicators at baseline and follow-up

	Baseline					*Follow-up*						
Group	*Min*	*Max*	*Mean*	*Median*	*S.D.*	*Min*	*Max*	*Mean*	*Median*	*S.D.*	*% median reduction*	*p value*
					PM_{10} (μg/m^3 over 24 hours)							
Intervention (n=36)	0	2842	599.1	389.5	678.3	0	1495	349.4	320.5	358.6	18%	p <.01
Control (n=38)	44	1920	448.1	341	514.1	0	1374	294	243	362.3	29%	p=.01
					CO (ppm over 24 hours)							
Intervention (n=36)	4.5	600	209.7	125	202.6	0	600	163.8	111.5	173.7	11%	p=.15
Control (n=38)	10	600	209.8	150	191	0	600	179.8	117.5	202.4	22%	p=.46
					CO child (ppm hours)							
Intervention (n=36)	0	25	4.3	1.9	6.3	0	8.8	1.85	1	2.5	47%	p=.02
Control (n=38)	0	25	3.5	2.1	4.7	0	25	3.46	.9	2.7	57%	p=.09

Table 3: Indoor air pollution indicators among indoor burners

	Baseline					*Follow-up*						
Group	*Min*	*Max*	*Mean*	*Median*	*S.D.*	*Min*	*Max*	*Mean*	*Median*	*S.D.*	*% med-reduction*	*P value*
					PM10 (μg/m^3 over 24 hours)							
Intervention (n=14)	52	2842	669.52	416	688.35	41	936	222.15	64.5	277.57	85%	P<.01
Control (n=14)	44	1920	457.92	218	517.99	31	1374	320.36	155.5	274.07	28%	P=.08
					CO (ppm over 24 hours)							
Intervention (n=14)	20	600	231.88	162.5	104.38	2	600	144.15	50	186.38	69%	P.=.01
Control (n=14)	10	600	213.66	150	192.49	3	600	129.07	93	209.42	38%	P=.9
					CO child (ppm hours)							
Intervention (n=14)	25	600	118.91	50	153.98	4	300	65.54	33	83.46	34%	P=.31
Control (n=14)	10	600	91.08	50	111.72	0	600	104.4	49	152.34	<1%	P=.9

reduced by 34% in the intervention group and remained the same among the control group.

Discussion

The study builds on previous South African studies (von Schirnding et al., 1991a; Terblanche, 1998; Terblanche et al., 1993; Terblanche et al., 1992; Bailie et al., 1999; Sanyal and Maduna, 2000; Röllin et al., 2004) and confirms the problem of household reliance on solid fuels and high levels of indoor air pollution in rural South Africa. Households were reliant on solid fuels such as wood, cow dung and crop residues with excessively high levels of documented indoor air pollution. For example, the upper ranges of PM_{10} (24 hour) documented in this study (1495–2842 μg/m^3) are comparable to studies conducted elsewhere in Africa (1300-2100μg/m^3), South Asia (2000-2800 μg/m^3) and Latin America (520-870 μg/m^3) (Smith, 1999).

The study designed, implemented and evaluated a relatively simple and replicable community counselling model to reduce indoor air pollution indicators amongst a rural population in South Africa. Results showed that while overall indoor air pollution indicators were reduced by a similar magnitude in both groups; when stratified by indoor burning (where the highest risk of exposure occurs), the intervention group performed significantly better than the control group. The net median effect (subtracting the median percentage reduction observed in the control group from the intervention group) equalled: *PM_{10}=57%, CO=31%* and *CO (child)=33%* amongst indoor burners.

The observed reductions, however, were lower compared to those documented in studies of technical interventions such as improved cook stoves and cleaner energy sources (Budds et al., 2001; Ballard-Tremeer and Mathee, 2000). Albalak et al., (1999b), for example, found an 85% reduction [geometric mean] in $PM_{3.5}$ amongst households using improved plancha stoves compared to households burning open fires indoors. Similarly, Ezzati et al., (2000a) found a 48% reduction in PM_{10} during burning and a 77% reduction during smouldering amongst households using an improved ceramic wood stove compared to households burning open fires. The study also found that a household move towards (cleaner burning) charcoal showed the greatest reductions in indoor air pollution (87-92%) (Ezzati et al., 2000a). Similar reductions were found for improved stoves (plancha) by McCracken and Smith (1998)(87% reductions in PM2.5) and by Reid et al., (1986) – 66% reductions in TSP. This study, however, found comparable reductions in child exposure (approximately 33%) to the recent randomised control improved cook stove trial in Guatemala (Bruce et al., 2006).

The results of this study can also be directly compared to studies that have focused on improved behaviours. Surridge et al., (2005), for example, found that a reverse ignition process amongst coal burning households that used braziers in South Africa reduced PM_{10} by 80-90% in a laboratory setting and 50% under actual field conditions. Stove maintenance may also play a role in exposure reduction. Reid et al.,(1986) suggests that correct pot fit may reduce PM10 by 77% and CO by 94% and cleaning flues of existing stoves may reduce CO by 89% (Reid et al., 1986). A study by Ballard-Tremeer and Jawurek (1996) found that compared to an open fire, improving an open fire by burning fuels on a raised grate 10mm off the ground was associated with 20% lower TSP and 41% lower CO emissions. Some of the highest reductions (94% lower PM and 97% lower CO) were achieved by simply opening a door during burning under test conditions (Still and MacCarty, 2006).

The study provides tentative evidence that a health behaviour change intervention (based on a novel community counselling model) has the potential to reduce indoor air pollution under actual field settings among rural communities who are unlikely to benefit from technical interventions. A methodological strength of this work was that it included a before-after component to understand the effectiveness of the intervention, included a similar control group that did not receive the intervention, took into account seasonality (winter) when exposures were highest; included a period of evaluation of twelve months or more (Cave and Curtis, 1999) and measured child exposure in addition to stationary levels of air pollution.

However, a major weakness of the study was that the control group showed evidence of a possible Hawthorne Effect (see Barnes, 2010 for a possible explanation). However, the intervention group performed significantly better in the indoor environment (where exposure risk is much higher) pointing towards the value of the intervention in the indoor environment. Further weaknesses of the study design included the fact that it only captured two 'snapshots' of exposure (once before and once after the intervention) and was therefore unable to capture variability in child exposure (daily, weekly and monthly); had a relatively small sample size and did not take into account clustering at the village level. Nonetheless, the study was still formative in nature and applied a more rigorous methodology than in previous studies of the role of behavioural change.

Conclusion

Previous interventions to reduce child indoor air pollution exposure have been largely technical in nature and in many cases have proven to be prohibitive for the world's poor. This study provides evidence, albeit on a small scale, that a health behavioural change intervention can reduce child exposure to indoor air pollution over a twelve month period. However, more powerful epidemiological studies are needed to determine, in particular, if indoor air pollution reductions can be translated into child respiratory health gains. It is hoped that this paper will contribute to the ongoing investigation into the role of behavioural change to reduce child indoor air pollution exposure in rural Africa.

Note

1. Mafikeng is a local municipality consisting of approximately 270 000 inhabitants with a growing industrial sector (Statistics South Africa, 2003) hence the possibility of outdoor pollution influencing indoor air pollution readings.

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References

Albalak, R., Frisancho, A.R. and Keeler, G.J. (1999a). Domestic biomass fuel combustion and chronic bronchitis in two rural Bolivian villages. *Thorax* 54, 1004-1008.

Albalak, R., Keeler, G.J., Frishncho, A.R. and Haber, M. (1999b). Assessment of PM_{10} concentrations from domestic biomass fuel combustion in two rural Bolivian highland villages. *Environ. Sci. Technol.* 33, 2505-2509.

Bailie, R.S., Pilotto, L.S., Ehrlic, R.I., Mbuli, S., Truter, R. and Terblanche, P. (1999). Poor urban environments: use of paraffin and other fuels as sources of indoor air pollution. *Journal of Epidemiology and Community Health* 53, 585-586.

Ballard-Tremeer, G. and Jawurek, H.H. (1996). Comparison of five rural, wood-burning cooking devices: efficiencies and emission. *Biomass and Bioenergy* 11, 419-430.

Ballard-Tremeer, G. and Mathee, A. (2000). Review of interventions to reduce exposure of women and young children to indoor air pollution in developing countries. Washington D.C.: WHO/ USAID Global Consultation.

Barnes, B. R. (2005). Interventions to reduce child exposure to indoor air pollution in developing countries: behavioural opportunities and research needs. *Children, Youth and Environments* 15, 67-82.

Barnes, B. R. (2010). The Hawthorne Effect in community trials in developing countries. *International Journal of Social Research Methodology* 13*, 357-370.*

Barnes, B. R., Mathee, A., Thomas, L. & Bruce N. (2009). Household energy, indoor air pollution and child respiratory health in South Africa. *Journal of Energy in Southern Africa* 20, 4-13.

Barnes, B.R., Mathee, A. and Moiloa, K. (2005). Assessing child time-activity patterns in relation to indoor cooking fires in devloping countries: a methodological comparison. *International Journal of Hygiene and Environmental Health* 208, 219-225.

Barnes, B.R., Mathee, A., Shafritz, L.B., Krieger, L., Favin, M. and Sherburne, L. (2004a). Testing selected behaviours to reduce indoor air pollution exposure in young children. *Health Education Research* 19, 543-50.

Barnes, B.R., Mathee, A., Shafritz, L.B., Krieger, L. and Zimicki, S. (2004b). A behavioural intervention to reduce child exposure to indoor air pollution: identifying possible target behaviours. *Health Education and Behaviour* 31, 306-317.

Bruce, N. and colleagues (September 2006). Research lessons and future directions from the RESPIRE project. Workshop repoert: Internat-ional Conference of Environmental Epidemiol-ogy and Exposure, Paris, France.

Bruce, N., Perez-Padilla, R. and Albalak, R. (2000). Indoor air pollution in developing countries: a major environmental and public health challenge. *Bulletin of the World Health Organisation* 78, 1078-92.

Budds, J., Biran, A. and Rouse, J. (2001) What's Cooking: A review of the health impacts of indoor air pollution and technical interventions for its reduction. Loughborough: Loughborough University.

Cave, B. and Curtis, V. (1999). Effectiveness of promotional techniques in environmental health. Task no: 165, London: London School of Hygiene and Tropical Medicine.

Dicken, K. and Griffiths, M. Dicken, K. and Griffiths, M., (Eds.) (1997). Designing by dialogue a program planners guide to consultative research for improving young child feeding. Washington DC: Health and Human Resources Analysis (HHRAA) Project.

Ezzati, M., Lopez, A.D., Rodgers, A., Vander Hoorn, S. and Murray, C.J.L. (2002). Selected major risk factors and the global and regional burden of disease. *The Lancet* 360, 1347-1360.

Ezzati, M., Mbinda, B.M. and Kammen, D.M. (2000a). Comparison of emissions and residential exposure from traditional and improved cook stoves in Kenya. *Environ. Sc. Technol.* 34, 578-583.

Ezzati, M., Saleh, H. and Kamen, D.M. (2000b). The contributions of emissions and spatial micro-environments to exposure to indoor air pollution from biomass combustion in Kenya. *Environmental Health Perspectives* 108, 833-9.

Goldemberg, J. (2004). Rural energy in developing countries. New York: UNDP, UNESCA & WEC.

Harrison, R.M. (1999). Measurements of concentrations of air pollutants. In: Holgate, S.T., Samet, J.M., Koren, H.S. and Maynard, R.L., (Eds.) *Air pollution and health*, London: Academic Press.

Manibog, R.F. (1984). Improved cooking stoves in developing countries: problems and opportunities 9, 199-227.

McCracken, J.P. and Smith, K.R. (1998). Emissions and efficiency of improved wood-burning cook stoves in highland Guatemala. *Environment International* 24, 739-747.

National Institute for Occupational Safety and Health (NIOHS) (1994). Manual of Analytical Methods (NMAM). *Ohio: US Department of Health, Education and Warfare.*

Nel, R., Terblanche, P., Danford, I., Opperman, L.B.P. and Pols, A. (1993). Domestic fuel exposure as a risk factors fro development of upper respiratory illnesses and lower respiratory illnesses in rural and urban communities. *Clean Air Challenges 1993 (conference proceedings)* paper 7, 1-5.

Norman, R., Barnes. B. R., Mathee, A., Bradshaw, D. and the South African Comparative Risk Assessment Collaborating Group. (2007). *South African Medical Journal* 95, 630-637.

Reid, H.F., Smith, K.R. and Sherchand, B. (1986). Indoor smoke exposures from traditional and improved cook stoves comparisons among rural Nepali women. *Mountain Research and Development* 6, 293-304.

Röllin, H.B., Mathee, A., Bruce, N., Levin, J. and von Schirnding, Y. (2004). Comparison of indoor air quality in electrified and un-electrified dwellings in rural South African villages. *Indoor Air* 14, 208-216.

Sanyal, D.K. and Maduna, M.E. (2000). Possible relationship between indoor air pollution and respiratory illness in an Eastern Cape community. *South African Journal of Science* 96, 94-96.

Smith, K.R. (1999). Indoor air pollution. *Pollution management in focus. Washington DC:* World Bank.

Statistics South Africa (2003). *Census in Brief 2001*. Pretoria: South African Government.

Still, D. and MacCarty, N. (2006). The effect of ventilation on carbon monoxide and particulate levels in a test kitchen. *Boiling point* 52, 24-26.

Surridge, A.D., Kgobane, K.B. and Chauke, G.R. (2005). Strategy to combat the negative impacts of domestic coal combustion: Basa Njengo Magogo. *Clean Air Journal* 14, 13-16.

Terblanche, A.P., Opperman, L., Nel, C.M. and Nyikos, H. (1993). Exposure to air pollution from transitional household fuels in a South African population. *J Expo Anal Environ Epidemiol* 3, 15-22.

Terblanche, A.P., Opperman, L., Nel, C.M., Reinach, S.G., Tosen, G. and Cadman, A. (1992). Preliminary results of exposure measurements and health effects of the Vaal Triangle Air Pollution Health Study. *South African Medical Journal* 81, 550-6.

Terblanche, P. (1998). Vaal Triangle air pollution and health study. Pretoria: MRC.

Tun, K.M., Win, H., Ohnmar., Zaw, A.K.M.T., Myat, K.K.S., Kyi, S. and Lwin, T.T. (2005). Indoor air pollution: Impact of intervention on acute respiratory infection (ARI) in under-five children. *Regional Health Forum* 9, 30-36.

Von Schirnding, Y., Bruce, N., Smith, K.R., Ballard-Tremmer, G., Ezzati, M. and Lvovsky, K. (2002). Addressing the impact of household energy and indoor air pollution on the health of the poor. Geneva: World Health Organisation.

Von Schirnding, Y.E.R., Yach, D., Blignaut, R. and Mathews, C. (1991a). Environmental determinants of acute respiratory symptoms and diarrhoea in young coloured children living in urban and peri-urban areas of South Africa. *South African Medical Journal* 79, 457461.

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