THE EVALUATION OF A BEHAVIOURAL INTERVENTION TO REDUCE THE IMPACT OF INDOOR AIR POLLUTION ON CHILD RESPIRATORY HEALTH

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DECLARATION

I, Brendon Barnes, declare that this thesis is my own work. It is being submitted for the degree of Doctor of Philosophy in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

Signed: 

Date: 20 September 2007

LIST OF PUBLICATIONS AND CONFERENCE PRESENTATIONS

Journal articles

Barnes, B. R. (2007) The politics of behavioural change for environmental health promotion in developing countries. Journal of Health Psychology 12 (3) (531-8).

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ABSTRACT

Indoor air pollution has been associated with acute lower respiratory infections amongst children less than five years old in developing countries. Very little is known about the potential role of behavioural change in reducing child indoor air pollution exposure. This thesis explores three questions: did people change their behaviours following exposure to an intervention that promoted the health benefits of behavioural change? Were changes in behaviour attributable to the intervention? What were the motivations and barriers to behavioural change? The evaluation included a quantitative and a qualitative study. The quantitative study utilised a quasi-experimental before-after design amongst an intervention village (n=98 households). Results were compared to a similar control village (n=121) that did not receive the intervention. Baseline data were collected during winter 2003 and follow-up data were collected during winter 2004 (12 months later). A qualitative evaluation, using two rounds of 4 focus group interviews each, was used to answer questions that emerged from the quantitative study. Indoor air quality - PM_{10}, CO and CO (measured on the youngest child) - were measured over a 24 hour period in randomly selected households before and after the intervention in the intervention (n=36) and control (n=38) groups. After adjusting for confounding factors, there was no statistical association between having the received the intervention and the likelihood of burning outdoors at follow-up (OR=1.16; 95% CI 0.6-1.8). Indoor air quality data showed significant median reductions in PM_{10} (94-96%), CO (85-97%) and CO (child) (83-95%) amongst households that burned outdoors compared to those that burned indoors. Results from the qualitative study suggest that motivations for outdoor burning included: health considerations, reaction to participating in the study, reduced drudgery and prestige. Barriers to outdoor burning included the need for space heating

during winter, perceptions of low indoor air pollution risk and gender relations. This study highlights the *potential* for exposure reduction through behavioural change and is original for three reasons. It is the first behavioural intervention study designed to reduce indoor air pollution in a rural African setting. Secondly, it is the first intervention study in the indoor air pollution field to identify the factors that influenced behavioural change. Thirdly, it is one of the first studies to align debates about behavioural change in the field of indoor air pollution with those in the broader environmental health promotion literature.

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ACRONYMS

ARI	Acute respiratory infections
ALRI	Acute lower respiratory infections
CO	Carbon monoxide
DALYs	Disability adjusted life years
LPG	Liquified petroleum gas
MRC	Medical Research Council of South Africa
$\mu g/m^3$	Micrograms per cubic metre
NIOH	National Institute for Occupational Health
PM	Particulate matter
PM_{10}	Particulate matter of 10 microns or less in aerodynamic diameter
PPM	Parts per million
TSP	Total suspended particulates
URI	Upper respiratory infections
USAID	United States Agency for International Development
WHO	World Health Organization

CHAPTER 1: INTRODUCTION

1.1 Problem Statement

Indoor air pollution caused by the indoor burning of biomass fuels such as wood and animal dung, has been associated with acute lower respiratory infections (ALRI) such as pneumonia amongst children younger than five years old in developing countries. At the level of prevention, the sustainability of technical interventions has been questioned in poor rural contexts. Behavioural change may offer a short to medium term solution in reducing exposure in such contexts. Yet very little is known about the role of behavioural change in relation to child indoor air pollution exposure in poor rural contexts.

1.2 Purpose of the study

The purpose of this study was to evaluate a behavioural intervention that aimed to reduce child indoor air pollution exposure in rural South Africa.

1.3 Introduction

A story:

It was a cold winter morning and I arrived at the Oliphant family homestead at 07h30 to collect air quality monitoring equipment that I had installed the previous day. I was happy to see the smoke from the wood fire as I approached, signalling that the family were home. It was also bitterly cold and I looked forward to warming myself next to the outdoor fire. Until I entered the segotlo - a square shaped outdoor burning area enclosed by a wall of interwoven dried sticks - the wood smoke had snaked slowly skywards into the cold heavy morning air directed by the small fire below it. I greeted the old man who was stacking small pieces of dried wood in a corner of the segotlo. As I crouched next to the fire with palms outstretched, the smoke malevolently encircled me.

My first reaction was to calmly step aside. Somewhat predictably, however, the smoke followed. With tears beginning to well and trying my best to conceal the sting in the back of my throat, I moved quickly trying to outmanoeuvre the smoke while maintaining my conversation with the old man. The smoke followed. Discomfort soon turned to mild panic as I tried to 'shake' the smoke by scuttling awkwardly from one end of the segotlo to the next.

"Stand still," said the old man in Afrikaans (a language we both understood) as he shifted the glowing embers on the hollowed metal sheet on the ground. He bent over the fire, pursed his lips and blew gently under the embers. A small flame flickered back to life. "I'll show you some magic to keep smoke away," as he placed a black three legged pot filled with water to the side of the fire. "Lift your right arm and point your (index) finger at the fire like this. Bend your finger a little. It won't work unless your finger is slightly bent. Hold it like that and the smoke will stop bothering you."

I did exactly what he said…and nothing. The smoke defiantly clung to me, more pungent than before. "You have to believe in it for it to work." I closed my eyes (which thankfully provided respite from the stinging smoke) and tried again; this time trying my best to believe in the 'magic'. Incredibly, the smoke began to move, lethargically at first but it soon returned to its skyward trajectory. "I told you" he said knowingly.

I used this trick whenever smoke followed me over the three years of the study. Understandably, the bent finger trick inevitably brought about smiles and the occasional fits of laughter from inquisitive onlookers. Embarrassment aside, I persisted, not knowing how or why the technique worked – just knowing that it did. After consulting several air

> pollution experts, most of whom seemed equally baffled or sceptical by the trick, I would only recently figure out that the bent finger part of the trick has nothing to do with keeping smoke away at all.
>
> The fact that one keeps motionless (because you are concentrating on keeping a pointed index finger slightly bent) means that very little air movement, particularly pockets of low pressure, are created around you as occurs when you attempt to move away from smoke. Smoke, of course, moves with air from areas of high to low pressure and this is the reason that smoke 'follows' you when you try to move. Contrary to the automatic reaction of moving away from the smoke, people who have lived with wood smoke for most of their lives remain motionless until the smoke naturally shifts away from them. Although he probably knew I would not be able to be motionless on that day, I wished old Mr. Oliphant could have just told me to keep still instead of inflicting three years of embarrassment on me.

Similar to the 'pointed finger' trick, central to this study is the notion that substantial indigenous knowledge of indoor air pollution (and ways of reducing exposure to it) exists and people draw on a number of practices at different times to protect themselves from smoke. I would learn of at least 18 practices that people engaged in to protect their children from the harmful effects of indoor air pollution in this context and I am confident that there are many more. Practices relate to where fires are burned, how fires are ignited and tended, how different fuel combinations and characteristics affect exposure, the use of ventilation when fires are burnt indoors and the location of children in relation to fires.

This thesis focuses on one practice – a shift from indoor to outdoor burning[1]. In evaluating an intervention that promoted, amongst others, the health benefits of outdoor burning in a poor rural context, this study attempts to answer three research questions that have, to date, been poorly discussed in the indoor air pollution literature. Is behavioural change possible in poor rural contexts that are unlikely to benefit from technical interventions? Can behavioural change be attributable to having received an intervention that promoted the health benefits of behavioural change? What are the motivations and barriers to behavioural change? In reflecting on these questions, this study interrogates some of the fundamental assumptions that underlie current (or assumed) notions of 'behavioural change' in the indoor air pollution literature.

Until recently, for example, the dominant theoretical assumption in the literature was that poor people need to be 'educated' about the health effects of indoor air pollution and offered alternative behaviours for them to change or improve their current behaviours. This assertion was based on the assumption that individual caregivers had insufficient knowledge about the health effects of their children's air pollution exposure and improving that knowledge would facilitate caregivers to re-evaluate where and how they burn fires during winter which, in turn, would influence them to engage in protective behaviours. The health education for behavioural change approach manifested itself not only in the numerous references in the literature to the need to educate caregivers of young children about indoor air pollution but also in two intervention studies in Tibet (Tun et al. 2005) and in China (Ezzati and Baris, 2006)

[1]The intervention promoted three behaviours: 1) shift to outdoor burning, and if this was not possible, 2) improved ventilation practices and 3) improved child location practices in the indoor environment. This thesis focused only on outdoor burning because it had the greatest potential to reduce child indoor air pollution exposure compared to the other two behaviours. The impact of improved ventilation and child location practices, while important, will be discussed in other publications arising from this work.

(these studies are described in more detail in the chapter two – the literature review chapter). Both studies, however, showed that health education on its own was insufficient to motivate poor families to engage in protective indoor air pollution practices.

In setting out with this study, I suspected that behavioural change was far more complicated than the picture represented in the indoor air pollution literature. That is, that behavioural change represented a *simple*, even cost-effective, alternative to improved technologies in resource-poor contexts and that educating caregivers of young children of the health effects of indoor air pollution would lead to behavioural change. There appeared to be a large gap between how the indoor air pollution field was conceptualising behavioural change (often reduced to simple health education) compared to more complicated debates that were evident within the broader health and behavioural change literature. This raised an important question, if health education was not sufficient to induce behavioural change, then what other factors influenced caregivers of young children to protect their children from indoor smoke (or not)?

In answering this question, therefore, this thesis highlights a more complex picture of the role of human behaviour in relation to indoor air pollution than has been previously reported and is original for three reasons. Firstly, it is the first behavioural intervention study designed to reduce indoor air pollution in a rural *African* setting (two previous behavioural interventions were conducted in Asia). Secondly, it is the first behavioural intervention study in the indoor air pollution field worldwide to identify the factors that influenced behavioural change in a context that is unlikely to benefit from technology in the short to medium term. Thirdly, it is one of the first studies to align debates in the field of indoor air pollution with those in the broader health and behavioural change literature to understand the important but neglected role of human behaviour in relation to indoor air pollution. In so doing, this thesis builds on the existing body of indoor air pollution reduction knowledge that is more inclusive of understanding how and why people protect themselves from indoor smoke rather than an exclusive focus on biomass fires or the technologies used to burn them (where most of the research attention has been focused).

The following section provides an outline of the thesis and where each of the chapters fits in.

1.4 Chapter outline

Following the introductory chapter, chapter two (literature review) introduces the reader, in more detail, to the concern of indoor air pollution and child acute lower respiratory infections (ALRI) in developing countries. It highlights why indoor air pollution and resultant child ALRI is viewed as a major public health challenge and justifies why children less than five years old were selected for this study. Chapter two proceeds to review the indoor air pollution prevention literature and highlights two important gaps, namely, the poor sustainability of technical interventions in poor rural contexts and the weak knowledge base of the role of behavioural change to reduce indoor air pollution in developing countries. It introduces the reader to the broader health and behavioural change literature in developing countries, discusses how the current study attempts to contribute to the gaps in the indoor air pollution literature and concludes by describing the study aim and objectives.

The aim of this study was to evaluate an intervention designed to reduce child indoor air pollution exposure. Chapter three describes the quantitative and qualitative methodologies used to evaluate the intervention and highlights how the research techniques were employed together to answer different questions of the evaluation. Chapter four describes the intervention and how it was designed and implemented. Because very little conceptual information was available to inform the design of the intervention, chapter four has a strong focus on the formative research that guided the design of the intervention. Chapter five describes the results of the quantitative evaluation while chapter six describes the results of the qualitative evaluation. Chapter seven reflects on the findings in relation to the objectives of the study and discusses the implications for future studies, theory and air pollution policy. Chapter eight concludes the work.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The current chapter reviews the bodies of academic literature[2] that framed this thesis, namely, indoor air pollution and acute respiratory infections amongst children less than five years old; household energy patterns; indoor air pollution prevention; and behavioural change for environmental health promotion. Based on this review, it highlights the knowledge gaps that led to the justification of the study. In terms of the overall thesis, this chapter provides the basis for the formulation of the aims and objectives as well as a summary of the literature to which the results of this study could be compared in the discussion chapter (chapter seven). Before proceeding, however, it is important to discuss the evidence of the association between indoor air pollution and child ALRI in developing countries that provides the starting point for this work before reviewing the *prevention* literature.

2.2 Indoor air pollution and child ALRI in developing countries

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). In South Africa, despite recent rapid economic growth and a significant increase in the proportion of households with access to electricity, solid biomass fuels still account

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[2] Literature was obtained using the Medline, Psychlit, Pubmed and Google (scholar) search engines. Search terms included: indoor air pollution developing countries//ARI developing countries//household energy patterns developing countries//health and behav* theory//air pollution health. No date limits were set. The review had a strong focus on developing country experiences.

for 29% of the overall household energy share (Statistics South Africa, 2003). This statistic, however, disguises the fact that households in some rural municipalities are almost exclusively reliant on biomass fuels (Statistics South Africa, 2003) and even when electrified a large proportion of households continue to use biomass fuels for their energy requirements (Mathee et al, 2000).

When burned indoors in open fires or rudimentary appliances for cooking and heating purposes, 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 (SO_2) and volatile organic compounds into the living environment (Smith, 1987; Bruce et al. 2000). The United States Environmental Protection Agency (USEPA) health standard for PM_{10} (particulate matter of 10 microns or less in aerodynamic diameter) is 150 $\mu g/m^3$ (micrograms per cubic meter) over a 24 hour period (USEPA, 1996). Studies of indoor air quality in developing countries have documented pollutant concentrations between 10 and 100 times higher than this standard (Saksena and Smith, 2003). Figure 2.1 highlights two young children in the current study being exposed to high levels of pollution.

Figure 2.1 Children in the vicinity of biomass fires in the current study

Exposure to indoor air pollution has been associated with a number of health outcomes including chronic obstructive pulmonary disease, lung cancer, nasopharyngeal cancer, tuberculosis, low birth weight, diseases of the eye (Bruce et al. 2000; Smith et al. 2000) and, of particular concern for this work, ALRI such as pneumonia amongst children less than five (Bruce et al. 2000; Smith et al. 2000). ALRI amongst children less than five years old was selected as the health outcome of interest in this study due to its significant contribution to the global and local disease burden. ALRIs are the single leading cause of death amongst children less than 5 years old worldwide (Murray and Lopez, 1997) and one of the top killers of South African children (von Schirnding et al. 1991b; Bradshaw et al. 2003). Globally, ALRIs accounts for approximately 1.9 million deaths amongst children under 5 years old each year (Williams et al. 2002) and are associated with or cause 30.3% of all deaths amongst this age group (Kirkwood et al. 1995).

Young children are considered to be more susceptible to ALRI through indoor air pollution (particularly particulate) 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, children tend to follow their caregivers' around, for example, through carriage on their caregivers backs (Mtango et al. 1992) and often spend extended periods of time in the vicinity of indoor fires during peak cooking and heating times (Mathee et al. 2000).

It is important to note that the association between indoor air pollution and child ALRI is complex and a number of factors are thought to influence it. Factors relate to a) levels of indoor air pollution, b) *exposure* to the polluted air (through, for example, the amounts of time that children spend breathing in the polluted air) and c) factors related to children's susceptibility to ALRI (including low birth weight, nutrition, crowding, family history of infection, environmental tobacco smoke and immunization history) (Bruce et al. 2000; Kirkwood et al. 1995; Victora et al. 1999; Victora et al. 1994; Kirkwood et al. 1995).

In the first published study in the epidemiological literature, Sofoluwe (1968) found that Nigerian children diagnosed with bronchiolitis and bronchopneumonia were living in homes with high levels of gaseous pollutants from cooking fires and tended to spend an average of 3.1 hours per day close to fires (Sofoluwe, 1968). Since then several epidemiological studies from developing countries including Tanzania (Mtango, 1986; Mtango et al. 1992), Zimbabwe (Collings et al. 1990), Nigeria (Johnson and Aderele, 1992), The Gambia (Armstrong and Campbell, 1991; De Francisco et al. 1993; O' Dempsey et al. 1996), Nepal (Pandey et al. 1989), India (Shah et al. 1994; Pandey et al. 1989; Mahalanabis et al. 2002), Papua New Guinea (Anderson, 1978), Brazil (Victora et al. 1994), Argentina (Cerqueiro et al. 1990) and three studies from the United States of America (Morris et al. 1990; Robin et al. 1996; Honicky and Scott Osborne III, 1991)(focusing on wood burning stoves similar to those used in developing countries) have considered the association between indoor air pollution and child ALRI. The studies show relatively consistent associations with odds ratios (indicating the strength of the association) that range from 2.2 to as high as 12.2 with the majority being in the region of 2 to 2.5 (Smith, 2003).

In South Africa, although epidemiological studies of the health effects of indoor air pollution exposure are limited (for example, only 7 epidemiological studies that have considered indoor air pollution and child ALRI could be sourced for this review), these 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). Similarly, proxies of indoor air pollution exposure have been found to be associated with child ALRI morbidity and mortality in the South African literature. Amongst others, a failure to use electricity for cooking and heating (von Schirnding et al. 1991a) (OR=2.5) (Dudley et al. 1997) (OR=3.5) as well as living in areas that are exposed to high levels of both indoor and outdoor air pollution were found to be associated with child ALRIs (Zwi et al. 1990)(OR=1.88). A study by 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 rural communities living in the Eastern Cape province of South Africa.

One of the largest and methodologically rigorous South African studies at the time – 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 amongst school going children 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 ALRI (OR>5) amongst children in homes burning wood or coal (Nel et al. 2003). A study by Wesley and Loening (1996), however, showed no effect of domestic air pollution on the *severity* of respiratory infections. Although South African epidemiological indoor air pollution studies are few, they are relatively consistent with the international evidence with the likelihood of ALRI between 1.88 and 5 times higher amongst children exposed to indoor air pollution compared to children who are not.

It is important to note, however, that the body of epidemiological evidence (including South African studies) has a number of shortcomings. Firstly, compared to the plethora of literature on outdoor air pollution and health studies in developed countries, relatively few epidemiological studies have actually focused on indoor air pollution and child ALRI in developing countries. A review of epidemiological studies for this work, for example, could only identify 25 studies from which reliable health and/or exposure indicator information could be obtained. Secondly, only a small number of epidemiological studies have measured children's exposure to indoor air pollution. Instead, studies have mostly used proxies of exposure such as carriage on mothers' backs during cooking, no access to modern fuels or estimates of the amount of time that children spend in the vicinity of fires to determine child indoor air pollution exposure (Ezzati and Kammen, 2002; Smith, 2002). Thirdly, many studies have not adequately dealt with the role of the (many) confounding factors highlighted above (Bruce et al. 1998). Fourthly, there has been very little consistency in the way that studies have defined ALRI (Smith et al, 2000).

An important study by Ezzati and Kammen (2001a) in rural Kenya, however, attempted to address the shortcomings of earlier epidemiological studies. The study measured indoor air pollution (PM_{10} and CO) in 55 households as well as the behavioural patterns and respiratory health status of 229 occupants (including 93 infants) for two years. The authors were able to formulate the first exposure-response relationship between indoor air pollution exposure and ALRI (both upper and lower respiratory infections) amongst children less than five years old. The curve followed a concave function with the rate of increase declining between 1000-2000 $\mu g/m^3$ (Ezzati and Kammen, 2001a). Figure 2.2 highlights the exposure-response curve outlined by Ezzati and Kammen (2001a) and shows how the mean fraction of illness with both upper respiratory infections (that occur in the upper respiratory tract) and lower respiratory tract infections increase with increasing levels of PM_{10}.

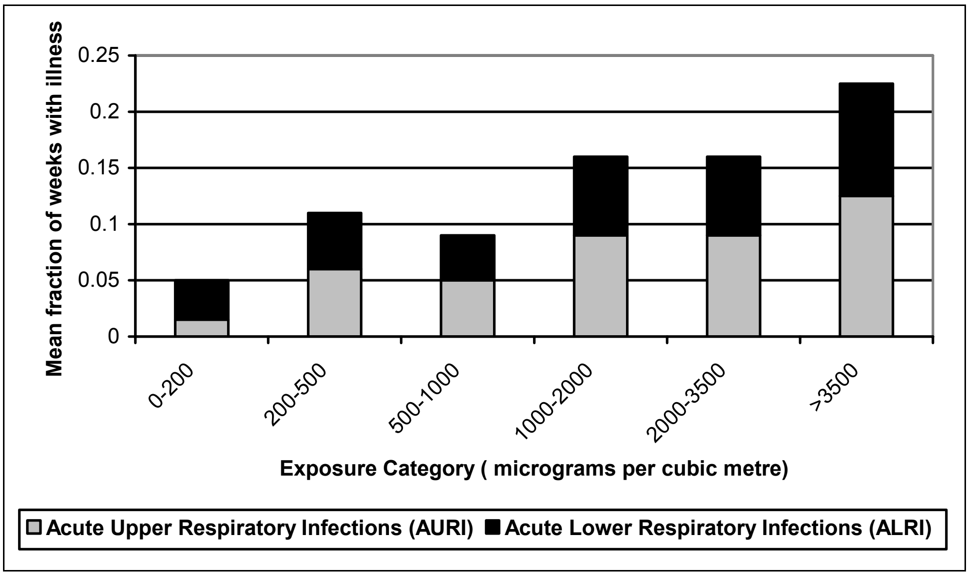

Figure 2.2 Exposure-response relationship between particulate exposure and child acute respiratory infections in rural Kenya

Source: Ezzati and Kammen (2001a).

Several reviews have been conducted of the epidemiological evidence (Ezzati and Kammen, 2002; Bruce et al. 2000; Smith et al. 2000; Zhang and Smith, 2003). These reviews include detailed discussions of the association between indoor air pollution and child ALRI, other health outcomes, as well as important discussions of confounding factors such as age, crowding, nutrition and low birth weight that influence the association. The main point being made here, however, is that despite the relatively small scale nature of the epidemiological evidence, studies have highlighted strong and relatively consistent associations between indoor air pollution and child ALRI (von Schirnding et al. 2002). In addition, the epidemiological evidence is 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). More sophisticated research designs continue to highlight the negative health impacts at increasingly lower levels of exposure to outdoor air pollution (Holdren and Smith, 2004). In addition, concerns of the association are further enhanced through the high household reliance on biomass fuels and the high burden of child ALRI experienced in developing countries (Ezzati et al. 2004).

Recent works (Smith, 2000; World Health Organisation, 2003; Ezzati et al. 2002) have attempted to formulate global and regional burden of disease estimates attributable to indoor air pollution based on the evidence above. Estimates by Ezzati et al. (2002) suggest that exposure to indoor air pollution may be responsible globally for the excess mortality of 1.6 million people each year and is the fourth largest disease risk factor accounting for 3.6% of attributable disability adjusted life years (DALYs) in high mortality developing countries (Ezzati et al. 2002). Highlighted in Table 2.1 is the fact that indoor air pollution is associated with over 800 000 deaths of children less than five years old in high mortality developing countries. Indoor air pollution is only surpassed by child and maternal underweight (14.9% of DALYs), unsafe sex (10.2%) and poor water, sanitation and hygiene (5.5%) as a leading cause of death and ill health in high mortality developing countries (Ezzati et al. 2002).

Table 2.1 Burden of disease associated with indoor air pollution exposure by development status

Category	Children under 5 mortality per year	Adult mortality	Burden of disease (thousands of DALYs)
High Mortality Developing Countries	808 000	232 000	30 392
Low Mortality Developing Countries	89 000	468 000	7 595
Established Developed Countries	13 000	9 000	550

Source: Ezzati et al. (2002).

The scale and impact of indoor air pollution on child ALRI raises the question: how effective are prevention interventions in reducing indoor air pollution exposure? The next section (2.3) discusses intervention strategies that have been used to reduce child indoor air pollution exposure in developing countries. It not only summarises what is known about the effectiveness of interventions in terms of indoor air pollution reduction but also points out the sustainability challenges of those interventions in poor rural contexts in developing countries. The poor sustainability of technical interventions provided the initial justification for the behavioural change approach adopted in this study.

2.3 Indoor air pollution prevention interventions

2.3.1 Introduction

By the late 1990s enough epidemiological evidence of and scientific consensus on 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: 1) cleaner burning fuels, 2) improved cook stoves (ICS), 3) dwelling modification and 4) behavioural change (von Schirnding et al. 2002; Ballard-Tremmer and Mathee, 2000). Indeed, a shift from biomass to cleaner burning fuels has a number of implications for the achievement of the Millennium Development Goals (MDGs) beyond improved health including, but not limited to, goals one, three, four, five and seven (summarised in Table 2.2 below).

Table 2.2 The implication of cleaner household energy sources on the Millennium Development Goals

Millennium Development Goal	Implications of cleaner household energy
Goal1: Eradicate extreme poverty and hunger	• Save time and money from being ill. • Increased fuel efficiency may lead to monetary savings where fuels are purchased. • Opportunities for income generation at the household level.
Goal 3: Promote gender equality and empower women	• Reduced drudgery of collecting fuel. • Reduced cooking time. • Involvement of women in household energy decisions may improve equality at the household level.
Goal 4: Reduce child mortality	• Reduction in child ALRI. • Reduction in burns from direct contact with fires.
Goal 5: Improve maternal health	• Reduce chronic respiratory problems among women.
Goal 7: Ensure environmental sustainability	• Reduced reliance on biomass will ease pressure on forests that have been harvested at an unsustainable rate.

Source: Adapted from the World Health Organization (2006).

The intervention field understandably turned towards the first two, notably cleaner burning fuel and ICS interventions based on evidence of their potential effectiveness to reduce indoor air pollution and, of course, improved quality of life. It is important to note that interventions are not homogenous, with a wide within-category variation, differences in contexts in which they have been implemented and differences in the range of pollutant emissions. With ICS initiatives, for example, technologies include the *jiko* (Kenya), *chula* (India and Nepal), *tamang* (Nepal), *plancha* (Guatemala) and *vesto* (South Africa) with a wide variety of sub-types existing within these categories (REDWP, 1993).

In addition, technical interventions have been implemented long before the health concerns of indoor air pollution emerged on the household energy agenda in the early 1980s. The promotion of cleaner fuel and ICS interventions, for example, gained momentum in the 1970s because of environmental (such deforestation, soil degradation and global warming) (Ahuja et al. 1987) and quality of life concerns (such as women's time collecting and tending inefficient biomass fires) (Holdren and Smith, 2004; Barnes et al. 1997). Historically, therefore, interventions have not always had indoor air pollution and health as their main outcome of interest. Nonetheless, a number of laboratory and field studies that measured emissions *had* been undertaken. The following section reviews what is known about the effectiveness of indoor air pollution prevention strategies but, importantly, highlights why many of those interventions have failed in developing countries in the past.

2.3.2 The effectiveness of technical indoor air pollution interventions

Several reviews of intervention studies were conducted in the early 2000s (Budds et al. 2001; Ballard-Tremmer and Mathee, 2000) that attempted to consolidate the evidence of the impact(s) of indoor air pollution interventions on exposure and, where possible, in relation to health. Compared to emissions from open solid fuel fires, the reviews found that the use of modern fuels such as LPG and kerosene were associated with 98-100% less emissions, charcoal with 70-90% less emissions, hoods (extraction devices under which fires are burned) with 50% less emissions, ICS (no chimney) with between 50% less and 50% higher emissions and ICS (with chimneys) with up to 66% less emissions (Ballard-Tremmer and Mathee, 2000).

Less evidence existed on the effectiveness of dwelling modification on indoor air pollution. A study of indoor air pollution in 420 households in India, however, found that in addition to fuel type, the strongest predictor of indoor air pollution in the living environment was having a kitchen separate from the living area as well as improved ventilation (Mehta et al. 2002). Similarly, a study in Guatemala found that larger burning environments reduce concentrations of pollutants ($PM_{3.5}$) by every unit increase in volume (Albalak et al. 2001). A study in West Kenya showed that the provision of enlarged eaves (spaces between roofs and tops of walls) reduced $PM_{3.5}$ by 62% (Bruce et al. 2002). The evidence for technical intervention studies are summarized in Tables 2.3 – 2.5 below.

Table 2.3 Examples of cleaner fuel studies

Study	Study Type	Objective	Outcome measured	Results
Brauer et al. (1996) Mexico	Cross sectional	Compared PM_{10} and $PM_{2.5}$ in homes using 'biomass only', LPG only and a combination of biomass and LPG. Outdoor concentrations used as control	Indoor air pollution	PM_{10} was highest in biomass only homes (12.4 times higher than outdoors), followed by LPG and biomass combination homes (6.3 times higher than outdoors) and LPG only homes (1.8 times higher than outdoors). Concentrations of $PM_{2.5}$ showed a similar trend
Röllin et al. (2004) South Africa	Cross sectional	Compared concentrations of PM_{10} and CO between one electrified and un-electrified village	Indoor air pollution	Pollution concentrations were significantly higher in un-electrified homes compared to homes where electricity is used in rural South African villages
Raiyani et al. (1993) India	Matched field experiment	Compared pollutants across households using five different fuel types: cattle dung, wood, coal, kerosene and LPG over cooking times (2-4 hours).	Indoor air pollution	TSP: Cattle dung = 3 470 μg/m^3 Wood = 2 630 μg/m^3 Coal = 1 190 μg/m^3 Kerosene = 520 μg/m^3 LPG = 500 μg/m^3 CO: Cattle dung = 174 mg/m^3 Wood = 189 mg/m^3 Coal = 110 mg/m^3 Kerosene = 137 mg/m^3 LPG = 24 mg/m^3
Cerqueiro et al. (1990) Argentina	Case control	Compared ALRI status amongst children living in homes that used coal versus electricity versus LPG.	Child ALRI plus confounding factors	OR=9.9 & 2.2 for children living in coal & LPG burning homes respectively
Johnson and Aderele (1992) Nigeria	Case control	Compared risk factors for ARI compared to healthy controls	Child ALRI plus confounding factors	OR = 12.2 for children exposed to wood smoke than those exposed to kerosene and LPG

Table 2.4 Examples of dwelling modification studies

Study	Study type	Objective	Outcomes measured	Results
Albalak et al. (2001) Guatemala	Cross sectional	To understand the factors that influence indoor air quality.	Indoor air pollution	Larger burning environments reduced concentrations of pollutants ($PM_{3.5}$) by every unit increase in volume(Albalak et al. 2001).
Bruce et al. (2002) West Kenya	Before-after	To understand the impact of enlarged eave spaces on indoor air quality.	Indoor air pollution	The provision of enlarged eaves (spaces between roofs and tops of walls) reduced $PM_{3.5}$ by 62%
Mehta et al. (2002) India	Cross sectional	To understand the role of housing characteristics in predicting indoor air pollution	Indoor air pollution	Having kitchen separate a strong predictor of indoor air pollution in the living environment.

Table 2.5 Examples of improved cook stove studies

Study	Study type	Objective	Outcomes measured	Results
Reid et al. (1986) Nepal	Cross-sectional	Compared improved 'Chulo' Vs traditional stoves	Indoor air pollution	PM$_{10}$ during cooking: Improved = 1 130 μg/m^3 Traditional = 3 140 μg/m^3 CO during cooking: Improved = 67 ppm Traditional = 300 ppm
Pandey et al. (1990) Nepal	Longitudinal before-after	Compared improved 'Tamang' Vs traditional stoves	Indoor air pollution	RSP during cooking (1 hr): Tamang = 3000 μg/m^3 Traditional = 8200 μg/m^3 CO during cooking (1hr): Tamang = 11.6 ppm Traditional = 82.5 ppm
Albalak et al. (2001) Guatemala	Cross sectional	Compared improved 'Plancha' Vs LPG/open biomass fire Vs open biomass fire	Indoor air pollution	PM$_{3.5}$ (14 hr): Plancha = 330 μg/m^3 LPG/open fire = 1200 μg/m^3 Open fire = 1930 μg/m^3
Ezzati et al. (2001a) Kenya	Longitudinal monitoring	Compared improved wood stoves Vs improved charcoal Vs traditional 3-stone fire	Indoor air pollution	Improved wood stoves reduced PM$_{10}$ by 48% compared to 3 stone method during burning period.
McCracken and Smith (1998) Guatemala	Cross sectional	Improved 'Plancha' Vs traditional stoves	Indoor air pollution	Plancha emits 87% less PM2.5 and 91% less CO per kJ of useful heat delivered.
Wafula et al. (2000) Kenya	Cross sectional	Improved 'Jiko' Vs traditional 3-stone fire	Child ALRI plus confounding factors	Child ALRI significantly less in Plancha Vs traditional 3-stone (OR=2.6)
Bruce et al. (2002) Kenya	Before-after	Households offered hoods, ICSs, windows and enlarged eave spaces.	Indoor air pollution	The largest reductions were evident in households receiving hoods (PM$_{3.5}$ reduced by 75%, kitchen CO by 77% and personal CO by 35%). Improved stoves and windows did not significantly reduce indoor air pollution
Barnes et al. (1997)	Cross sectional	Compared 4 stoves (n=3) over 9 observations: open fire, *plancha*, LPG stove and no stove in use (control).	Indoor air pollution	Open fire (PM$_{2.5}$) = 528 μg/m ; plancha = 96 μg/m^3; LPG = 57 μg/m^3; no stove in use = 56 μg/m^3.
Ballard-Tremeer and Jawurek, (1996) South Africa	Laboratory	Compared the emissions of 5 cooking devices: open fire, 'improved open fire' (with raised grate), one-pot metal stove, 2-pot ceramic stove & 2-pot metal stove on CO TSP.	Indoor air pollution	Emissions were lowest with improved open fire (with raised grate) and 2-pot ceramic stove. TSP: open fire = .891, improved open fire = .523, 1 pot metal = 0.976, 2 pot metal = 1.595, 2 pot ceramic = .492
Ramakrishna et al. (1989) India	Cross sectional	Compared CO and TSP in homes using improved versus traditional fires	Indoor air pollution	CO significantly reduced in homes using improved stoves compared to traditional fires. TSP varied greatly and no conclusions could be drawn.

While evidence of the exposure reducing potential of various intervention options existed, the body of intervention literature was characterized by a number of gaps. The most notable of these concerns was that very few of the studies reviewed evaluated the impact of interventions on *health outcomes* (von Schirnding et al. 2002) and those that did, (for example, Wafula et al. 2000; Johnson and Aderele, 1992; Cerqueiro et al. 1990) did not measure indoor air pollution exposure. Given the range of confounding factors (for example, low birth weight, nutrition, immunization history and crowding) that are associated with child ALRI, the degree of health gains attributable to indoor air pollution reduction, if it all, were unclear. Longitudinal experimental intervention studies that assessed the association between indoor air pollution exposure, health outcomes and the range of confounding factors that were thought to influence this relationship were clearly needed.

In response to these calls, large intervention studies were initiated to address the impact of indoor air pollution reductions on health. The Guatemala randomised control cook stove trial by Bruce, Smith and colleagues (unpublished) monitored baseline indoor air pollution exposure before the introduction of improved stoves and then weekly surveillance of child ALRI for 12 months after the intervention. Improved stoves were randomly assigned to half the study households while the remainder continued to cook on open fires (see http://www.who.int/indoorair/interventions/guatemala/en/ and Bruce et al 2006). Similarly, an improved cook stove trial in China (Ezzati and Baris, 2006) focused on evaluating the impacts of improved cook stoves together with health education activities in four provinces. Results were compared to populations that only received health education and a control group that received no intervention (http://www.54rz.com/iap/eg/index.asp.). Preliminary results of both of these studies point towards significant reductions in indoor air pollution exposure associated with improved cook stoves but the Guatemalan study showed a positive but non significant impact on child ALRI. It was too early to ascertain the health benefits of the improved cook stove trial in China at the time of writing.

Studies of household energy patterns in developing countries, however, reflect an uncomfortable dilemma: interventions show significant potential to reduce indoor air pollution but often because of their poor sustainability, their effectiveness deteriorates rapidly under actual field conditions (explained below). Despite increasing optimism that large-scale technological interventions will provide health benefits, there are contexts that are unlikely to benefit from technical interventions in the short to medium term. The poor sustainability of technical interventions is the focus of section 2.3.3 that follows.

2.3.3 Sustainability challenges of technical interventions in rural contexts

It is generally accepted that technical interventions, particularly access to cleaner burning fuels, is the most effective, yet because of the high cost, also the most difficult to sustain indoor air pollution intervention strategy in developing countries (Mehta and Shahpar, 2004). The 'energy ladder' model (see Figure 2.3) 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 kerosene (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).

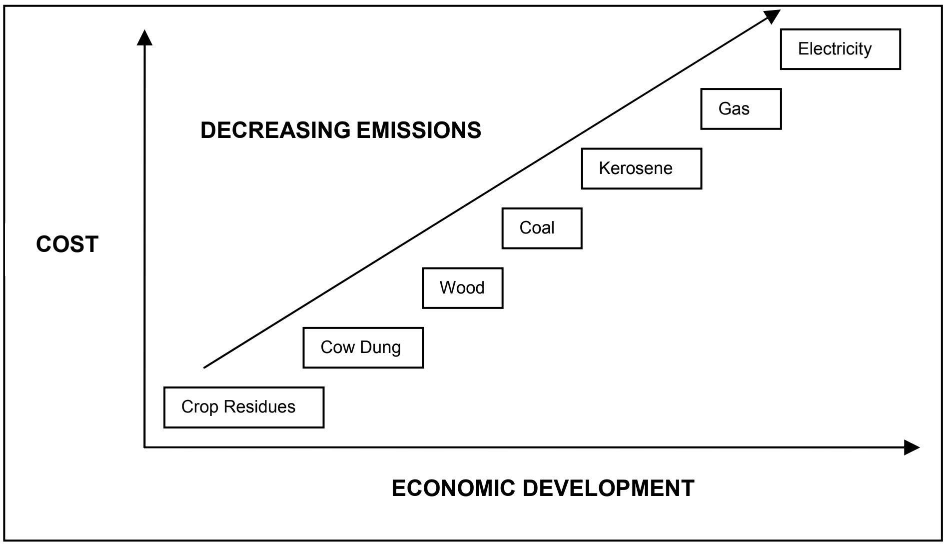

Figure 2.3 The energy ladder model

Source: Smith (1987).

It was initially thought that as developing countries progressed economically and household incomes increased, there would be a natural progression up the energy ladder towards a higher reliance on cleaner burning fuels such as LPG and electricity similar to the processes that occurred in developed countries (Smith et al. 1994). In England, for example, the transition up the energy ladder was driven by a combination of deforestation (which inspired the transition to coal in the late 1700s and early 1800s), effective legislation inspired by catastrophic air pollution events such as the London smog of 1952 due to excessive coal burning, the increasing availability of modern fuels such as gas and electricity and, importantly, household income growth to be able to afford the use of modern fuel (Brimblecombe, 1999).

Studies showing evidence of movement up the energy ladder in developing countries, however, are generally limited to urban contexts (Hosier and Dowd, 1987; Leach, 1987; Smith et al. 1994) where access to modern fuels is better, fuel policies (and concomitant pricing structures) are more regulated and proportionally more households are able to afford cleaner burning fuels. The trend up the energy ladder is slowest amongst poor, rural households and some rural contexts have even witnessed a reversal 'down' the energy ladder away from cleaner burning fuels to an increased reliance on biomass fuels (WEC & FAO, 1999). The failure to progress to the use of modern fuels in poor rural contexts may be due to a number of factors.

Firstly, access to modern fuels is poor with many contexts experiencing absolute energy poverty, that is, the complete absence of access to modern fuel sources (WEC & FAO, 1999). From a supply perspective, it is expensive and logistically difficult to set up energy dissemination chains in rural areas for households to access cleaner fuels such as electricity and LPG. Extending centralised electricity supplies to a rural context, for example, can cost as much as seven times more than providing electricity in urban areas (Goldemberg, 2004). Consequently, providing access to modern (yet more expensive) energy supply chains in rural contexts is often prohibitive for most developing countries.

Secondly, from a demand perspective, it is estimated that approximately 50% of poor rural households collect biomass free of charge from 'invisible trees' (which do not show up on satellite or forestry surveys) within their village or very close by (Leach, 1987). Contrary to earlier perceptions that poor rural communities obtained most of their wood fuel from cutting down trees in forests or buying wood that is cut from forests, wood is often sourced from fallen branches, sticks and deadwood (Bembridge and Tarlton, 1990). Similarly, animal dung is also collected free of charge from within villages. Consequently, even if household access to modern (but more expensive) fuels such as electricity or LPG is guaranteed, households continue to use ‘free’ and renewable biomass instead of, or in combination with, more expensive cleaner burning fuels (for example, households may use non-biomass fuels for lighting because of the relatively low cost but biomass fuels for cooking and heating).

Progression up the energy ladder in developing countries, therefore, does not necessarily imply a displacement of biomass fuels by modern fuels. Most rural households continue to rely on multiple fuel sources for different energy needs. A South African study in the rural North West province (in close proximity to the current study) (Mathee et al. 2000; Röllin et al. 2004), 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. Cooking and space heating needs were fulfilled by up to three types of solid biomass fuels including wood, crop residues and cow dung (Mathee et al. 2000). Thus, even with improved access to modern fuels, households continued to use solid biomass fuels with important implications for indoor air quality. ICS initiatives - the most popular alternative intervention strategy - have traditionally focused on removing/reducing the polluted air in the living environment instead of replacing the fuels themselves.

The successful dissemination and uptake of ICS interventions at the household level are generally context specific and are linked to a number of factors including the design of the stove (to meet household domestic energy needs such as cooking, heating and food curing), marketing strategies, subsidization, commercialization processes (including local job creation), user perceptions, community participation as well as local energy policies (Barnes et al. 1994; Budds et al. 2001). Similar to cleaner fuel interventions, however, the financial inability of poor households to, first, afford the initial purchase of stoves and, second, to maintain the stove after it has been acquired remains a concern in developing countries.

Although the initial purchase prices of stoves are relatively cheap (as low as 1-3 United States Dollars for a *Jiko* stove in Kenya), prices are still beyond the reach of many poor households (Barnes et al. 1994). Even if the initial purchases of stoves are subsidized, which often occurs in large scale programmes, maintenance costs are prohibitive. It is estimated that only 10% of ICSs programs worldwide are still working after two years (Manibog, 1984) and the stoves that are in use, are often poorly maintained resulting in poorer efficiencies and emissions under conditions of actual use compared to initial laboratory testing. Consequently, the intended cost, time-saving and indoor air pollution reduction motivations of ICSs over traditional fires is often significantly reduced after stoves have been installed (Ezzati et al. 2000a; McCracken and Smith, 1998; Albalak et al. 2001).

Research has shown that ICS programs are more likely to succeed in contexts where biomass fuels are purchased (people are motivated by cost savings for purchasing fuels) and where fuels are scarce (women are motivated by time-savings in collecting less wood) (Ramakrishna et al. 1989; Barnes et al. 1994). This means that a significant proportion of the world's population where access to ICSs is poor, who cannot afford to purchase and maintain ICSs, and who live in contexts where biomass is collected for free close to the living environment, are unlikely to benefit from the indoor air pollution reduction potential of ICSs. According to (Goldemberg, 2004), even though ICSs may play an important role in improving the welfare of poor rural populations, "unless truly cleaner-burning biomass stoves can be developed at reasonable costs – in many areas, improved stoves are probably not sustainable in the long run" (p. 372).

It is not my intention to oversimplify the complex relationship between poverty, household energy technology, air pollution and health in developing countries. The point being made, however, is that the 'housekeeping' effort through modern fuels and ICS initiatives to move air pollution out of the living environment that occurred in developed countries and some urban contexts in developing countries has largely stalled and even reversed in some rural contexts in developing countries. Many rural areas do not have access to modern fuels and even if modern fuels are accessible, such projects normally favour the minority who are able to afford them. Consequently, poor rural households continue to rely on biomass fuels for their domestic energy needs. Indeed, household reliance on biomass is projected to grow in developing countries due to growing poverty and increasing population pressures (Barnes et al. 1997).

Despite significant development efforts and evidence of their effectiveness, the costs to governments, donor agencies and households associated with technical intervention efforts are still prohibitive for many poor rural contexts in developing countries. I have highlighted one particular context where this is particularly true: poor rural areas where biomass is abundant, obtainable free of charge (or at very little monetary cost) and where the costs (supply and maintenance) associated with improved burning technologies are prohibitive. If we are to assume that current technology-based interventions are highly dependent on (slow) regional and household socio-economic growth in developing countries, then fuel, ICS and household modification interventions must be viewed as medium to long term strategies. Cheaper strategies are needed to reduce child indoor air pollution exposure *until* access to cleaner burning fuels and ICS programs are more accessible and sustainable.

Having assessed the limitations of large-scale technical interventions particularly in poor rural contexts in developing countries, an important question is: can behavioural change, independent of new technology, offer a useful alternative approach in poor rural contexts? The following section discusses the potential for behavioural change to offer an alternative intervention option in developing countries.

2.4 The role of behavioural change to reduce indoor air pollution exposure

2.4.1 Introduction

As scientific attention turned towards evaluating the health benefits of technical indoor air pollution interventions in the early 2000s, the field was also beginning to understand the behavioural determinants of indoor air pollution exposure (Ezzati et al. 2000b). Exposure is understood to be a function of energy sources, ventilation characteristics of the location of burning and, importantly, human behaviours (Ballard-Tremeer and Mathee, 2000). Behaviour(s) may account for the wide range of exposure estimates documented from households with similar energy patterns (for example, fuels and stove types) and ventilation characteristics. Logic and piecemeal scientific evidence (presented below) suggest that what people actually *do* (that is, their behaviours) within the burning micro-environment – for example, where they burn fires, how fuels are prepared, how fires are kindled, how they use ventilation and where children and adults are located in relation to indoor fires - affects indoor air pollution exposure. Similar to the evidence on technical interventions, however, the evidence of the impact of behavioural change on both indoor air pollution exposure as well as child ALRI was weak (von Schirnding et al. 2002; Favin et al. 1999).

2.4.2 The potential effectiveness of behavioural change

As highlighted above, a number of behaviours are thought to influence indoor air pollution exposure (Barnes 2005). Of particular importance to this work, however, is the potential to shift the site of burning from the indoor environment to the outdoor environment. The potential impact of burning location in reducing exposure has been underscored by two studies. A study in rural Bolivia (Albalak et al. 1999b) measured indoor air pollution exposure in two similar villages – one where cooking was done indoors and one in which cooking was primarily done outdoors. The villages were similar in terms of socio-demographic, cultural and climatic conditions. The only difference was behavioural: cooking was done in small kitchens with very little ventilation in the 'indoor cooking village' while cooking was done primarily outdoors in an area defined by semicircular wall made of root plant in the 'outdoor cooking village'. Monitoring of PM_{10} was done in three locations in both villages: the home, the kitchen and outdoors. Amongst others, results showed significant differences in personal exposures between the two villages. Estimated daily PM_{10} exposure for infants during the non-work season (when people tend to spend more time indoors) were estimated to be three times higher (15360µg/hr/m^3 derived from stationary levels of PM divided by the reported time to be in the vicinity of fires) for the indoor cooking village compared to the outdoor cooking village (5760µg/hr/m^3) (see Figure

2.4) (Albalak et al. 1999b). The impact of reduced indoor air pollution exposure on child ALRI, however, was not described.

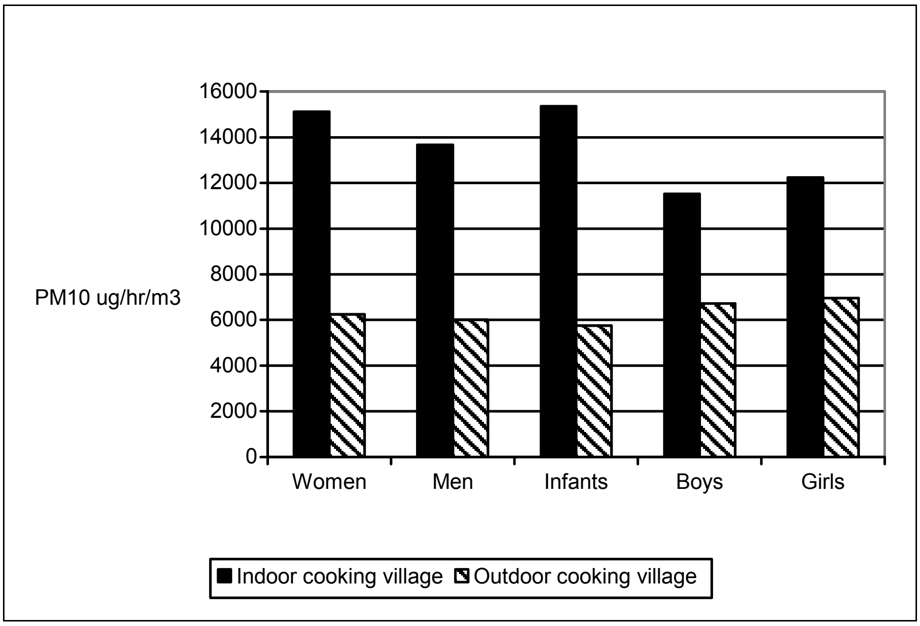

Figure 2.4 Impact of burning location on exposure in rural Bolivia

Source: Albalak et al. (1999b).

More recently, a cross sectional study by Fidelis et al. (2006) in Burkina Faso, using traditional attributable fraction formulae based on current estimates of risk and ventilation coefficients, estimated that changing the location of burning from indoors to outdoors reduced the attributable fraction of indoor air pollution for under five ARI from 0.54 to 0.25 – halving the proportion of ARI attributable to indoor air pollution. The study was based on the assumption that outdoor burning would significantly reduce indoor air pollution because of improved ventilation conditions when cooking outdoors. Despite the weaknesses of the study (for example, actual indoor air pollution levels/exposure were not measured, potential confounding factors were not controlled for and only 51 households were interviewed), the study highlighted the health gaining potential of outdoor as opposed to indoor burning (Fidelis et al. 2006).

Other studies have highlighted the protective role of behaviours in the *indoor environment*. A study in urban South Africa, for example, 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 (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 PM_{10} by 80-90% in laboratory testing (indoor air pollution levels, however, were not reported), by approximately 50% under actual field testing, took a shorter time to cook with and less coal was used (Surridge et al. 2005). The 'Basa Njengo Magogo' project (which, translated means 'make your fire like the old lady' is based on the fact that the idea was perfected by an old lady in a pilot phase) has been included in South Africa's Integrated Household Clean Energy Strategy (Surridge et al. 2005).

Figure 2.5 The Basa Njengo Magogo campaign in South Africa

Laboratory studies in the early 1980s showed that well tended fires display much higher levels of efficiency and potentially lower emission characteristics than previously thought, and in some cases are comparable to efficiency figures obtained from improved cook stoves (Bussman and Visser, 1983 cited in Manibog, 1984). Behaviours such as using smaller stones to hold the pot snugly, tending the fire with shorter pieces of wood that are kept constantly under the pot, the use of dry wood of uniform sizes and the use of pot lids may all improve the efficiency and potential emissions of wood fires (Manibog, 1984). Similarly Ballard-Tremeer and Jawurek (1996), highlighted the potential of raising a wood fire off the ground by placing it on a raised metal grate resulted in significantly lower emissions than a wood fire burned on the ground and comparable, and sometimes better than, emissions from improved cook stoves per burning.

The maintenance and proper use of cooking appliances may also impact on the emissions of those appliances. A study in Nepal (Reid et al. 1986) focused on poor pot fit and poor flue cleaning of improved cook stoves in relation to indoor air pollution. The study found that particulate matter was reduced by over four times (from 4900 to 1100 $\mu g/m^3$) and CO by 16 times (from 500 to 31 parts per million [ppm]) when correct fitting pots were used in improved cook stoves. The study also found that cleaning stove flues (by removing 1.5 liters of soot) reduced CO from 500 to 56 ppm (Reid et al. 1986).

Child time-location patterns in relation to indoor fires are an important behavioural determinant of indoor air pollution exposure (Ezzati and Kammen, 2001a). For indoor air pollution to lead to ALRI, children must breathe in polluted air, that is, *exposure*. Studies have highlighted the fact that exposure may not only be a function of whether or not children are exposed to indoor air pollution (for example while carried on their caregivers backs)(Armstrong and Campbell, 1991; O' Dempsey et al. 1996; Mtango, 1986), but *how long* they spend breathing in the polluted air (Pandey et al. 1989) and *where* in relation to the fire they are exposed (the further away from the fire the lower the pollutant concentrations) (Ezzati et al. 2000b). Table 2.6 summarizes behavioural intervention options for which some evidence exists in the published literature.

Table 2.6 Summary of behavioural intervention opportunities

Behavioural outcome	Description
Burning location	• Shift from indoor to outdoor burning (Albalak et al. 1999b; Fidelis et al. 2006) or, if available, a separate room (Mehta et al. 2002).
Ignition method	• Reverse ignition process for coal fires (Surridge et al. 2005).
Tending fires	• Use smaller pieces of wood of uniform sizes. • Dry wood. • Make sure pot fits snugly over fires. • Use pot lids (Bussman and Visser, 1983 cited in Manibog, 1984).
Use and maintenance of cooking appliances	• Make sure appliance is used per manufacturer's specifications & well maintained (Reid et al. 1986).
Child location patterns	• Reduce the amounts of time children spend in close proximity to indoor fires (Pandey et al. 1989). • High risk behaviours include carriage on caregivers' backs while cooking (Armstrong and Campbell, 1991; O' Dempsey et al. 1996) and sleeping in the burning room (Mtango, 1986). • Potential exists for moving children further away from fires based on findings that concentrations diminish further away from fires (Ezzati et al. 2000b).

It is relatively clear that behavioural change offers the *potential* to reduce child exposure to indoor air pollution. What is less clear, however, is *how* to achieve these impacts. The following section (2.4.3) discusses the factors that are thought to influence behavioural change.

2.4.3 Factors that influence behavioural change

A number of factors, including but not limited to health considerations, are thought to influence behavioural change. Despite this, health education of caregivers of young children is widely purported in the published indoor air pollution literature as the most effective strategy to achieve behavioural change. This is reflected by the many calls for "parental education" (Armstrong and Campbell, 1991, p428), "education of caretakers" (Robin et al. 1996, p865), "maternal education' (Cerqueiro et al. 1990, p. s1027), "public awareness" (Shah et al. 1994, p 113) and so forth to reduce indoor air pollution exposure at the household level. Matsie (1988), for example, concludes that "knowledge of chemical changes which take place in the lungs and blood, the oxygen and carbon dioxide exchanges shall have to be understood for the concept of clean air to have meaning for the rural and urban Blacks" (p. 34). Similarly, a study by Dasgupta et al. (2006) recommended that:

> "For children in a typical household, pollution exposure can be halved by adopting two *simple* measures: increasing their outdoor time from 3 to 5 to 6 hours per day, and concentrating outdoor time during peak cooking periods. We recognize that weather and other factors may intervene occasionally, and that child supervision outdoors may be difficult for some households. However, the potential benefits are so great that neighbours might well agree to pool outdoor supervision once they are aware of their implications for their children's *health*" (Dasgupta et al. 2006, p. 453, my emphasis).

The assumption that health education is an effective and simple means to behavioural change has been tested in two recent studies. A health education intervention 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 health education intervention. The key messages are not well described in the article but the health education 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 was no significant differences between the two groups on 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. The trial was relatively small scale and 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.

In a comprehensive Chinese behavioural trial; Ezzati and Baris (2006) (unpublished) tested the effectiveness of 'health education and behavioural activities' (HEBA) together with improved cook stoves in four rural provinces in China (Gansu, Guizhou, Shaanxi and Inner Mongolia). Study populations in each of the provinces were divided into three groups at the township level: one group received improved cook stoves together 'health education and behavioural activities' (HEBA), the second group received only HEBA without the technology while the third group received no intervention (control group) (Ezzati and Baris, 2006). Extensive baseline monitoring including knowledge, practices, indoor air pollution exposure (PM_{10}, CO and SO_2) and health outcomes were conducted before the intervention (see http://www.54rz.com/iap/eg/index.asp.):

The HEBA implementation involved the following steps in all provinces: 1) explain the source of indoor air pollution, 2) explain the health hazards of exposure, 3) explain the benefits of fuel, stoves and ventilation improvements and 4) alternative stove use behaviour. Results suggest that although there were incremental increases in knowledge of indoor air pollution, the HEBA on its own showed no impact on indoor air pollution exposure (PM_{10}, CO and SO_2). The combination of HEBA with improved stoves showed measurable improvements in indoor air quality (by as much as 85%) and efficiency.

Both studies concluded that health education (in other words changing the way that people think about the health consequences of exposure) on its own does not lead to behavioural change for indoor air pollution reduction. This raises the critical question: if health education is not associated with behavioural change, then what other factors may influence people to engage in protective behaviours? To date, however, very little is known about the role of factors (beyond knowledge of health effects) in explaining behavioural change for indoor air pollution reduction in developing countries.

Several factors are presumed to influence behavioural change on their own or, by the very least, to mitigate the effects of any given intervention. However, none of them have been tested in actual intervention studies. Factors include household income (Dasgupta et al. 2006; O' Dempsey et al. 1996), child age (caregivers perceive the need to keep younger children warm because of the fear that the cold will lead to respiratory illness)(Mathee et al. 2000), child sex (girls are more likely to be exposed than boys although the reasons for this are not entirely clear)(Armstrong and Campbell, 1991), caregiver age (caregivers less than 40 years old may find it difficult to change their behaviours given the burden of their domestic responsibilities, for example, cooking and cleaning) (Balakrishnan et al. 2004), caregiver education (a lack of formal education has been found to be a risk factor for exposure and child ALRI) (Shah et al. 1994; Etiler et al. 2002), dwelling type (informal dwellings are less thermally efficient than formal dwellings) and ambient temperature (participants may find it more difficult to change their behaviours, particularly a shift to outdoor burning, on colder days compared to warmer days) (Holmer, 2004). In addition, socio-cultural factors (for example, indoor fires serve as an important socialising point at night) may influence whether people change their behaviours or not (Mehlwana & Qase, 1999). Except for socio-cultural factors (explored in the qualitative study), each of the above factors were measured and treated as confounding factors in the quantitative study.

In short, emphasis has been placed on health education as a means to achieve behavioural change to reduce indoor air pollution exposure in developing countries with disappointing results. Very little is known about other factors (listed above) beyond intrapersonal perceptions of health that may influence behavioural change in the indoor air pollution field. In addition, discussions about behavioural change in the indoor air pollution literature have not adequately reflected debates about behavioural change in the broader environmental health literature in developing countries. It is worthwhile at this point to summarise these key debates on the role of behavioural change for environmental health promotion in developing countries.

2.5 Behavioural change and environmental health in developing countries

Behavioural change interventions have been used to address a number of infectious diseases in developing countries including diarrhoeal disease (Curtis and Cairncross, 2003), dengue fever (Lloyd et al. 1994), malaria-control (Kroeger et al. 1996) and schistosomiasis (Kloos, 1995), as well as nutrition and infant weaning (Brown et al. 1992). Behavioural interventions are not homogenous of course and differ in their scale, message and communication strategy. However, in their simplest form (and the form indoor air pollution interventions have adopted), the philosophy behind such strategies is that through the communication of environmental risk, individuals will review their current behaviours and change them according to the advice given. Behavioural change, in turn, will reduce their exposures to environmental hazards and, consequently, improve not only their own but their families' health.

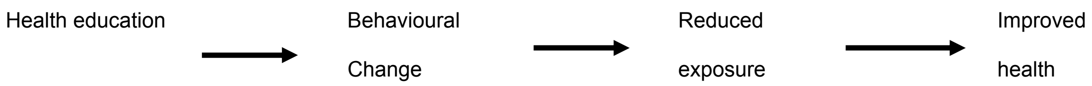

Figure 2.6 Health education for behavioural change model

Source: Hubley (1986).

In reality, however, behavioural change interventions are complex and reviews of the published evidence have shown that they fail far more often than they succeed (Loevinsohn, 1990; Cave and Curtis, 1999). Loevinsohn (1990), for example, found only three out of 67 published studies had sufficient methodological rigour to claim impacts on behavioural change. In a follow-up review of the published behavioural change literature, Cave and Curtis (1999) could only find five articles out of 242 studies with sufficient rigour to determine impacts. Of these, four demonstrated impacts on health and only two of these showed evidence of behavioural change. Whilst both these publications focus mainly on the methodological rigour of evaluation studies, Cave and Curtis (1999) also conclude that the "possibility that health promotion/education is ineffective is the null hypothesis, and should not be ruled out in future studies" (p.15). They proceed to suggest that any claims to their effectiveness should be treated with a dose of 'healthy scepticism'(Cave and Curtis, 1999).

Why have so many behavioural interventions had limited impact on behaviours or health? This question has been explored in the literature from a number of angles. At the level of conceptualisation, historically, behavioural interventions were often informed by simplistic notions of human behaviour in relation to environmental health promotion. The assumption that a lack of *biomedical* understanding(s) of the health problem is at least part of the reason that many people do not engage in protective behaviours dominated the field (Bunton et al. 1991). It was assumed, therefore, that improving health related knowledge of a health concern (through traditional health education) will ultimately result in behavioural change which, in turn, will improve health. Improving caregivers' knowledge and perceptions about the health condition becomes *the* leverage point, and central motivating factor, for behavioural change.

As health education evolved, particularly influenced by the move toward health promotion in the early 1990s (Parker et al. 2004), the health education for behavioural change model was problematised for a number of reasons. The first critique focused on the tendency of behavioural change interventions to focus on improving knowledge of health effects (Hubley, 1986). Contrary to assumptions that poor people are largely ignorant of the health effects of a particular environmental exposure, intended beneficiaries often have a sound understanding of the environment and health concern prior to the intervention (Bembridge and Tarlton, 1990). Other factors (barriers) beyond the control of individual cognitions of health may inhibit the performance of protective behaviours (David Jenkins, 2003). 'Educating' communities of what they probably know already, and not attending to the (physical and economic) barriers that inhibit the performance of protective behaviours, may not be sufficient to affect behavioural change (Nutbeam and Harris, 2001). The 'empty vessel fallacy' (Bunton et al. 1991) that is, 'by merely pouring health information into the supposedly empty minds of an eagerly awaiting target population, health educators can ensure success of their programs' (p. 1511) has been shown to be largely ineffective (Kloos, 1995).

Second, is the often misplaced assumption that even if participants are willing and able to change their behaviours, improved *health* is the most important motivator to do so. A number of factors, not necessarily related to environment or health, may be important motivators for behavioural change. A recent study by Jenkins and Curtis (2005) in rural Benin, for example, explored poor people's motivations for acquiring latrines that have been shown as potentially effective in reducing diarrhoeal disease pathogens. Forty households were interviewed on their decisions to install a pit latrine. The study found that health played only a minor role in latrine adoption. Other motivations included prestige (latrines were a symbol of higher social standing), well being (convenience and comfort, privacy, protection from dangers such as insects and snakes when defecating in bushes) and situational (for example, desire to increase rental income from property). Interestingly, participants viewed the installation of a pit latrine as a symbol of higher social class and a mechanism to 'achieve a better life' (Jenkins and Curtis, 2005).

The third critique focused on the tendency of behavioural interventions to (over)focus on the *intrapersonal* level at the expense of more 'upstream' interventions that might be more effective in addressing the source of environmental pollution rather than exposure to it. Environmental health problems, particularly in developing countries, are complex and "in reality are a constellation of linked problems" (Kreuter et al. 2004) that are often embedded in extreme poverty (Macfarlane et al. 2000). Given the complexity of the causes of environmental health concerns in developing countries, not least of which is poverty and inequality, the focus of so many behavioural interventions on intrapersonal perceptions of health has been questioned in resource-poor contexts. On the other hand, behavioural interventions have often been justified precisely because of a failure of more 'upstream' economic and technological development in developing countries in achieving any significant preventive health impact (Favin et al. 1999). Similar to the initial justification for this study, behavioural interventions are informed by the notion that individuals cannot rely solely on slow economic and development processes in developing countries to achieve better health but should take it upon themselves to improve their health.

Theory plays a critical role in guiding how interventions are conceptualised and implemented. Krieger (2001) points out that while it is relatively obvious to identify patterns of ill-health, this does not necessarily translate into a common understanding of the cause of that ill health. It is for this reason, she argues, that theory is key (Krieger, 2001). Behavioural scientists and practitioners now, more than ever, have a range of theoretical models to assist them with planning the content of interventions and deciding at what level(s) interventions are pitched. At the intrapersonal and interpersonal level, these include a plethora of models such as the Heath Belief model, the theories of reasoned and planned action, Social Learning Theory and so forth (2001); planning models such as Applied Behavioural Analysis (Graeff et al. 1993) and Trials of Improved Practices (Dicken and Griffiths, 1997); process models such as the Transtheoretical model, Diffusion of Innovation and Social Marketing and so forth (see Nutbeam & Harris, 2001). These theories have a common focus of influencing individual behaviours by changing the manner in which people think about the health effects of a particular disease outcome.

The concept of 'environmental health promotion' has been used to describe an ecological intervention approach that lies at the intersection between environmental health and health promotion (Howze et al. 2004). While acknowledging the relative importance of intrapersonal perceptions of health, this approach also considers factors that operate and interlink at multiple levels including the *intrapersonal* (e.g. knowledge and attitudes), *interpersonal* (e.g. social support and childcare assistance), *community* (e.g. community working groups) and *policy* (e.g. energy and clean air policies) (Parker et al. 2004). An ecological approach also allows for different methods of intervention implementation. In contrast to a moralistic (Jensen, 1997) health education approach (where behavioural change is the main focus, participants are educated about health effects by knowledgeable educators, communities have very little conceptual input and the main outcome is behavioural change) that this study and others adopted, an ecological approach also considers a more democratic intervention design and implementation which involves the extensive consultations with the community (Cole et al. 1999), the acknowledgement that environmental health problems are equally determined by physical conditions as well as by lifestyle (behaviours), and implementers play the role of facilitators rather than educators.

The move to an ecological approach away from an intrapersonal approach to behavioural change coincided with a move away from 'risk factor epidemiology' (Parkes et al. 2003) that focused on behavioural risk factors towards a more complex understanding of the interaction between the person and the broader socio-political environment. The field of social epidemiology, in particular, acknowledged the importance of the political economy of socioeconomic factors (such as poverty and inequality) together with psycho-social processes (Krieger, 2001) in predicting environmental health risk. This model assumed that changes in the broader environment will produce changes in individuals and vice versa which are crucial in implementing environmental changes (McLeroy et al. 1988).

Despite this, the role of explicit[3] theory in the behavioural change field (including indoor air pollution) has been limited (Cave and Curtis, 1999). It is not my intention to represent the behavioural change field as unanimous or that many interventions have evolved from simplistic health education for behavioural change that has been found to so ineffective in the literature. Indeed, most published studies continue to rely heavily on the traditional health education for behavioural change approach, often under the guise of health promotion, have not been based on explicit theory and do not reflect the complexities of behavioural change for environmental health promotion in developing countries. It is also not my intention to suggest that interventions that are based on explicit theory are necessarily more effective. Indeed, western theories have often been (mis)used in developing countries with poor results (Barnes, 2007). Similarly, interventions showing effectiveness have not always been based on explicit theory. What is clear, however, is that *successful* behavioural interventions assume a complex understanding of the role of behavioural change that permeates through the planning, intervention and evaluation phases of a project that does not necessarily assume a link between people's intrapersonal perceptions of health (how they think) and behaviours (what they do) (Hubley, 1988).

[3] It is not fair to assume that because an intervention is not based on explicit theory that it is atheoretical. Health education is based on the *implicit* theory that at least part of the problem can be attributed to poor knowledge of a disease.

There is a significant conceptual gap between how the indoor air pollution field is currently approaching behavioural change and the broader environmental health literature that has shifted, in principle anyway, its focus to be more inclusive of factors that may operate on a number of levels. Debates in the broader behavioural change literature provided a theoretical gaze under which the results of this study could be analyzed and interpreted. They also informed the use of a two pronged (mixed method) methodological approach to identify the factors that influenced behavioural change: a quantitative deductive approach which tested the factors proposed in the indoor air pollution literature at the intrapersonal and household level as well as a qualitative inductive approach which allowed for analysis of factors at all levels that were not previously documented in the indoor air pollution literature (discussed in more detail in chapter four). The discussion chapter (7) discusses the results of this study in relation to broader debates in the behavioural change literature.

Based on the literature reviewed in this chapter, the following section summarises the key gaps in the literature and proceeds to the study aim and objectives.

2.6 Gaps in the literature

- Indoor air pollution remains a serious environmental health threat in developing countries. Although technical interventions have been shown to be effective and sustainable in certain contexts, there is a particular need for sustainable interventions that can be implemented in poor rural contexts where biomass fuels are collected free of charge and close to the living environment.

- Behavioural change offers the potential for indoor air pollution reduction but very little is known about the effectiveness of behavioural interventions in poor rural contexts.
- Even less is known about the factors that influence behavioural change for indoor air pollution reduction in developing countries. There is a particular need to clarify the role of health education in inducing behavioural change in line with current debates within the broader behavioural change literature.

2.7 Study aim and objectives

Aim

The aim of this study is to evaluate a behavioural intervention that was designed to reduce the impact of indoor air pollution on child respiratory health (through exposure reduction) in a poor rural context of South Africa.

Objectives

1. To determine whether there were shifts in burning location following a behavioural intervention that promoted the health benefits of outdoor burning.
2. To determine the impact of behavioural change on indoor air pollution and child exposure.
3. To determine whether behavioural shifts were attributable to the intervention.
4. To qualitatively understand the motivations for and barriers against outdoor cooking and highlight opportunities to improve the intervention.

The objectives of the study were formulated to reflect two key themes of the thesis: *effectiveness* and *sustainability*. Objectives 1 & 2 were formulated to better understand the effectiveness of behavioural change in relation to child exposure reduction, and importantly, to discuss whether such reductions are significant enough to be potentially protective of child respiratory health. Objectives 3 & 4 were formulated to better understand the sustainability of the intervention by investigating the factors that influenced behavioural change. The next chapter presents the methodology that was used to evaluate the intervention.

CHAPTER 3: METHODOLOGY

3.1 Introduction

Chapter two highlighted, amongst others, the need for well-designed intervention studies to evaluate the impact of interventions on child indoor air pollution exposure. In response to this, the evaluation design needed to be powerful enough to attribute changes in behaviours and indoor air pollution exposure to the intervention while excluding rival explanations. It was equally important for the evaluation to identify the factors that might induce and influence the sustainability of behavioural change. The current chapter presents the quantitative and qualitative methodology used to evaluate the intervention in order to achieve the objectives presented at the end of chapter two.

The following chapter (four) describes the intervention in more detail. However, it is pertinent at this point to briefly summarize the main points of the intervention for the rest of the methodology chapter to make sense. The study took place in a poor rural setting in the North West Province of South Africa. Over 98% of households were reliant on biomass fuels collected free of charge within the village or close by. Outdoor burning in designated outdoor kitchens was common practice in winter during the warmer parts of the day. However, over 75% of households brought a fire indoors during early evening for space heating where periods of intense exposure occurred. The ideal behaviour was defined as ‘burn exclusively outdoors’. However, knowing that cold winter temperatures might make this difficult to do so, if fires were brought indoors, then improved ventilation practices (for example, open windows) and reductions in the amounts of time children spent in the vicinity of fires were promoted. This thesis, however, focuses on outdoor burning because of its potential for large reductions in exposure. The impact of ventilation and child location when fires were brought indoors is beyond the scope of this work and is discussed in other publications. The intervention was implemented by trained communicators through two door to door visits to study participants in the intervention group. Families were informed of the health effects of indoor air pollution exposure and behavioural change was negotiated with families. The following section (3.2) describes the study design that was used to evaluate the intervention.

3.2 Study design

The evaluation of the intervention was divided into two components: a quantitative and a qualitative study. The quantitative evaluation employed a quasi-experimental before-after study design with a control group (Reichardt and Mark, 1998). Baseline data were collected between 18 July and 2 August 2003 in both the intervention and control group. The intervention was implemented immediately after baseline data collection amongst the intervention group and not in the control group. Post-intervention data were collected from both groups 12 months later between 17 July and 1 August 2004. The qualitative evaluation used focus group discussions with study participants in both the intervention and control group. Two rounds of focus groups were conducted after follow-up quantitative data collection process in late 2004. The first focus group was conducted four weeks after the end of the quantitative data collection phase and was based on predefined questions. However, the second round of focus group interviews took place 6 weeks after the first round and 10 weeks after the quantitative data collection. The lengthy gap allowed the author to analyse the quantitative and first round of qualitative data and refine the questions based on the emerging results. Figure 3.1 illustrates the overall study design and timing of the data collection phases.

Study group	Quantitative evaluation					Qualitative evaluation			
Intervention	O	→	X	→	O	→	FG	→	FG
Control	O	→	→	→	O	→	FG	→	FG
	July 03		August 03		August 04		September 04		November 04

Legend	
O	Quantitative cross sectional assessment
X	Behavioural intervention implemented
FG	Focus group

Figure 3.1 Evaluation study design

A number of quantitative study designs were initially considered for the evaluation of the intervention including:

- A randomised intervention trial within one village where the intervention would be implemented amongst a randomly selected sample of households while the remaining households would serve as the controls. Behaviours and exposure would be measured before and after the intervention. However, the likelihood of message contamination and the difficulty in finding one large enough village made this design unfeasible.
- A two-group randomised intervention study at the village level where a group of randomly selected villages received the intervention and another group of control villages did not. Similar to the previous study, outcome variables would be measured before and after the study. Although a powerful study design, the budget of this work did not allow for a study of this magnitude. In addition, it would have

been a challenge to have found a large group of un-electrified communities given the accelerated rate of electrification (1000 households per day) occurring in rural South Africa.

- A one group before-after study design where the outcome variables would be measured before and after the intervention. However, the lack of a control group would have weakened the confidence in the findings.

It was believed that the two group before-after design employed in this study offered a useful and cost-effective evaluation methodology for the purposes of this study. In terms of the qualitative study, a number of data collection options were considered such as individual personal interviews and observational methods. Consistent with the objective to understand the factors that influenced behavioural change, it was believed that focus group discussions *after* the quantitative data collection phase offered the most useful qualitative method. Not only were the focus group discussions relatively cost-effective, they also allowed for a group of participants to discuss the variety of (and sometimes contradictory) factors that influenced individual decisions to burn outdoors or not. Focus group discussions therefore encouraged a variety of responses that could be clarified and discussed in a single meeting.

3.3 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. The North West province has an estimated population of 3.4 million people and is the sixth largest (in land area) province in South Africa. Over

65.1% of the North West province's population live in rural areas (Statistics South Africa, 2003) and the province is ranked as the third lowest in South Africa terms of quality of life as reflected in the Human Development Index (North West Provincial Government, 2003). The study villages are located in the Mafikeng local municipality, one of 21 local municipalities in the North West province. The municipality serves a population of 164 963, a high proportion of which (15.3%) are less than four years old. The area is characterised by high unemployment (only 28% of adults between 15-65 years old are formally employed), low household incomes (23% of households earn less than 800 South African Rands or 106 USD per month) and low educational attainment (32% of adults over 20 years old have no formal education or have only completed part of their primary school education). Over 66% of those unemployed live in rural areas. The study area was severely deprived compared to South African national averages (Statistics South Africa, 2003). The main spoken language is seTswana (95% of households) followed by Afrikaans (75%) and xiTsonga (47%) (Statistics, South Africa, 2003).

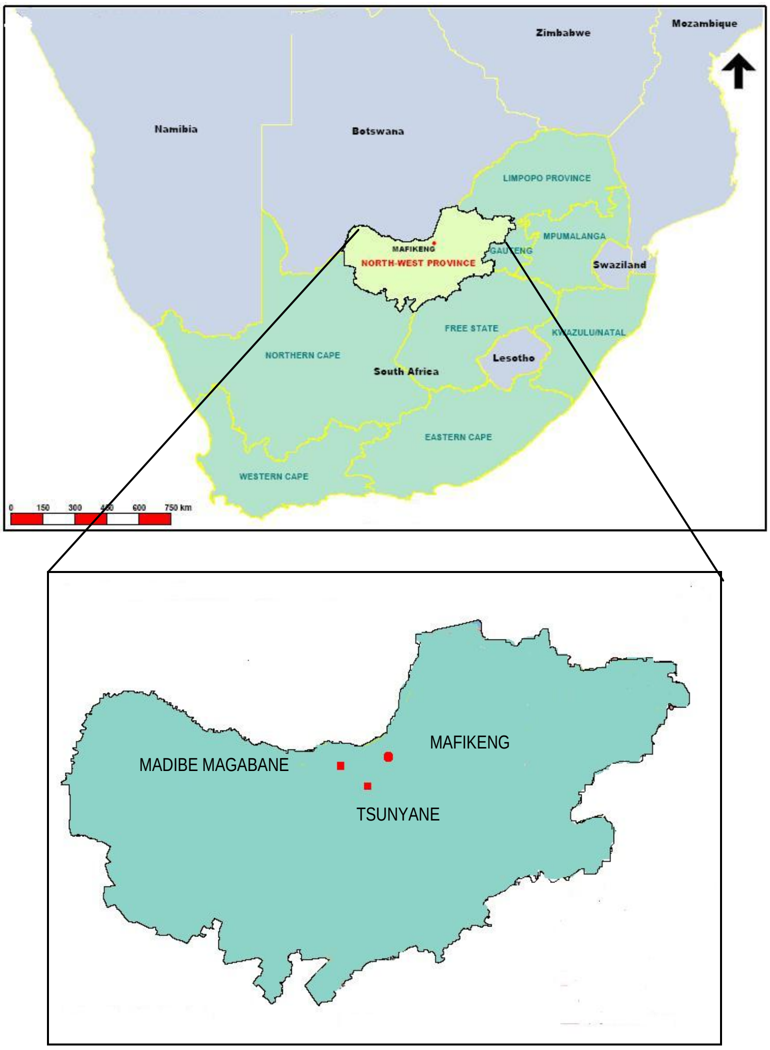

Figure 3.2 Location of the study site

It is important to note that between 1978 and 1994, the Mafikeng local municipality was part of Bophuthatswana, a so called 'independent' state that, amongst others, served as a cheap labour source for the apartheid system. Prior to this period and before Botswana's independence in 1966, Mafikeng was the governing centre of Bechuanaland, a British protectorate that extended into present day Botswana. In 1994 the area was officially incorporated into South Africa. However, a history of colonisation and administrative changes means that the municipality remained desperately underserved from an environmental health perspective. Despite valiant efforts at service delivery after 1994, at the time of writing, over 56% and 66% of households in the province had no access to piped water in the home and flush sanitation respectively (Statistics South Africa, 2003). In addition, many rural areas, such as the study villages, experience high energy poverty, that is, are with poor access to modern fuels such as kerosene and LPG and no access to electricity (North West Provincial Government, 2003).

From a climatic perspective, the study area is characterised by semi-arid conditions, with large seasonal temperature variations. For example, the average daily maximum temperature equals 32 degrees Celsius during January (summer) and average daily minimum temperature equals 0.9 degrees Celsius during July (winter) (South African Weather Bureau, 2005). During winter, although maximum temperatures can reach 24 degrees Celcius, early morning and night time temperatures can be as low as -5.1 degrees Celcius (South African Weather Bureau, 2005). The municipality experiences very low rainfall (less than 500 millimetres a year) and high wind speeds particularly during later winter (South African Weather Bureau, 2005). Vegetation types include dry bushveld and Kalahari deciduous Acacia thornveld (North West Provincial Government, 2003). Trees are found in relative abundance close to rural villages and villagers typically collect dead branches and dried sticks for fuel. In addition, cattle and donkey dung is collected free of charge from communal grazing fields or along paths and used as fuels.

Figure 3.3 Girl collecting wood free of charge from within a village

3.4 Research participants

The study recruited a sample of 324 households in the intervention (n=149) and control groups (n=175) respectively in 2003. Eligibility was defined as a household in which one or more children four years old or less lived during the sampling exercise in 2003. The unit of analysis was defined as the household. Indoor air quality data were sampled from a random sample of 100 households (n=50 in the intervention and n=50 in the control group). A household was defined as all occupants living in a predefined homestead which was usually demarcated by a boundary fence and allocated through communal land tenure principles. The index child was defined as the youngest child living within a household. Data were collected at both the individual (age and sex of child and so forth) and the household level (burning location, household indoor air pollution data, socio-economics and so forth). Because the study focused on children less than five years old who were subsequently followed up for one year, children less than four years old in 2003 were included in the study.

3.5 Sample size calculations

Sample size calculations were calculated a priori using the STATA 9 software package, by drawing on practical recommendations by Lenth (2001) and Lipsey (1998) and through discussions with a biostatistician. Calculations for the number of households were based on a power estimation of .85, alpha=.05 and an expected 15% (a relatively small effect size) improvement in the number of households that shifted from indoors to outdoors following the intervention. Results suggested that a minimum sample size of n=148 in each group would be required. Baseline sample sizes in both the intervention (n=149) and control (n=175) groups met this criteria but left very little allowance for loss to follow-up that the study experienced.

A separate sample size calculation was conducted for the monitoring of indoor air pollution. Sample size calculations were based on expected reductions in indoor air pollution that might occur as a result of a shift from indoor to outdoor burning. The mean and standard deviation values for PM_{10} measured in kitchens in an indoor burning village (mean=3690µg/m^3, standard deviation=5380µg/m^3) and an outdoor burning village (mean=430µg/m^3, standard deviation=140µg/m^3) in a Bolivian study (Albalak et al. 1999) were used as the basis to make this calculation. Calculations for the number of households in which indoor air pollution was measured were based on a power estimation of .90 and an alpha=.05. Results suggested that a minimum sample size to be able to detect such differences was n=24 in each group. The study, however, was able to afford to sample n=50 households in each group at baseline. Separate sample size calculations for CO were not deemed necessary as CO was measured in every household in which PM was measured.

3.6 Sampling strategy

The North West Province was selected because of the high reliance on biomass fuels in rural areas. Once approval had been obtained from the North West Department of Health, the two villages were purposively selected after extensive consultations with stakeholders including ESKOM (the national electricity provider), the North West Province Department of Health, the Mafikeng Provincial Hospital and members of the study team (described in more detail in section 4.6). From an intervention perspective, the two villages represented an indoor air pollution ‘worst-case’ scenario by displaying characteristics of contexts (highlighted in chapter two) that were unlikely to benefit from technical interventions in the short to medium term. Characteristics included:

1) Households had very low incomes (derived from South African Census data).
2) There was little access to modern fuels such kerosene or LPG and no access to electricity.
3) Solid biomass fuels in the form of wood and animal dung were in abundance and widely used.
4) Fuels were collected free of charge and were sourced close to the living environment (ascertained through anecdotal evidence).

In short, the villages provided the ideal context to test the hypothesis that behavioural change was an effective intervention option in poor rural contexts where more expensive technology was unlikely to succeed in the short term. In addition, because motivations such as monetary and time savings are negated by the absence of any technological intervention, the setting also provided an ideal opportunity to test the hypothesis that improving *health* related perceptions would be sufficient to facilitate exposure reductions.

From a methodological perspective, household data from the 2001 census (Statistics South Africa, 2003) suggested 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 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 large enough to achieve a reasonable sample size and the villages displayed similar characteristics to the villages used in the formative research to apply the lessons learned from these phases of research. In addition, the two villages were approximately 35 kilometres from each other with relatively little social contact between them to minimise message contamination (assessed through anecdotal evidence).

To compile a sampling frame, members of the research team conducted door to door visits to every household in the intervention (n=655) and control (n=627) villages at the beginning of winter 2003 (2-17 June 2003), interviewed an adult of the house and completed a study registration form. The roles and responsibilities of the research team are described in section 3.10. The registration form had questions on the number of children less than four years old living in the household and women who were pregnant living in the household (it was initially envisaged that newborns could be potentially recruited into the study). All households with one or more children were invited to participate (on the spot) while those without were thanked for their time and excluded from the study.

The study utilised a purposeful criterion (Patton 1991) sampling strategy in that it included every household that had one or more children less than four year old in 2003. The sampling strategy is described as *purposeful* as research participants were non-randomly selected (that is, all households with a child four year or less were included) and *criterion* as research participants needed to fulfil a predefined criterion (that is, include a child that is four years old or younger in 2003). The study was explained in seTswana (or a language of their choice), to the primary caregivers of the household using a research participant information sheet as a guide. The participant information and informed consent procedures were approved by the Wits Ethics Committee for Research on Human Subjects (Clearance Number: M03-05-43) (see Appendix C). 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.

Because households in the rural villages do not follow conventional household numbering patterns, the household registration form also included detailed information on the closest landmark and household identification. For example, a household without a number could be identified as “the mud house with green front door situated along the main road between the wind-pump and the chief’s house.”

Fifty households 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. PM and CO are known to be associated with child ALRI. A 24 hour cut-off was used to be able to capture the full range of burning activities (for example, cooking and heating) over a one day period. Using a shorter period, for example, could have led to either missing early morning or late evening space heating exposures. 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 air quality sampling procedures are described in more detail below.

3.7 Quantitative study

3.7.1 Outcome measures

In line with the understanding of how burning location might influence indoor air pollution, it was envisaged that the behavioural intervention will impact on 1) outdoor cooking, which in turn will impact on 2) indoor air quality (PM_{10} and CO) and child CO exposure. Consequently, burning location was the main outcome measure of the quantitative evaluation.

In addition, a number of factors (described in section 2.4.3 above) were thought to affect the impact of the intervention on burning location such as household income, child age, child sex, caregiver age, caregiver education, dwelling type and ambient temperature on the day of measurement. These factors were treated as confounding factors and controlled for in the analysis. The conceptual framework for the quantitative study is highlighted in Figure 3.4 below. A description of the outcome variables used in the quantitative study (including categories and justification) are presented in Table 3.1 below.

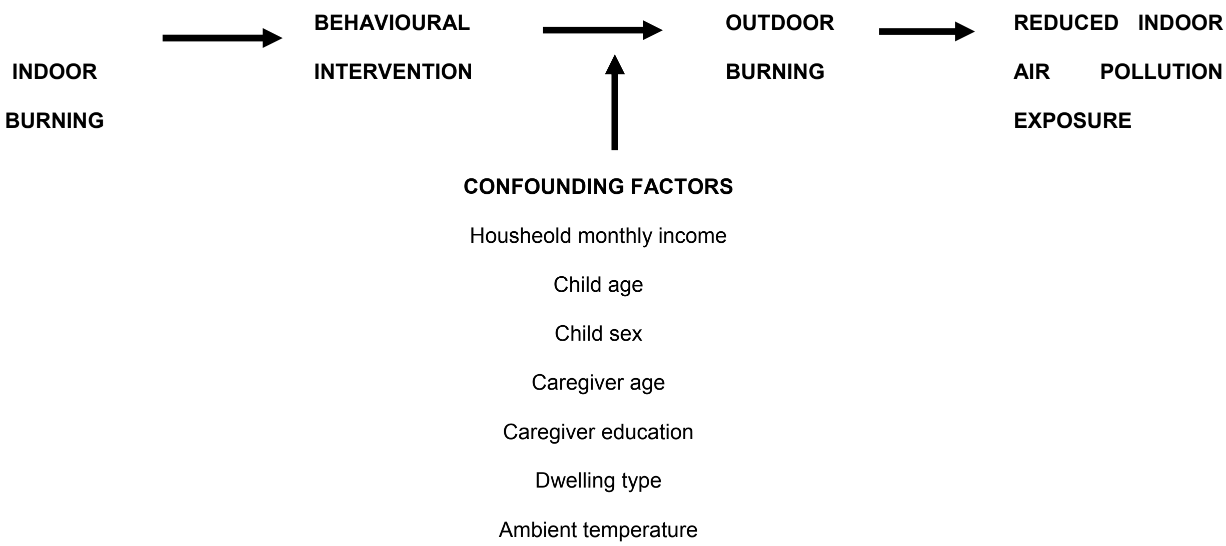

Figure 3.4 Conceptual framework for the quantitative study

Table 3.1 Outcome variables measured in the quantitative study

Variable	Categories	Justification
Burning location (dependent variable)	Outdoors vs indoors	Outdoor burning has been associated with significant reductions in indoor air pollution and exposure (Albalak et al. 1999a). A shift from indoor to outdoor burning may significantly reduce indoor air pollution and exposure.
Intervention (independent variable)	Received the intervention vs did not receive the intervention	Health education is widely purported to induce protective indoor air pollution behaviours (Tun et al. 2005). Having received the intervention might influence caregivers to burn outdoors.
Household monthly income	≤ R1000 per month vs ≥R1001 per month	Low household income has been associated with higher indoor air pollution and child ALRI (O' Dempsey et al. 1996; Dasgupta et al. 2006). The categories used in this study were based on households living on less than the equivalent of 1 USD per person per day (World Bank poverty line calculated using the average of 7 persons per dwelling for the study area [Statistics South Africa2003] over 30 days at an exchange rate of USD4.8 to R1).
Child age	≤ 18 months vs ≥ 19 months	Children younger than 18 months are more likely to be carried with carers into the room used for burning to keep warm (Mathee et al. 2000) and are more susceptible to ALRI through indoor air pollution exposure (Williams et al. 2002).
Child sex	Male vs Female	Girls are more exposed to indoor air pollution because they are more likely to be carried on the carers backs while they cook (Armstrong and Campbell, 1991). Reasons for this are not clear.
Caregiver age	≤ 40 years old vs ≥ 41 years old	Women who are younger than 40 years old are more likely to be involved in cooking as well as child caring (Balakrishnan et al. 2004; Victora et al. 1994). Because of the burden of their domestic responsibilities, women younger than 40 years might find it difficult to burn outdoors.
Caregiver education	No formal education vs formal education	A lack of formal education has been found to be a risk factor for both indoor air pollution and child ALRI (Etiler et al. 2002). Even very little formal education has been found to be protective of ALRI (Shah et al. 1994).
Dwelling type	Informal vs formal	Informal dwellings (in which one or more walls of corrugated iron) are not as thermally efficient as formal dwellings made from cement or mud bricks. Participants living in informal dwellings may find it difficult to burn outdoors as the inside of the dwellings would be cold.
Minimum ambient temperature	≤6 degrees Celsius vs ≥7 degrees Celsius	Minimum temperature on the day of measurement was used as the basis for classification. Minimum temperatures equal to or lower than 6 degrees Celsius were classified as 'very cold' and 7 degrees Celsius or more as 'moderately cold' based on standard comfort criteria (Holmer, 2004). It was expected that households that were interviewed on days that were classified as 'very cold' would find it very difficult to burn outdoors because of the comfort of indoor burning.

3.7.2 Materials and methods

Burning location

Burning location was measured using an interview questionnaire (see appendix A). The questionnaire was translated into seTswana using localised concepts and meanings, piloted amongst a convenience sample (n=23) of caregivers in the rural village of Mantsa (located approximately 10 kilometres from Mafikeng) before the study commenced and revised accordingly. Indoor burning was defined as the action of bringing a fire indoors from the outdoors regardless of the time of day or the duration of the burning. A section of the questionnaire included a column with 10 minute time slots (from 06h00 until 20h00). Caregivers were asked: "If you can think back to yesterday, can you please tell me where you burned fires. How long did you burn outdoors, from what time to what time? Did you take the fire indoors? If yes, from when to when?" Based on mothers' answers, researchers shaded in the relevant cells of the questionnaire with a pencil. The interviewer filled in the appropriate items in the questionnaire based on the caregiver's responses to predefined questions. The interview questionnaire remained the same during both the 2003 and 2004 assessments and was completed by the same caregiver in both assessments. Each interview took approximately 45 minutes to complete.

Indoor air pollution

The monitoring of respirable particulates amongst a sub-sample of households (N=100; n=50 in the intervention and n=50 in the control group) 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. The preparation, collection and analysis of the air pollution samples were done by the author. 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. *It is important to note that sampling was only undertaken indoors in the inkwe (burning room).* Pumps with cyclones were located at a standard height (breathing height of adults) and distance (approximately 1.5 meters) from where study participants reported to burn their 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 (not to disturb the particles captured on the filters) until they could be transported to the NIOH 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 same procedure was applied to samples collected in both 2003 and 2004.

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. See Figure 3.5 for a photograph of a study child with a CO tube.

Figure 3.5 Study child with attached carbon monoxide diffusion tube

Confounding factors

Data on household income, child age, child sex, caregiver age, caregiver education and dwelling type were obtained through self report in the interview questionnaire.

Temperature data for the relevant study days were obtained from the South African Weather Bureau from a weather station located approximately 15 kilometres from the study sites.

3.7.3 Data analysis

Data for each year were captured into the STATA version 9 software package. Two datasets, one for each year, were created. The data were double entered, cleaned and analysed for consistency. Each household, and eligible child living within that household, were assigned a unique identification in 2003. The two data sets were merged based on household identification numbers. Missing data were analysed to determine whether missing data was systematic or not (for example, poorer households may have been more likely to be lost to follow-up).

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 variable of interest were analysed. For continuous data such as indoor air pollution measurements, univariate analyses included graphical representations such as box and whisker plots, histograms and measures of central tendency. For the categorical data, frequency tabulations were calculated. Much of the data (except the indoor air quality data) were recoded into categorical (binary) variables based on the criteria set out in Table 3.1 above.

To determine the differences between groups for each year, two by two cross tabulations based on the Chi Squared (χ^2) measure of association were employed for the categorical data. The McNemar test was used to detect before-after differences within each group for the categorical data. For the (continuous) indoor air quality measurements, distributions of values 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.

Until this point in the analysis, two data points were available for each variable, one for 2003 and one for 2004. For example, a child could be living in a home where burning location = indoors in 2003 but shifted to burning location = outdoors in 2004. 'Turn around tables' (Bowling, 2002) based on shifts between baseline and follow-up were created for both groups. Four groups could be identified based on shifts or non shifts in burning location:

1. Remained outdoors in 2003 and 2004.
2. Shifted from indoors to outdoors between 2003 and 2004.
3. Remained indoors in 2003 and 2004.
4. Shifted from outdoors to indoors between 2003 and 2004.

Data for each child were further recoded into binary categories, a favourable and non-favourable outcome, in order to employ binary logistic models. A positive outcome included scenarios number two (remained outdoors) and three (indoors to outdoors) highlighted above. Scenarios number one (remained indoors) and four (outdoors to indoors) were assigned to the negative outcome group.

Table 3.2 Data analysis of burning location

Turn around tables for burning location

Remained outdoors	w
Shifted from indoors to outdoors	x
Remained indoors	y
Shifted from outdoors to indoors	z

2 x 2 tables for the association between intervention and burning location

		Burning location	
		Outdoors (w + x)	Indoors (y + z)
Intervention	Received intervention	a	b
	No intervention	c	d

Odd Ratios = *ad/bc*

The same principle was applied to each of the confounding factors. Factors were first analysed as independent variables in relation to outdoor burning. Following this, they were stratified and analysed as potential effect modifiers in relation to having received the intervention or not. If there were no significant shifts between baseline and follow-up, the baseline data were used. Once the data were classified into binary variables, two by two tables were employed at the bivariate level and binary logistic regression was used at the multivariate level (Hair et al. 1995).

3.8 Qualitative study

The qualitative evaluation employed two rounds of focus group discussions with a random selection of study participants in both the intervention and control groups using a random purposeful sampling strategy (Patton, 1991). Participants were stratified by suburb to minimise travel inconvenience and randomly allocated to a focus group discussion. The first focus group interviews were conducted four weeks after the 2004 data collection activities and were based on a set of pre-determined questions (see Appendix B). The second round of focus group interviews were conducted between 11 and 15 November 2004 (approximately six weeks after the first round of focus groups) and were based on both the quantitative results that were emerging as well as clarifications from the first round of focus group discussions. Four focus groups were held during the first interview round (two each in the intervention and control group) and the same number in the second round. In all, 8 focus group discussions were conducted. Because of the rapport established between research participants and between the participants and the research team in the first focus group, and the potential for comparability of responses in the focus groups, the same participants were invited to both rounds of interviews.

The focus groups typically included between 6 and 8 participants and were conducted in seTswana. Participants were usually female caregivers of young children although two focus group discussions included one male in each. Although males were not specifically invited to the focus group interviews, it was difficult to not allow them to participate. Their inclusion, however, proved useful in response to issues of gender and household decisions over where to burn (explored in more detail at later stage).

Selected participants were informed of the purpose of the interviews, assured of confidentiality, the inconvenience they may experience and the fact that the interviews were going to be tape recorded as approved by the Wits Ethics Review Committee. Participants were asked to participate and sign a consent form. A separate consent form was signed for the interviews to be tape recorded. Participants included a trained interviewer, the author, a research assistant (to translate to the author) and the research participants. The interviewer used a semi-structured interviewer schedule to guide the interview. Typically, research participants sat in a circle while the interview was conducted while the research assistant would quietly translate to the author. The author, with the assistance of the research assistant and the interviewer, would occasionally ask questions when necessary. In the intervention group, the interviews were conducted under a tree where community meetings are held (see Figure 3.7 below) and a school crèche. In the control group, interviews were conducted in a church and in one participant's home.

The focus group interviews were between one and two hours in length. Participants were offered light snacks and beverages during the interviews and a child minder was available to look after young children during the interviews. The first round of focus groups included standardized questions on caregivers' knowledge and perceptions of indoor air pollution exposure, the motivations and barriers against the promoted behaviours as well as reactivity to the research team, particularly the air pollution monitoring equipment. A set of questions relating to the processes of implementation of the intervention were asked in the intervention group and not the control group during the first round of focus groups. Questions included: How courteous were the communicators? How clear were the messages? Can you recall any of the messages?

If so, which ones? The second round of interviews focused on questions and clarifications arising from the first round of interviews and the data that were emerging from the quantitative study. As rapport had been established and the participants were familiar with the study and the research team, the tone of the interviews was more focused, open and honest. The second round also focused on identifying indigenous concepts and meanings that could provide linkages and explanations for the (sometimes unexpected) findings that emerged from the outcome evaluation.

Figure 3.6 Focus group interview in the intervention group

Interviews were tape recorded, translated from seTswana to English and transcribed into a word processing programme using a modified Jefferson method (Potter and Wetherall, 1987). Interview transcripts were assigned an identity code based on group (intervention or control), round of interview (one or two) and the number of the interview (one two, three or four). Research participants were assigned a random alphabetical letter to facilitate confidentiality. Overall, 345 pages (double spaced 12 font) of interview transcripts were available for analysis.

The data were analysed using a thematic analysis (Miles and Huberman, 1994). Thematic analysis was used because of its function to identify themes not previously espoused in the literature. The author was also previously trained in this technique and this approach was used during the two formative research phases of this study (explained in the following chapter). Transcripts were read to identify key descriptive 'themes' arising from the text. Themes usually included answers to questions formulated at the beginning of the study such as, "which diseases are caused by smoke from fires?" Answers to these questions were assigned a descriptive code. Abbreviations of the descriptive codes were written in the margins of the interview transcript. The full description of the codes and extracts for the transcripts were cut and pasted into a separate file. The relatively standardized questions asked of both groups during the first round of interviews meant that the descriptive codes could be compared across intervention and the control group. The next stage of the analysis focused on discovering patterns that provide explanations for the manner in which the descriptive codes fit together. Pattern codes also identified linkages between findings of the quantitative study and the findings of the qualitative interviews. The author collected extensive field notes both during the two quantitative data collection phases as well as during the focus group interviews. These notes were continuously referred to during the analysis.

3.9 Validation

While important in their own right, indoor air quality data were used as a triangulation method to validate caregiver reports of burning location. Except for one case (at follow-up), all households that burned outdoors had significantly (see section 5.4) lower indoor air pollution values compared to households that burned indoors. The particular household reported to burn outdoors but air pollution readings were high (PM_{10} > 1000µg/m^3, CO >200ppm) suggesting that she burned indoors. In other words, over 98% of households accurately reported their burning location. In addition, the qualitative study served as a form of methodological triangulation to confirm findings from the quantitative study and to explore in more detail factors that did not feature in the quantitative study.

3.10 Roles and responsibilities

Figure 3.7 summarizes the author's role in relation to the project. The author was responsible for overall project management including the design, implementation and evaluation of the intervention study; site selection and sampling strategy; training and management of fieldworkers and intervention communicators; the preparation and measurement of indoor air pollutants; quality control; the analysis of both the quantitative and qualitative data; and the communication of study results.

The author was fortunate enough to have a number of advisors who offered input throughout the project. Summarised in Figure 3.7, these can be classified as academic advisors from the University of the Witwatersrand, institutional advisors from the South African Medical Research Council (MRC) (the author was an employee and the study was financially supported by the MRC) and an external advisor from the University of Liverpool in England. The names and roles of each of the advisors are summarised in Figure 3.7 below.

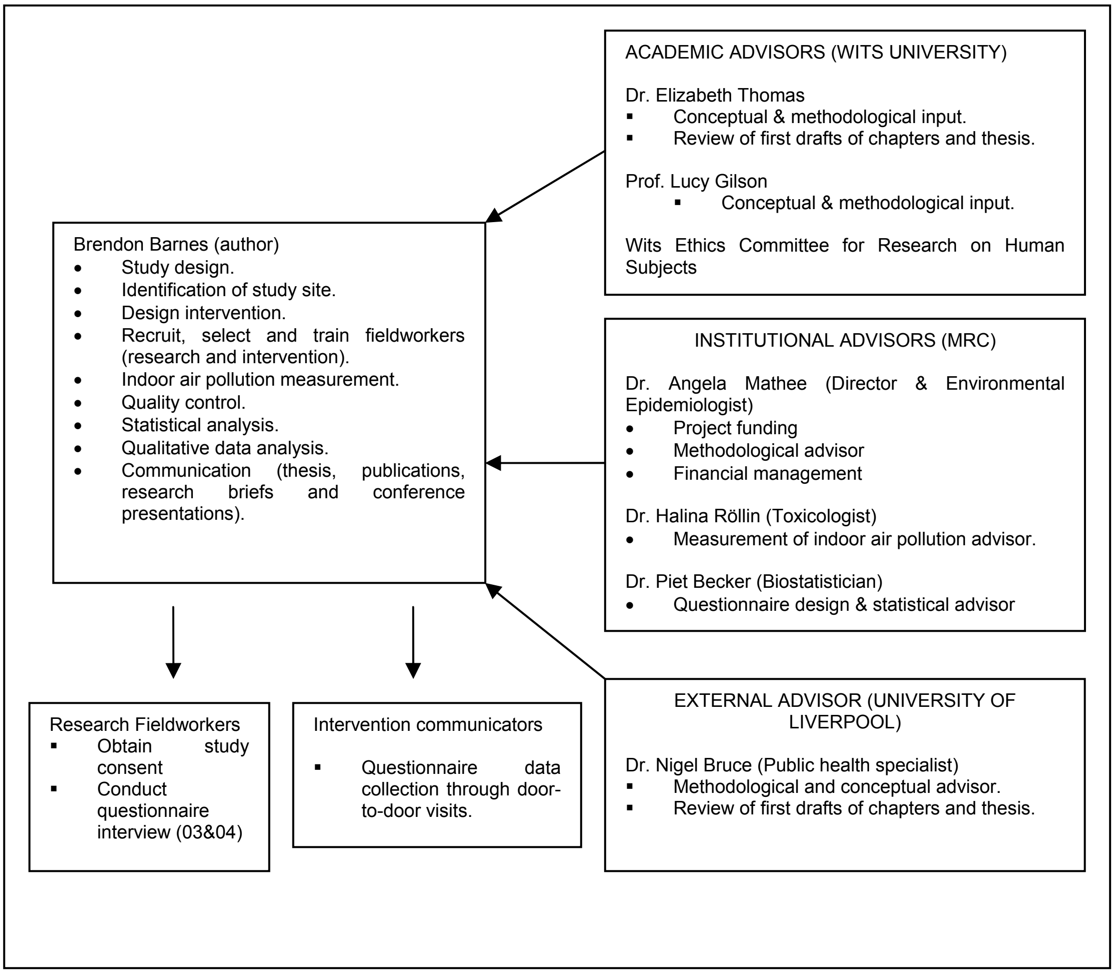

Figure 3.7 Roles and responsibilities

CHAPTER 4: THE INTERVENTION

4.1 Introduction

This chapter describes the design and implementation of the intervention that promoted the health benefits of behavioural change. The chapter begins by describing the baseline household burning location patterns. It describes the key baseline behaviours that the intervention attempted to modify and the formative research undertaken to inform the selection of the promoted behaviours. In addition, it describes the key messages that the intervention promoted, the communication strategy to implement the intervention and the communicators who implemented the intervention.

4.2 Baseline burning location behaviours

At baseline (2003), approximately 98% of households in the study villages were exclusively reliant on solid, biomass fuels in the form of wood and cow dung at the beginning of the study (Statistics South Africa, 2003). Child indoor air pollution exposure in this context occurred largely as a result of 1) the indoor burning of biomass fires combined with the fact that 2) children spend varying amounts of time in the vicinity of fires. Fires were usually ignited outdoors and burned on a flat, circular piece of corrugated iron (approximately 50 centimetres in diameter) placed on the ground and referred to as a *senke* (which literally translated means zinc). Burning on the *senke* enables fires to be moved to different locations/structures within the homestead without re-igniting them.

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* (burning room) during colder parts of the day.

The *inkwe* (which translated means 'small house') was a small one-roomed dwelling made from traditional materials (mud and cow dung wall and floor with thatched roof) that served as a multi-purpose dwelling used for storage and additional sleeping space. Fires were brought indoors into the *inkwe* during cold winter evenings and cold mornings. Historically, the *inkwe* served as the temporary residence (during the construction of the main house) when families originally moved to the villages. The *inkwe* is normally a square (but sometimes round) structure, approximately 4 metres in length, 4 metres in breadth and 3.2 metres in height. From a ventilation perspective, a typical *inkwe* has a door leading to the outside and one or two small windows.

The primary residence varied in size and was usually constructed with concrete blocks and a corrugated iron roof while some dwellings were constructed with corrugated iron walls. Except for the few households that used wood stoves (that are in a fixed location in the kitchen of the main house) and paraffin, very little indoor air pollution exposure was thought to occur in the main household. See Figures 4.2-4.4 for photographs of the structures described above. Figure 4.5 shows the floor layout of a typical homestead. Children less than five often followed their caregivers around (Mathee et al. 2000) and were often in the vicinity of indoor fires particularly during the early morning and early evening during winter when temperatures were low. Children were found to spend between 52% and 61% of the total time that indoor fires were burning in the *inkwe* (Barnes et al. 2005). Formative research also highlighted the fact that during winter many households opened one ventilation source (for example, a window) until smoke dissipated and then closed them again to retain the heat generated by indoor fires.

Figure 4.1 Smoke emitted from inkwe during indoor burning

Figure 4.2 Structures relevant to burning

Figure 4.3 Outdoor burning in the *segotlo*

Figure 4.4 Fire brought into the *inkwe* while children are present

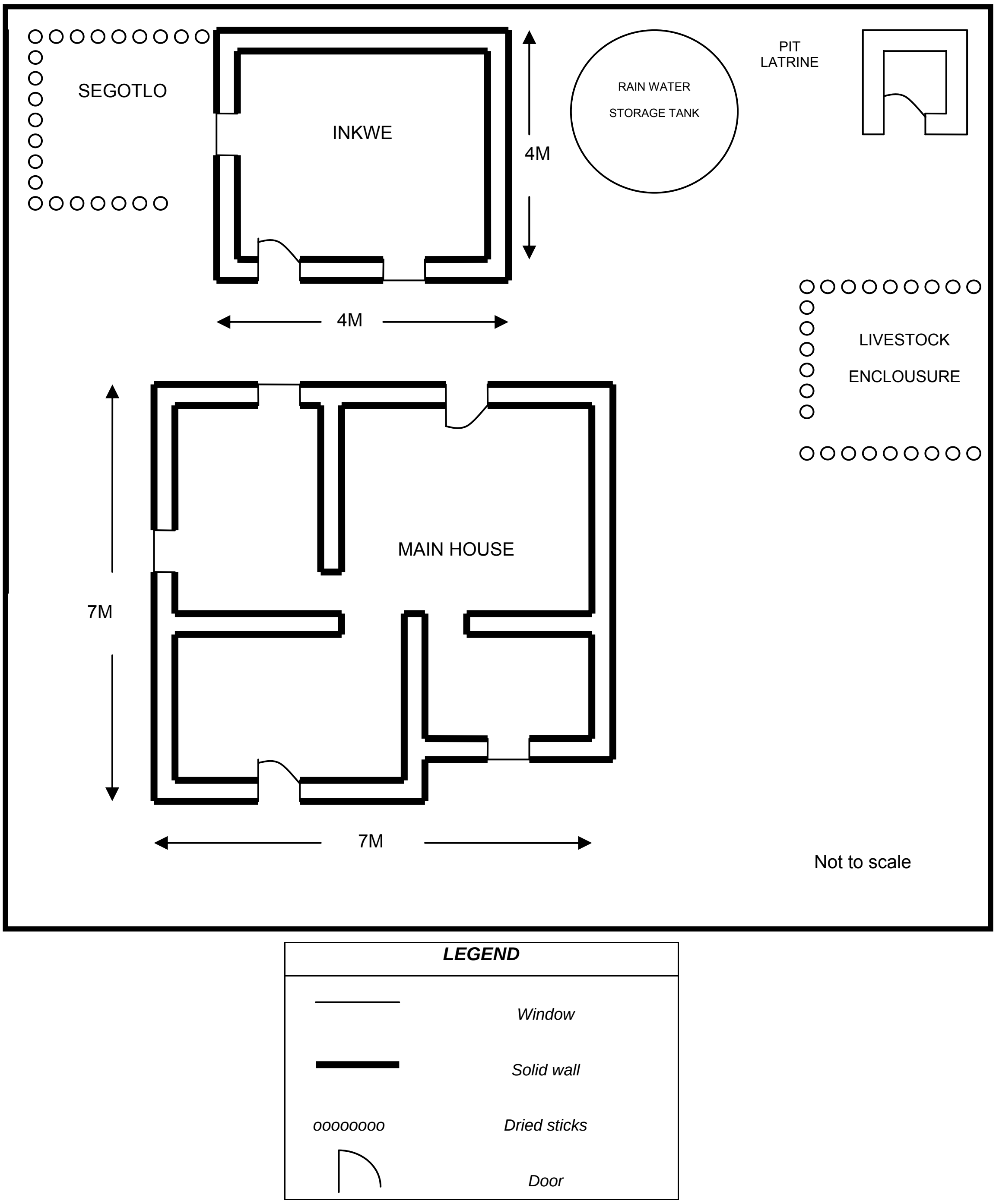

Figure 4.5 Floor layout of structures relevant to burning in one study homestead

4.3 Formative research

A number of possible protective air quality behaviours could be identified at the beginning of the project. These included burning outdoors, drying biomass fuels before burning, using smaller pieces of fuel, ventilating (opening windows and doors) while fires are indoors, varying the duration of indoor burning and the durations that children spend in the vicinity of indoor fires; all of which were practiced to varying degrees. In other words, assuming that reductions in indoor air pollution exposure could be achieved through behavioural change, most participants experienced deficits of existing practices (performance deficits) rather than skills deficits (new skills) (Graeff et al. 1993). To facilitate sustainable behavioural change, therefore, the intervention needed to enhance/modify existing behaviours and not necessarily teach the target audience *new* practices.

It was established relatively early in the process that the study would promote outdoor burning as the 'ideal behaviour' given evidence of its potential to significantly reduce indoor air pollution (Albalak et al. 1999b). In addition to its potential effectiveness, the fact that over one third of households reported to burn exclusively outdoors during winter meant that an opportunity existed for the promotion of this practice. However given the barriers to burning outdoors (for example, cold weather), the study needed to promote alternative behaviours if fires were brought indoors.

However, because no published studies were available to inform the selection of the promoted indoor behaviours, a key question needed to be answered by the formative research: which behaviours should the intervention promote? A key criterion, of course, was that the promoted behaviours needed to be both a) effective (logically or demonstrated in the published literature) in reducing exposure and b) not too difficult to perform particularly during the cold winter months. The behaviours also needed to be acceptable (willingness to perform) and feasible (ability to perform) to the target population (Dicken and Griffiths, 1997). Two phases of formative research were conducted during winter 2001 and winter 2002 respectively. Both phases have been published elsewhere (Barnes et al. 2004b; Barnes et al. 2004a) and the reader is referred to these for an extended discussion. A brief summary of the formative research is presented here.

In addition to outdoor burning, phase one attempted to narrow the selection of possible *indoor* behaviours from those that were originally considered. Based on observations of household behavioural patterns (n=40) and interviews with caregivers (n=67), it was recommended that four behavioural clusters should be considered for the main intervention. These were to: 1) improve stove maintenance practices (in the limited number [less than 2%] of homes where stoves are available), 2) increase the duration that two ventilation sources are opened while a fire is burning inside the inkwe, 3) reduce the time that children spend close to burning fires and 4) reduce the duration of solid fuel burning (Barnes et al. 2004b).

Phase two (conducted during winter 2002) investigated the feasibility (ability to perform) and acceptability (willingness to try) of the four recommended indoor air pollution reduction behaviours over a four week period. Improving stove maintenance and reducing the duration of solid fuel burning proved to be very difficult for most families. Based on these findings, it was recommended that the main intervention should focus on improving 1) child location and 2) ventilation practices (Barnes et al.

2004a) when fires are brought indoors in addition to the envisaged ideal behaviour of 3) burning outdoors in the *segotlo*.

4.4 Promoted behaviours

Based on the two phases of formative research, the ideal behaviour was defined as:

1. Burn exclusively in the *segotlo* outdoors.
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.

4.5 Intervention implementation

Following baseline data collection activities at the beginning of winter 2003 (described in the previous chapter), the intervention was implemented during the first two weeks of August 2003 (winter). The objectives of the intervention were:

- To improve caregivers' knowledge and perceptions of child indoor air pollution exposure and respiratory health (health education component).
- To negotiate modifications to existing behaviours based on the key messages outlined above (behavioural component).

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 (n=149) 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 communicators are described in more detail in section 4.6 to follow). 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.

Informed by elements of the Health Belief Model (Nutbeam and Harris, 2003), the intervention recognised that it was not enough to offer people information about the harmful effects of child indoor air pollution exposure, but that it was also necessary to improve perceptions of just how susceptible children were to these effects (for example, even spending a little time in the vicinity of smoke can result in harmful effects) and, importantly, how serious the health consequences are (children can become very ill and die from indoor air pollution exposure) (Aboud, 1998). In addition, the intervention aimed to build caregivers' confidence in their ability to perform the behaviours, in part, by removing as many of the perceived and real barriers (for example, household support for behavioural change) that were likely to inhibit behavioural change (Elder 2000; Graeff et al. 1993).

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 survey 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 burn outdoors. Although communicators proposed outdoor burning, 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. 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.

4.6 The communicators

The study employed six trained health communicators to implement the intervention. Communicators were female first language seTswana speaking Masters students aged between 28 and 38 years old and recruited from the University of the North West in Mafikeng. Communicators all had counselling and health communication experience. The university was selected as the source of the applicants as the study had had previous success with this approach during the formative research. The university also proved useful in fulfilling the capacity building obligations of the study (the

MRC has a strong emphasis on capacity building for studies it funds). The communicators participated in a week long training course covering topics related to indoor air pollution and health, the study design and key messages of the intervention. The training course was designed and implemented by the author. Funding for the training was sourced from the MRC. The communicators were also trained in the TIPs methodology, models of behavioural change and interviewing skills. Each communicator was required to visit a minimum of five study households a day over the two week period. The following chapter discusses the results of the quantitative study.

CHAPTER 5: QUANTITATIVE RESULTS

5.1 Participation

At baseline, the sample size included 149 and 175 households in the intervention and control groups respectively. The study, however, experienced a high level of attrition. At follow-up, 98 (65%) and 121 (69%) of the households assessed at baseline in the intervention and control groups respectively were located at follow-up.

Table 5.1 Baseline and follow-up sample size

	Group	
	Intervention	Control
Baseline (B)	149	175
Follow-up (F)	98	121
Difference (B-F)	51 (34%)	54 (31%)

The overall attrition rate was 32.5%. Patterns of missing data were analysed by the following factors: household monthly income (p=.87), household size (p=.36), number of people present during the day (p=.58), caregiver age (p=.25), caregiver education level (p=.66), child age (p=.42) and child sex (p=.98) to assess whether loss to follow-up affected the characteristics of the sample. There was no evidence of any systematic differences in loss to follow-up in the intervention compared to the control group in the variables studied. Amongst the sub sample selected for indoor air pollution monitoring (n=50 in the intervention group and n=50 in the control group) at baseline, the study could locate 36 households in the intervention and 38 in the control groups respectively. Missing observations were excluded and only those households from whom information was obtained for *both* assessment points were included in the analysis.

Anecdotal evidence (from interviews with neighbours and tenants) suggested that much of the attrition was due to migration for employment purposes. Households temporarily migrated to farms in neighbouring provinces where they are employed during the maize harvesting season, which is locally referred to as 'to Transvaal'(verb) [4]. Families return to the villages after the harvesting season, which typically takes between one and two months. In some cases, homesteads were left to stand empty during this period while in others; other families would rent the property. It was, however, not possible to quantify the extent of 'Transvaal' migration in relation to other reasons for migration as families were not available for interviewing. It was also not financially feasible to go back after one or two months to do the interview when they returned. A discussion of the implications of attrition in this study will be picked up in chapter 7 (discussion chapter).

5.2 Background characteristics

5.2.1 Baseline

The two groups were well balanced at baseline. Children less than five years old, caregiver, household and temperature characteristics were remarkably similar in both the intervention and control groups at baseline. In addition, these characteristics

[4] The term is derived from the fact that many families were temporarily employed on farms in or on the border of Gauteng and the North West province. Gauteng province was called the Transvaal province during the pre-1994 South African dispensation.

remained constant between baseline and follow-up with the exception of significant *increases in household monthly income* and *decreases in ambient temperatures* (explained below). Each of these variables shifted to similar degrees in both groups. Increases in household income offered the study an opportunity to explore the role of income in relation to outdoor burning while the much colder winter temperatures at follow-up provided an opportunity to test the ability of households to cook outdoors under really cold conditions.

At baseline, children less than five years old living in the study households had similar characteristics. The mean number of children less than five years old at baseline was 1.6 (ranging from 1 to 5) in the intervention group and 1.4 (ranging from 1 to 4) in the control group (significance of between group difference at baseline p=.33). The mean child age of the index children was 23 months (ranging from 1 to 50 months, standard deviation=15.3) and 25 months (ranging from 1 to 55 months, standard deviation=14.6) in the intervention and control groups respectively (between group difference at baseline p=.33). Approximately 14% of children remained in the category 0-18 months in both groups over the 12 month study period (in other words were 6 months or less at baseline). There were more females in the control group (52%) compared to the intervention group (48%) (the significance of between group difference at baseline p=.46).

Caregiver characteristics were also similar in both groups at baseline. The mean caregiver age was 46 years old (ranging from 18-78 years) in the intervention group and 44 years old (ranging from 15 to 76) in the control group (significance of between group difference at baseline p=.49). Interestingly 20% and 18% of caregivers were over the age of 60 years in the intervention and control groups respectively. Anecdotal evidence suggested that a high proportion of caregivers were grandparents or older relatives who looked after young children while their biological parents sought employment in the larger urban areas hence the relatively high mean caregiver age. Caregiver's educational attainment was low. Approximately 40% of caregivers in the intervention group had no formal education compared to 38% of caregivers in the control group (between group difference at baseline p=.79). Approximately 41% of caregivers in the intervention group and 42% of caregivers in the control group had (partially) completed primary school, while the remaining had (partially) completed secondary school.

In terms of household income, approximately 83% of households in the intervention group and 81% in the control group earned less than R1000 per month (equivalent to 140 United States Dollars (USD) a month calculated at the exchange rate of 1USD=R7.10 in January 2007). Monthly income was sourced mainly from old age pensions, child support grants, money sent from employed relatives and occasional temporary jobs on neighbouring farms. At baseline, conservative estimates (assuming a monthly income of R1000 per month by a mean household size of 7 people) indicate that over 80% of families were living on R5.37 (USD76 cents) or less than 1 USD per person per day.

Approximately 45% of dwellings were classified as 'informal' in the intervention group and 43% in the control group (between group difference at baseline p=.78). Dwellings were classified as informal if they had one or more walls made of corrugated iron. Main dwellings varied in size in both communities. In the intervention group the mean number of rooms per dwelling (excluding kitchen but including lounge) was 3.6 (ranging from 1 to 9) in the intervention group and 3.5 (ranging from 1 to 9) in the control group (between group difference at baseline p=.68). Approximately 35% of dwellings in the intervention group and 33% in the control group had dwellings with two rooms or less (excluding the kitchen) (between group difference at baseline p=.69).

The intervention and control groups were similar in terms of dwelling occupancy. The mean number of adults (15-64) who permanently resided in the dwelling was 5.4 (ranging from 1 to 21) in the intervention group and 4.8 (ranging from 1 to 21) in the control group (between group difference at baseline p=.4). Approximately 33% of households had 3 or more adults who permanently resided in the household in the intervention group compared to 35% in the control group. Overall, there were very similar population and household characteristics between the two sites.

Mean ambient minimum temperatures during the baseline assessment period were similar in both communities. The mean minimum temperature in the intervention group was 10.6 degrees Celsius (ranging from 2.7 to 13.6) and 11 degrees Celsius (ranging from 1.3 to 15.5) in the control group. Winter temperatures were relatively mild during 2003 when the baseline assessments took place (South African Weather Bureau, 2005).

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. Wood and cow dung were usually burned on a *senke* outdoors in the *segotlo* (outside cooking area). A very small proportion (less than 2%) of households in both groups reportedly used kerosene to compliment solid fuels. Kerosene was burned indoors in the main dwelling (not in the burning room) 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.

5.2.2 Follow-up

With the exception of two variables, most of the background characteristics remained the same in both groups at follow-up. Household monthly income and minimum ambient temperature, however, shifted significantly between baseline and follow-up. Household monthly income increased significantly in both groups over the 12 month period. In the intervention group, at baseline 83.5% of households earned less than R1000 per month while at follow-up the proportion of households in this category had decreased to 65.5% (significance of before-after difference $p<.01$). Similarly, in the control group at baseline 80.8% of households earned less than R1000 per month while at follow-up the proportion of households in this category had decreased to 65.3% (significance of before-after difference $p<.01$).

Increases in household incomes may be attributable to the increased number of households who became eligible for social grants (such as old age and child support grants) during this time. Eligibility for social grants is based on the possession of a valid South African identity document. Possession of identity documents in the study area was poor given the fact that the area belonged to Bophuthatswana (an independent state) prior to 1994. During the baseline assessments, there were a number of Department of Social Service initiatives (for example mobile identity document application offices) that were active in the study villages. This would have enabled access to social grants by new identity document holders.

At baseline, average minimum temperature during the study period was 10.52 degrees Celsius in the intervention group and 11 degrees Celsius in the control group. However the winter of 2004 was significantly colder with a mean minimum of 4.09 degrees Celsius in the intervention group and a mean of just 1.09 degrees Celsius in the control group. The follow-up temperatures were more consistent with the five year provincial average measured in July (0.9 degrees Celsius). Table 5.2 summarizes the background characteristics of the study sample at baseline and follow up that changed. They highlight in particular the two variables (household income and temperature) that displayed significant before-after shifts.

Table 5.2 Changes in household monthly income and ambient temperature between baseline and follow-up

Reference category		**Intervention (n=98)**	**Control (n=121)**
Monthly income (% less than R1000/month)	Baseline	81(82.7%)	101 (83.5%)
	Follow-up	61 (62.2%)	81 (66.9%)
	Before-after difference	20 (20.5%); χ^2=.10.2; p=.001	20 (16.6%); χ^2=8.9; p=.003
Minimum ambient temperature on day of measurement (degrees Celsius)	Baseline mean (s.d.)	10.52 (2.58)	11.00 (3.37)
	Follow-up mean (s.d.)	4.09 (3.2)	1.24 (2.40)
	Before-after mean difference*	6.44 (p=.000)	9.76 (p=.000)

*based on a Wilcoxon matched pairs test

In short, both groups displayed similar (deprived) background characteristics. Most of the characteristics remained constant between baseline and follow-up assessments.

However, there were significant increases in household monthly income as well as much colder conditions at follow-up compared to baseline.

5.3 The association between outdoor burning and selected variables

5.3.1 Intervention group

The main aim of the quantitative study was to determine a) whether or not there were improvements in burning location behaviours and, importantly, b) whether those improvements were attributable to caregivers having received the intervention. The study was based on the premise that burning outdoors will result in lower child exposure to air pollution compared to indoor burning. Outdoor burning, therefore, was treated as the dependant variable and exposure to the intervention as the independent variable.

At baseline, approximately three quarters of households brought a fire indoors for space heating during the early mornings or evenings. The remaining households burned outdoors exclusively. Burning location behaviours were similar in the two groups at baseline: 75.5% (n=74) of households brought a fire indoors in the intervention group and 74.4% (n=90) of households brought a fire indoors in the control group (between group difference χ^2=.03; p=.85).

At follow-up, however, both groups showed similar improvements in burning location behaviours. Amongst the intervention group, the proportion of indoor burning households was reduced from 75.5% (n=74) at baseline to 54.1% at follow-up (n=53) (within group before-after difference χ^2=9.9; p<.01). Amongst the control group the proportion of indoor burning households was reduced from 74.4% (n=90) at baseline to 57.9% (n=70) at follow-up (within group before-after difference χ^2=7.4; p<.01). Although the intervention group showed marginally greater improvements in terms of outdoor burning, there were no significant differences between the two groups in the proportions of indoor burners at follow-up (between group difference at follow-up χ^2=.31, p=.57). Figure 5.1 highlights the improvements in outdoor burning amongst the two groups between baseline and follow-up.

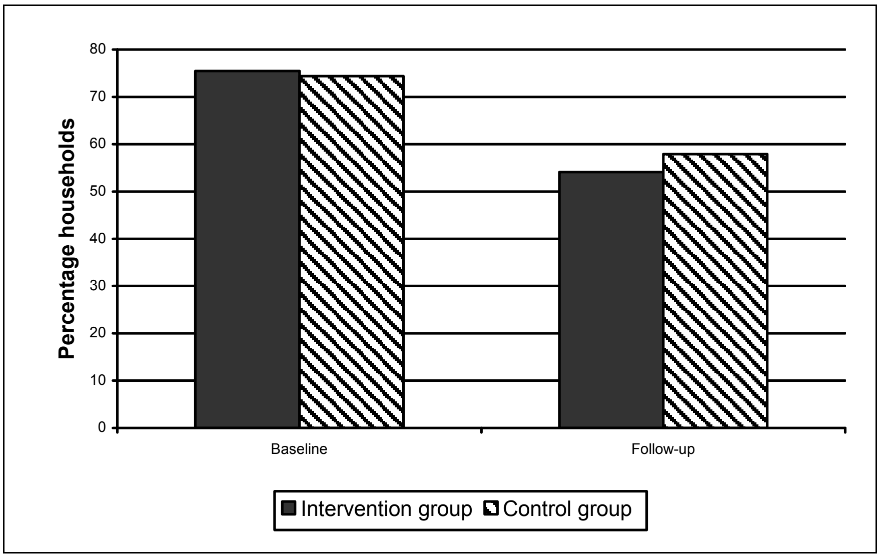

Figure 5.1 Proportion of indoor burning households at baseline and follow-up

The following two-by-two table (Table 5.3) summarizes the unadjusted association between exposure to the intervention (independent variable) and the likelihood of burning outdoors at follow-up (dependant variable). Households whose primary caregiver was exposed to the intervention were 1.16 times (or 16%) (95% CI 0.7-2) more likely to burn outdoors at follow-up compared to households in the control group.

Table 5.3 Association between the intervention and burning location

		Outdoor burning	Indoor burning	Unadjusted Odds Ratio	95% C.I.	p value
Received the intervention	Yes	45 (45.9%)	53 (54.1%)	1.16	0.7 - 2	.58
	No	51 (42.1%)	70 (57.9%)			

Classifying burning location into binary outcomes based on the likelihood of outdoor burning at follow-up, while practical, masked the potential (positive or negative) shifts in burning location behaviours that occurred *within* each group between baseline and follow-up. Household burning location patterns were also classified into four categories based on possible shifts in burning location practices:

1. Burned indoors at both baseline and follow-up assessments.
2. Shifted from outdoor burning at baseline to indoor burning at follow-up (negative shifts).
3. Shifted from indoor burning at baseline to outdoor burning at follow-up (positive shifts).
4. Burned outdoors at both baseline and follow-up assessments.

The intervention and control groups had similar proportions of households that continued to burn indoors at both assessments regardless of the intervention or participation in the study - 42.9% (n=42) of households in the intervention group burned indoors at both assessment points compared to 45.9% (n=45) of households in the control group. However, more households in the control group displayed negative shifts, that is, shifted from outdoors at baseline to indoors at follow-up (14.1%, n=17) compared to the intervention group (8.2%, n=8). Put slightly differently, households in the intervention group were less likely to bring a fire indoors at the much colder follow-up *if* they burned outdoors at baseline. This raises the possibility that intervention had a marginally protective effect in influencing people who would have normally considered indoor burning under very cold conditions to remain outdoors.

In terms of positive behaviours, 29.6% (n=29) of households in the intervention group moved from indoors to outdoors despite the colder weather. The proportion was similar in the control group where 31.4% (n=38) of households shifted their burning location from indoors to outdoors. More households in the intervention group remained burning outdoors (16.33%, n=16) compared to 10.74% (n=13) in the control group. Shifts in burning location are summarized in Figure 5.2. Although both groups showed significant improvements in terms of shifting outdoors, the intervention group were marginally less likely to shift indoors under colder conditions and more likely to continue with outdoor burning.

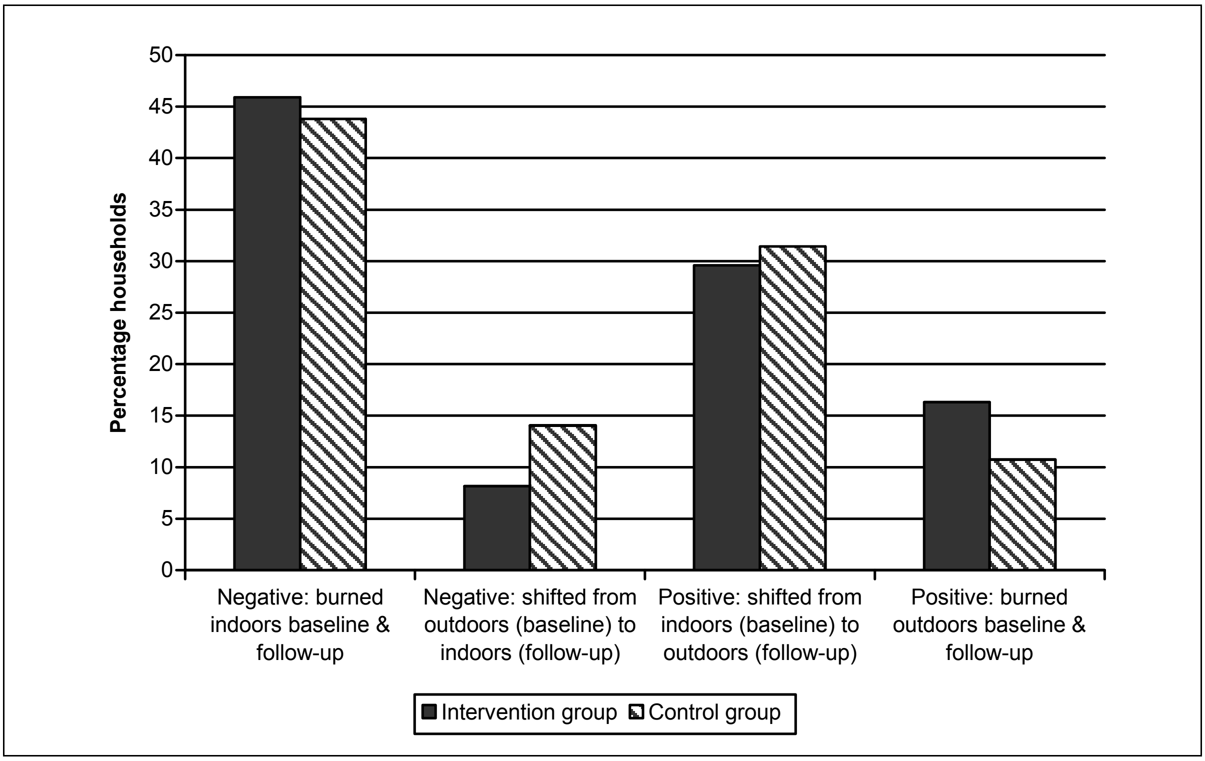

Figure 5.2 Shifts in burning location by group

In addition to having received the intervention (independent variable), the study was also interested in a number of potential confounding variables that could influence caregivers' decision to burn outdoors or to keep burning indoors. The following section describes the unadjusted associations between burning location and the confounding factors considered in the study.

5.3.2 Household income

In terms of household characteristics, the study investigated whether higher household monthly income at follow-up (equal to or greater than R1000 per month) was associated with outdoor burning. There was an elevated but non significant association between higher income and outdoor burning. Households that earned greater than R1000 per month at follow-up (in other words, remained in the high household income category at baseline and follow-up or shifted from low to high income) were approximately 1.5 times more likely to burn outdoors compared to households that earned less than this amount (p=.18).

The association remained non significant when higher household income category was stratified (that is R1000-R1500 versus less than R1000 per month; and above R1500 versus less than R1000 per month).

Table 5.4 Association between household income and burning location

		Outdoor burning	Indoor burning	Unadjusted Odds Ratio	95% C.I.	p value
Household income	≥R1000/month	38 (50%)	38 (50%)	1.46	.7 – 2.6	.18
	≤R999/month	58 (40.6%)	85 (59.4%)			

However, the association between income equal to or above R1000 per month and outdoor burning was stronger amongst the intervention group compared to the control group. Table 5.5 summarizes the association between household income and burning location stratified by group. Amongst the intervention group, 57% of households in the higher income category burned outdoors compared to 44% in the control group. When stratified by group, higher income households were twice as likely to burn outdoors in the intervention group (95%CI 0.9-4.6) compared to 1.1 times more likely amongst the control group (95%CI 0.5-2.4). The strength of the association between income and burning location occurred largely within households that received the intervention suggesting perhaps an interactive effect between the intervention and higher monthly income in influencing outdoor burning. Put simply, the intervention appeared to have a stronger effect in influencing outdoor burning amongst higher income earners compared to low income earners. Possible reasons for this are explored in chapter seven (discussion).

Table 5.5 Association between income and burning location stratified by group

Intervention group

		Outdoor burning	Indoor burning	Unadjusted Odds Ratio	95% C.I.	p value
Household income	≥R1000/month	21 (56.8%)	16 (43.2%)	2	.9 – 4.6	.09
	≤R999/month	24 (39.34%)	37 (60.6%)			

Control group

		Outdoor burning	Indoor burning	Unadjusted Odds Ratio	95% C.I.	p value
Household income	≥R1000/month	17 (43.6%)	22 (56.4%)	1.1	.5 – 2.4	.8
	≤R999/month	34 (41.5%)	48 (58.5%)			

5.3.3 Child characteristics

In terms of characteristics of the index child, there were no significant associations between child age and sex. Households that included a child younger than 18 months of age (throughout the study) were more likely to burn outdoors at follow-up compared to children 19 months or older although this difference was not significant. The likelihood of outdoor burning was remarkably similar in relation to the sex of the child with 44% of households in which the index child was male and 43% in which the index child was female burning outdoors at follow-up.

Table 5.6 Association between child age and burning location

		Outdoor burning	Indoor burning	Unadjusted Odds Ratio	95% C.I.	p value
Child age	≥ 18 months	21 (49%)	22 (51%)	.78	.40-1.5	.46
	≤ 19 months	75 (43%)	101 (57%)			

Table 5.7 Association between child sex and burning location

		Outdoor burning	Indoor burning	Unadjusted Odds Ratio	95% C.I.	p value
Child sex	male	48 (44%)	60 (56%)	1.05	.6-.18	.86
	female	48 (43%)	63 (57%)			

5.3.4 Caregiver characteristics

In terms of caregiver characteristics, the study explored the association between caregiver age and burning location. Specifically, the analysis attempted to understand whether older caregivers, through more life experience of indoor air pollution and/or possibly less domestic responsibilities, were more likely to burn outdoors compared to younger caregivers. An age cut-off of younger than 40 years old was used in the analysis as suggested by Balakrishnan et al. (2004).

Contrary to expectations, younger caregivers were more likely to burn outdoors compared to older caregivers although this association was non significant. Approximately 47% of caregivers who were 40 years or *younger* burned outdoors at follow-up compared to 41% of caregivers who were 41 years or *older* (OR=0.8, 95%CI 0.5-1.3). The stronger (but not significant) association between *younger* caregiver age and the likelihood of outdoor burning could be explained by a number of factors including younger caregivers being more aware of the health dangers of indoor air pollution exposure, less likely to be resistant to change in their domestic patterns (less set in their ways) or being more likely to feel the need to make a good impression (explored in more detail below). The non significant association was evident in both the intervention and control group.

Table 5.8 Association between caregiver age and burning location

		Outdoor burning	Indoor burning	Unadjusted Odds Ratio	95% C.I.	p value
Caregiver age	≥40 years old	44 (40.7%)	64 (59.3%)	0.8	.5 – 1.3	.36
	≤41 years old	52 (46.9%)	59 (53.1%)			

The study also explored the association between caregiver education status and burning location. More specifically, the study was interested in understanding whether caregivers who had received any formal education were more likely to burn outdoors compared to caregivers who were not. The assumption was based on the premise that caregivers who were formally educated could have been more aware of indoor air pollution and health concerns. There were, however, no significant associations between caregiver education and burning location. Similar proportions of caregiver with formal education (45%) and without formal education (42%) burned outdoors at follow-up (OR=1.1, 95%CI 0.64-1.9) (see Table 5.9). The association remained non significant when formal education was stratified into primary, secondary and tertiary education.

Table 5.9 Association between caregiver education and burning location

		Outdoor burning	Indoor burning	Unadjusted Odds Ratio	95% C.I.	p value
Caregiver education	Formal education	60 (44.8%)	74 (55.22%)	1.1	.6 – 1.9	.73
	No formal education	36 (42.4%)	49 (57.6%)			

5.3.5 Dwelling type

Study households were divided into two categories: informal dwellings (with one or more walls made of corrugated iron sheeting) versus traditional or formal dwellings. It was hypothesized that informal dwellings made of corrugated iron would have a lower thermal efficiency and consequently be much colder than formal/traditional dwellings (made of bricks and or mud and adobe). People living in informal dwellings would probably find it more difficult to burn outdoors during winter despite having received the intervention. Results showed no significant association between dwelling type and the likelihood of outdoor burning. The proportion of households that burned outdoors was similar across both dwelling types. Over 44% of households in the formal and 42% in the informal dwelling type burned outdoors (OR=1.1, 95%CI 0.6-1.9). Results were similar when stratified by intervention versus control group.

Table 5.10 Association between dwelling type and burning location

		Outdoor burning	Indoor burning	Unadjusted Odds Ratio	95% C.I.	p value
Dwelling type	Formal	55 (44.7%)	68 (55.3%)	1.1	.6 – 1.9	.76
	Informal	41 (42.7%)	55 (57.29%)			

5.3.6 Ambient temperature

Winter temperatures at follow-up were significantly colder compared to baseline, which provided a unique opportunity to explore the role of lower winter temperatures on burning location (indoors versus outdoors). More households (60%) burned indoors when minimum temperatures were 6 degrees Celsius or less compared to households (52%) that were assessed on days when temperatures were 7 degrees Celsius or higher. Although there was an effect of lower temperature on indoor burning (OR=1.3) differences were non significant (p=.33) (see Table 5.11).

Table 5.11 Association between ambient temperature and burning location

		Outdoor burning	Indoor burning	Unadjusted Odds Ratio	95% C.I.	p value
Temperature	**≥ 7 degrees Celsius**	43 (47.8%)	47 (52.2%)	1.3	.8 – 2.3	.33
	≤6 degrees Celsius	53 (41.1%)	76 (58.9%)			

In sum at the bivariate level, there were no significant associations between the variables considered in the quantitative study (including having received the intervention or not) and the likelihood of outdoor burning at follow-up. The following section explores whether the associations remained non significant at the multivariate level.

5.3.7 Multivariate analysis

At the multivariate level, the association between the various factors highlighted above and the likelihood of burning outdoors at follow-up were analysed using a binary logistic regression analysis. The effect of adjusting for confounding factors made little difference to the effect estimates (Table 5.12). In fact the odds of outdoor burning after receiving the intervention were slightly diminished after adjusting for confounding (adjusted OR=1, [95%CI 0.6-1.8] compared to the unadjusted OR=1.16, [95%CI 0.7-2]). Household income above R1000 per month remained associated with outdoor burning at the multivariate level. After adjusting for confounding, households that earned R1000 or above were 1.6 times more likely to burn outdoors compared to households that earned less than this amount.

The association between outdoor burning and higher household income remained stronger in the intervention group compared to the control group at the multivariate level. An analysis of the *interaction* between these two independent variables revealed that higher income households that received the intervention were 2.3 times more likely burn outdoors compared to their lower income counterparts with this association approaching significance (p=.06) at the p≤.05 level. Put simply, the intervention seemed to have a stronger effect amongst higher income households compared to lower income households.

There were no significant associations between dwelling type and outdoor burning at the multivariate level (OR 1.1; 95%CI 0.62-1.9). Older caregiver age maintained a negative association with outdoor burning (OR=.73, 95%CI .42-1.3) while caregiver education (OR=1; 95%CI.59-1.8) also remained non significant at the multivariate level. Higher outdoor temperatures although positively associated with outdoor burning (OR=1.4, 95% CI 0.77-2.5) remained non significant at the multivariate level. Table 5.12 summarizes the likelihood of outdoor burning after having received the intervention and after adjusting for confounding factors (shaded).

Table 5.12 Likelihood of outdoor burning after adjusting for confounding factors

Variable	Adjusted Odds Ratio	95% Confidence Interval	Standard Error	P value
Caregiver received intervention	1	.6 – 1.8	.3	.94
Household income ≥ R1000 per month	1.6	.9 - 3	.5	.11
Formal/traditional dwelling	1.1	.62 – 1.9	.3	.8
Caregiver age ≥ 40 years	.73	.42 – 1.3	.2	.26
Caregiver received formal education	1	.59 -1.8	.3	.88
Higher ambient temperature	1.4	.77 – 2.5	.4	.28

Pseudo R^2 = .0154.[5]

In summary, the quantitative analysis revealed that there were notable shifts in the number of households that burned outside at follow-up compared to baseline. Improvements in relation to outdoor burning, however, could not be attributed to the intervention alone nor to the confounding variables espoused in the literature. Moreover, the overall model had a poor predictive value (pseudo R^2 = .015) in determining the contribution of variables considered in the model. The following section discusses the implications of these findings in relation to the three indoor air pollution indicators [PM_{10}, CO and CO (child)] that were of interest to the study.

5.4 Indoor air quality

This section describes findings in relation to the distributions of indoor air quality indicators by intervention group as well as by indoor versus outdoor burning. Distributions of all three indoor air quality parameters violated assumptions of

[5] The pseudo R^2 statistics refers to the proportion of variance explained by the predictor variable, in this case, having received the intervention.

normality at both assessments (based on the Kolmogorov-Smirnov test). The significance of *between group* differences were therefore analyzed using the non parametric Mann Whitney rank sum test while the significance of *within group* before-after differences were analyzed using the Wilcoxon signed rank test.

The intervention and control group showed similar patterns in terms of indoor air quality at baseline, baseline-follow-up differences in indoor air pollution and patterns of indoor air pollution at follow-up. Although the intervention group displayed marginally higher levels of indoor air pollution at baseline, there were no significant differences between the intervention and control groups in terms of PM_{10} (p=.31), CO (p=.96) and CO (child) (p=.61). For example, 69% of households in the intervention group and 66% of households in the control group had PM_{10} levels higher than 150 $\mu g/m^3$ (24 hour) (USEPA, 1996).

Both groups, however, reduced indoor air pollution levels 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). While the control group had larger median differences (by approximately 10%) than the intervention group in all three indoor air pollution indicators, it is important to remember that the data were highly skewed and measures of central tendency need to be interpreted with this in mind.

There were also no significant differences between the two groups at follow-up. Non parametric Mann Whitney rank sum tests showed no significant differences between the two groups at follow-up in terms of PM_{10} (p=.65), CO (p=.96) or CO (child) (p=.31). Tables 5.13 – 5.15 summarize between group differences at baseline and follow-up as well as within group baseline-follow-up differences. They highlight, in particular, the baseline-follow-up shifts in indoor air pollution indicators amongst the intervention and control groups.

Table 5.13 PM_{10} by group at baseline and follow-up

Intervention group								
	n	**Min**	**Max**	**Mean**	**Median**	**Standard deviation**	**Inter-quartile range**	**% ≥ 150 μg/m³**
Baseline	36	0	2842	599.1	389.5	678.3	680	69%
Follow-up	36	0	1495	349.4	320.5	358.6	466	42%
Control group								
	n	**Min**	**Max**	**Mean**	**Median**	**Standard deviation**	**Inter-quartile range**	**% ≥ 150 μg/m³**
Baseline	38	44	1920	448.1	341	514.1	472	66%
Follow-up	38	0	1374	294	243	362.3	421	40%

* Values represent time -weighted averages expressed as μg/m³ over 24 hours.

Difference between intervention and control group at baseline: Mann Whitney rank sum test, p =.31.

Difference between intervention and control group at follow-up: Mann Whitney rank sum test, p =.65.

Before-after difference amongst the intervention group: Wilcoxon signed-rank test, p <.01.

Before-after difference amongst the control group: Wilcoxon signed-rank test, p =.01.

Table 5.14 CO by group at baseline and follow-up

Intervention group							
	n	**Min**	**Max**	**Mean**	**Median**	**Standard deviation**	**Inter-quartile range**
Baseline	36	4.5	600	209.7	125	202.6	247
Follow-up	36	0	600	163.8	111.5	173.7	248
Control group							
	n	**Min**	**Max**	**Mean**	**Median**	**Standard deviation**	**Inter-quartile range**
Baseline	38	10	600	209.8	150	191	257
Follow-up	38	0	600	179.8	117.5	202.4	275

*Values represent time weighted averages expressed as ppm over 24 hours.

Difference between intervention and control group at baseline: Mann Whitney rank sum test p =.96.

Difference between intervention and control group at follow-up: Mann Whitney rank sum test p =.98.

Before-after difference amongst the intervention group: Wilcoxon signed-rank test p =.15.

Before-after difference amongst the control group: Wilcoxon signed-rank test p =.46.

Table 5.15 CO (child) by group at baseline and follow-up

Intervention group							
	n	**Min**	**Max**	**Mean**	**Median**	**Standard deviation**	**Inter-quartile range**
Baseline	36	0	25	4.3	1.9	6.3	1.6
Follow-up	36	0	8.8	1.85	1	2.5	2.6
Control group							
	n	**Min**	**Max**	**Mean**	**Median**	**Standard deviation**	**Inter-quartile range**
Baseline	38	0	25	3.5	2.1	4.7	3.1
Follow-up	38	0	25	3.46	.9	2.7	2.2

* Values expressed as ppm hours

Difference between intervention and control group at baseline: Mann Whitney rank sum test p =.61.

Difference between intervention and control group at follow-up: Mann Whitney rank sum test p =.31.

Before-after difference amongst the intervention group: Wilcoxon signed-rank test p =.02.

Before-after difference amongst the control group: Wilcoxon signed-rank test p =.09.

Given that the intervention promoted outdoor burning as the ideal behaviour, the study was also interested in the impact of burning location (indoors versus outdoors) on indoor air pollution. Tables 5.16 – 5.18 summarize the indoor air quality differences by burning location in the sub sample of households (n=74) selected for indoor air quality monitoring. There were significant differences between households that burned indoors compared to households that burned outdoors amongst all three air quality indicators. The differences were significant at both baseline and follow-up assessments. Compared to indoor burning, for example, outdoor burning was associated with 84% lower median PM_{10} values at baseline and 98% lower values at follow-up. Compared to the USEPA PM_{10} guideline of 150 $\mu g/m^3$ over 24 hours, at baseline 74% of households that burned indoors exceeded this level compared to no households in outdoor burning households. At follow-up, 53% of indoor burning households exceeded the USEPA guideline while none exceeded the guideline amongst households that burned outdoors. Similar differences were evident in relation to CO values. Compared to indoor burning, outdoor burning was associated with a 70% reduction in median CO values at baseline and a 91% reduction at follow-up.

While actual indoor air pollution in the living environment is important, it is not always a useful predictor of *personal exposure*, which takes into account both indoor air pollution levels as well as the amount of time people spend breathing in the polluted air (Albalak et al. 1999b). In this study, because CO diffusion tubes were attached to individual children, CO (child) was used as an indicator of personal exposure. Similar to PM_{10} and CO, there were significant differences in CO (child) associated with outdoor burning compared to indoor burning. At baseline, outdoor burning was associated with 70% lower median child CO personal exposure values compared to indoor burning at baseline and 62% at follow-up.

It is also interesting to note the large variation in indoor air quality exposure typical of such settings. There were clear between group differences in child CO values in relation to indoor and outdoor burning households. However, individual values covered a relatively wide range within each group. Amongst indoor burning households, for example, values ranged from non detectable to the maximum detectable levels by the diffusion tubes (25 ppm hours). Similarly, amongst the outdoor burning group, child CO exposure values ranged from non detectable to 2.1 ppm hours. Low CO values amongst the indoor burning group and higher values amongst the outdoor burning group reflect the possible influence of child time activity patterns in relation to fires. It is likely that children with low exposure values living in indoor burning homes spent relatively little time in the burning room. Conversely, children with higher exposure values that lived in households that burned outdoors may have spent longer periods of time close to fires outdoors (possibly to keep warm). Even though there were no observations of this nature, it was also possible that the CO tube may not have been kept with the child throughout the sampling period. Table 5.16 - 5.18 summarize the indoor air quality data by burning location (indoors versus outdoors) at baseline and follow-up.

Table 5.16 PM $_{10}$ by burning location ($\mu g/m^3$ over 24 hours)

Baseline							
Burning location	**n**	**Min**	**Max**	**Mean**	**Median**	**Standard deviation**	**% ≥ 150 $\mu g/m^3$**
Indoors	55	44	2842	555.9	347	607.7	74%
Outdoors	19	0	93	33	54	50	0%
Follow-up							
Burning location	**n**	**Min**	**Max**	**Mean**	**Median**	**Standard deviation**	**% ≥ 150 $\mu g/m^3$**
Indoors	39	50	1495	416.3	363.5	361.7	53%
Outdoors	35	0	28	10	5	5.2	0%

Significance of between group difference baseline p = ≤.01.

Significance of between group difference follow-up p = ≤.01.

Table 5.17 CO by burning location (ppm over 24 hours)

Baseline						
Burning location	**n**	**Min**	**Max**	**Mean**	**Median**	**Standard deviation**
Indoors	55	10	600	221.8	150	196.8
Outdoors	19	0	85	43	45	30.5
Follow-up						
Burning location	**n**	**Min**	**Max**	**Mean**	**Median**	**Standard deviation**
Indoors	39	20	600	181.1	115	190.6
Outdoors	35	0	75	47	10	74

Mann Whitney: significance of between group difference p = ≤.01.

Mann Whitney: significance of between group difference p = ≤.01.

Table 5.18 CO (child) by burning location (ppm hrs)

Baseline						
Burning location	**n**	**Min**	**Max**	**Mean**	**Median**	**Standard deviation**
Indoors	55	0	25	4.2	2.1	5.6
Outdoors	19	0	1	.5	.6	.5
Follow-up						
Burning location	**n**	**Min**	**Max**	**Mean**	**Median**	**Standard deviation**
Indoors	35	0	25	2.8	2.2	5.4
Outdoors	39	0	2.1	.9	.8	.8

Mann Whitney: significance of between group difference p = ≤.01.

Mann Whitney: significance of between group difference p = ≤.01.

It is likely that there were significant differences in indoor air pollution between households that shifted from indoor to outdoor burning compared to households that burned indoors. Indeed, all three indoor air quality indicators were significantly reduced amongst the 14 monitored households that shifted from indoor to outdoor burning. Of particular importance to this study, however, were the differences in child CO values amongst this group.

Table 5.19 summarizes child CO values at baseline and follow-up amongst the sub-sample of children (n=14) that lived in households that shifted from indoor to outdoor burning. The mean CO (child) score was reduced from 4.3 ppm hours at baseline to 1.1 at follow-up (74%). The median CO (child) score was reduced from 4.6 ppm hours to .9 at follow-up (80.4%).

Table 5.19 Child CO amongst 14 households that shifted from indoors to outdoors

	min	max	mean	median	Std. dev.
Baseline	.8	25	4.3	4.6	5.4
Follow-up	0	2.4	1.1	.9	.7

Before-after difference amongst positive shift households: Wilcoxon signed-rank test: p=.01.

In short, a shift from indoor to outdoor burning was associated with a median reduction in PM_{10} of between 84-98%, in CO of between 70-91% and, importantly, in child CO exposure of between 62-80.4%. The intervention and control groups performed equally well when fires were moved from indoors to outdoors. However, despite improvements in outdoor burning, approximately 56% of households brought a fire indoors at follow-up. This raises the question: were there any significant differences in indoor air pollution between the intervention and control groups amongst household that remained burning indoors?

Results suggest that amongst households that burned indoors at baseline and follow-up (hereafter referred to as indoor burning households), the intervention group performed better than the control group. Amongst the intervention group, the median PM_{10} score was reduced by 84% ($p<.01$), CO score by 69% and CO (child) score by 34% ($p=.31$). Amongst the control group, the median PM_{10} score was reduced by 51% ($p=.08$), CO median score *increased* by 3% ($p=.9$) and the CO (child) median score was reduced by 1% ($p=.9$)

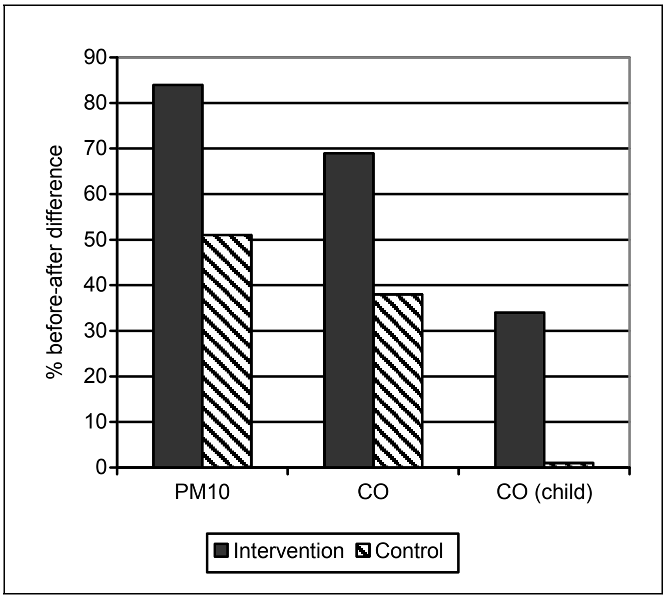

Figure 5.3 Percentage differences of indoor air pollution indicators amongst indoor burning households

Table 5.20 PM_{10} shifts amongst indoor burning households

Intervention group					
	min	max	mean	median	Std. dev.
Baseline	52	2842	669.52	416	688.35
Follow-up	41	936	222.15	64.5	277.57
Control group					
	min	max	mean	median	Std. dev.
Baseline	44	1920	457.92	218	517.99
Follow-up	31	1374	320.36	155.5	274.07

Table 5.21 CO shifts amongst indoor burning households

Intervention group					
	min	max	mean	median	Std. dev.
Baseline	20	600	231.88	162.5	104.38
Follow-up	2	600	144.15	50	186.38
Control group					
	min	max	mean	median	Std. dev.
Baseline	10	600	213.66	150	192.49
Follow-up	3	600	129.07	93	209.42

Table 5.22 CO (child) shifts amongst indoor burning households

Intervention group					
	min	max	mean	median	Std. dev.
Baseline	25	600	118.91	50	153.98
Follow-up	4	300	65.54	33	83.46
Control group					
	min	max	mean	median	Std. dev.
Baseline	10	600	91.08	50	111.72
Follow-up	0	600	104.4	49	152.34

5.5 Summary of the quantitative study

The quantitative study revealed a number of important points in relation to the effect of the intervention on burning location and indoor air pollution.

1. There were improvements in the number of households that burned outdoors at follow-up compared to baseline.
2. Outdoor burning was associated with significantly lower levels of indoor air pollution (PM_{10} by 94-96% and CO by 85-97%) and child CO exposure (83-95%) compared to indoor burning.
3. It was not possible, however, to attribute shifts in burning location to the intervention alone given the equally significant shifts in the control group that did not receive the intervention. Effects of the intervention, however, were noted 1) in relation to the proportion of households who shifted from outdoors to indoors and 2) lower levels indoor air pollution (particularly CO and child CO) amongst indoor burning households that did not shift to outdoor burning. Higher household income was a moderate but non significant predictor of outdoor burning. None of the other confounding variables considered were significantly associated with the likelihood of outdoor burning. The following chapter (six) discusses the findings of the qualitative study that attempted to answer a number of questions that arose from the quantitative study.

CHAPTER 6: QUALITATIVE RESULTS

6.1 Introduction

This study set out to test the hypothesis that changing the way that caregivers think about the health effects of their children's indoor air pollution exposure will result in a higher proportion of households that burned outdoors, which, in turn will reduce child indoor air pollution exposure. Given the nature of the quasi-experimental design employed in this study, ideally the intervention group would have shown improvements in outdoor burning and child indoor air pollution exposure, while the control group would have maintained the trajectory of high levels of indoor burning. This finding would have allowed for the conclusion that the behavioural intervention on its own showed a positive effect. Alternatively, both groups could have shown no behavioural change leading to the conclusion that the intervention had little or no effect. Chapter four, however, highlighted the fact that improvements in outdoor burning practices were evident in both the intervention and control groups, which were associated with significantly lower levels of indoor air pollution exposure.

The fact that the control group also improved their behaviours suggested that exposure to the intervention, and by implication a change in the way that caregivers think about the *health* effects of indoor air pollution, was not the only reason for a shift to outdoor burning. The quantitative evaluation, therefore, offered a picture of *what* happened in terms of outdoor burning and indoor air pollution exposure. The qualitative evaluation, on the other hand, set out to answer questions related to *why* caregivers may have changed their behaviours or not. In particular, the qualitative evaluation explored three questions: How useful was the health information in facilitating outdoor burning amongst the intervention group? What other factors influenced caregivers' decisions to burn outdoors or indoors, particularly in the control group? Why did so many caregivers not improve their behaviours? Thus, through focus group interviews described in chapter 3 as well as being informed by the author's informal notes and observations, the qualitative evaluation attempted to understand the motivations and barriers to behavioural change that could explain the observations described in the quantitative results chapter.

6.2 Motivations for behavioural change

The transcripts from the qualitative interviews were analysed for emerging themes that could explain the motivations for outdoor burning. The following key themes will be used together with extracts from the actual focus group interviews to illustrate the factors that influenced people to burn outdoors at follow-up.

6.2.1 Improved perceptions of health

Caregivers in the intervention group received the intervention through two door to door visits (two weeks apart). The first visit focused on imparting health information to the caregivers (and whoever was present at the time) about the health effects of indoor air pollution exposure followed by a discussion of current behaviours and ways of modifying them. The aim of the second visit was to see how caregivers were doing and encourage them to continue. Behavioural change was not forced on participants but negotiated and agreed upon. How useful was the intervention amongst the intervention group? The following extracts highlight a discussion of the health effects of indoor air pollution amongst the intervention group (extract one) and control group (extract two). The extracts are taken from the first round of focus group discussions that took place 8 weeks post intervention and 6 weeks after the post-intervention quantitative data collection activities. Transcription conventions are defined as:

P3	Participant number three
=	Speech interrupted by another speaker
(3)	Pause duration. For example, (3) indicates a 3 second pause.
CAPS	Emphasis by the speaker
Emboldened	Emphasis highlighted by the author

Extract 1 (intervention group)

Interviewer: When we were here last year, a woman visited each of you to inform you of the dangers of indoor fires. Do you remember?

All: Yes.

Interviewer: Were the messages clear?

P1: Yes the message was clear because we understood that the children must be kept away from the smoke because it causes them lung diseases.

P2: Yes, we understood that smoke is not good for children and also for adults =

P3: = but the danger of the smoke was emphasized more in children, it was emphasized that pneumonia (sehuba sa kgookgoo) is dangerous for children.

Interviewer: When we were here we asked you to perform some behaviours, can you recall them?

P1: We were asked to burn outdoors in the segotlo. She also asked me to open the windows and doors when we bring fires indoors.

P2: We were also told that the children must not come close to fires.

Interviewer: So were you able to burn outdoors this winter?

P5 & 4: Yes.

R6: I burned indoors last winter but after the woman visited, I decided to burn outdoors for the rest of last winter and this winter. Since I got this lung disease, even the smoke from candles makes me cough. I cough until I'm nearly dead! Don't get me wrong, I love fires, I was brought up with fires but I'm dead scared of them. I definitely keep my children away. You taught us a lot.

Brendon: (In Afrikaans) I'm, uh, sorry to interrupt but I'm trying to understand something here. Surely you knew this before the lady came to visit you last year? Did you not know that breathing in smoke is unhealthy and causes diseases before this study? You yourself said you've been sick from the smoke from fires before.

P6: Yes, of course. I knew about smoke =

P1: = I even learnt about it in school.

P6: ***Yes, me too. I knew that it causes lung sickness, makes children cough. But what I didn't know was how bad it was. I didn't know that children can die from it. The woman told me that children can get sick very quickly and die from it. I knew they could get sick but I didn't know they could die from what you call =***

P3: ***= pneumonia***

All: Yes.

Extract 2 (control group)

Interviewer: You mentioned smoke caused by indoor fires, what do you think is the effect of that smoke on children?

P3: I know that it is very dangerous it is not good for the baby

Interviewer: What do you think it can do?

P1: It can cause sickness

Interviewer: What kind of sickness?

P4: I don't know.

P3: You have to open windows to let the smoke out.

Interviewer: Okay, what is the reason for letting the smoke out?

P2: Like she said, it is not good for the child.

*Interviewer**:** I'm trying to find out what diseases are caused by smoke.*

P2: ***The smoke makes her cough.***

Interviewer: How do you know it is the smoke =

P1: = I just think it is. Children are always coughing when they are near smoke.

Interviewer: Okay, so you're saying that smoke makes children cough and that it is not good for children.

P5: Yes. It also hurts the eyes, makes them water.

P7: ***It makes you dizzy*** *especially when you bend over to blow on the fire like this "pheeuw pheeuw" ((showing actions)). You can sometimes fall down after you blow on the fire!*

All: ((Laughter))

P1: ***It causes chest problems.***

The above extracts illustrate the differences in perceptions of the health concerns related to indoor air pollution in the intervention and control communities. In terms of recalling the messages, caregivers in the *intervention group* could, for the most part, remember the key messages of the intervention; that is, burn outdoors in the segotlo, and if you bring a fire indoors; open windows and doors and keep children away from fires. In addition, participants could remember that intervention emphasized the dangers of smoke amongst children and more specifically, could identify pneumonia as the main disease outcome associated with child indoor air pollution exposure. Importantly, respondents cited exposure to the intervention and consequent improvements in their understandings of the health consequences as the primary reason for shifting their burning from indoors to outdoors. According to Respondent 6 in extract one, “I burned indoors last winter but after the woman (communicator) visited, I decided to burn outdoors for the rest of last winter and this winter.” She goes on to suggest that the intervention taught her a lot about the health consequences of indoor air pollution and that she is much more vigilant about keeping her children away from fires.

In-depth knowledge of a disease outcome (pneumonia) and what causes it (indoor air pollution) is not always sufficient to facilitate positive behavioural change. However, assuming that selected parts of the health information sharing was more useful in influencing whether caregivers choose to burn outdoors than others, which aspect(s) of the intervention, if any, enhanced caregivers’ decisions to burn outdoors? In extract one, I (usually quietly listening in on the conversations with help of an interpreter) interrupted the conversation which, like previous interviews, was leaning somewhat predictably towards how beneficial the intervention was. Amongst the intervention group, participants in earlier focus groups tended to emphasize the benefits of the intervention, for example, how much they had learned from us and even how ‘life changing’ participating in the study was. While I respected these opinions, I was also fully aware that there were barriers to outdoor burning (not least of which was the cold) and that for many caregivers, the intervention was asking them to engage in a very difficult behaviour. I also suspected that many participants were telling us what they thought we wanted to hear and that, in fact, the intervention could have taught them very little.

In extract one, after participant 6 expressed her gratitude about how much we had ‘taught’ her, I asked her whether or not she knew that smoke was unhealthy before the interview as she herself had mentioned that she had previously become ill presumably because of inhaling smoke. This line of questioning was also influenced by the concern that if participants knew about the harmful health effects of smoke pollution before the intervention but were continuing to burn indoors anyway, then other factors may be at play. She and participant 1 confirm that they did indeed know about the harmful effects of smoke before the intervention and that they had even learnt about it as part of their formal schooling education. According to them, they were previously aware that indoor air pollution was bad for them in a general sense and may cause "lung sickness" and "cough". What they were not fully aware of, however, was how serious the health effects of child indoor air pollution was, in other words children can die through pneumonia within a relatively short space of time (that is, within a few days). It is the improved perception of the seriousness of indoor air pollution exposure that participants reported to benefit from the intervention and which influenced them to engage in protective behaviours.

In comparison, many participants in the control group (extract 2) knew that smoke was harmful to young children but mostly associated symptoms such as cough, dizziness and teary eyes in the *vicinity* of fires with indoor air pollution exposure. These were usually short term upper respiratory symptoms that disappear after intense exposure smoke from fires. The control group rarely mentioned disease clusters that can occur beyond the immediacy of fires. When disease outcomes were probed, participants were mostly vague about the health effects and offered answers such as "it is very dangerous and not good for the baby". At the end of extract two, one participant mentions that indoor air pollution causes "chest problems".

Analyses of the qualitative data suggests that compared to the (similar) control group that did not receive the intervention, exposure to the intervention did increase caregivers' understanding of the specific disease outcome that is, pneumonia, associated with child indoor air pollution exposure. Much more valuable in influencing whether caregivers' burned outdoors, however, was the emphasis of the *seriousness* of pneumonia. In other words, children can die from pneumonia due to indoor air pollution exposure. More importantly, establishing the conceptual link between pneumonia and indoor air pollution may have influenced caregivers' decisions to burn outdoors. Whether caregivers actually managed to engage in protective behaviours, however, depended on whether or not certain enabling factors were in place at the household level such as support from the rest of the family and having alternatives to keeping warm (discussed in more detail below). The following section (6.2.2.) describes how participating in the study was reported by some participants to be a motivation for outdoor burning.

6.2.2 Reaction to participating in the study

Given the fact that the control group also demonstrated behavioural improvements, it was not possible to ignore the fact that participation in the study influenced caregivers' decisions to burn outdoors. There was no qualitative evidence to suggest that the control group had been exposed to the intervention messages through, for example, social contact (however this was still possible even though there no observations to this effect). The two villages were situated far from each other with no direct public transport routes between them. The qualitative evaluation, therefore, investigated whether participation in the study could have influenced decisions to burn outdoors.

Data collected from the control group suggested that there was indeed a reactive effect through participation the study. In particular, the analysis revealed two types of reaction: a short term reaction based on positive self presentation (sometimes referred to as a guinea pig effect), and a longer term, more meaningful, reaction to the study (Bowling, 2002). In terms of a short term reaction to the study, a small number of respondents who burned indoors at baseline reported that they burned outdoors at follow-up because they heard that study team had returned to the village and were asking questions about where people burned. The need to create a good impression was driven, in part, by various misunderstandings of the study. In the following extract, the interviewer notes that one of the respondents said she always has burned outdoors but has evidence from her baseline questionnaire that she, in fact, burned indoors at baseline. In questioning why this is the case, and encouraging the participants to be honest about why they burned in various locations, the respondent finally admits that she only burned outdoors while the researchers were in the study villages and then burned indoors when they were not. Extract three is taken from a focus group interview with the control group

Extract 3

Interviewer: So where did you burn this winter?

P1: Outdoors in the segotlo.

Interviewer: Do you always burn there?

P1: Yes I always burn there.

Interviewer: Honestly? Because last year you said that you burned indoors. I have it here on paper (questionnaire).

P1: No, no I burned outdoors.

Interviewer: We are not here to judge anyone. We just need to know why people burn indoors or outdoors. It is really important so that we can design future ways to help people cope with smoke.

P2: Okay, I burned indoors last year but outdoors this year. I saw your car and remembered that you were coming back this year.

Interviewer: Help me understand why some people would burn outdoors when we were here but indoors when we were not. What did those people think the study was about? (4) Okay, let me rephrase that, where do you think we are from?

P3: Wilhelminah told us that you were from ESKOM coming to check where we burn before we get electricity.

Interviewer: Mmm, still, why did you burn outdoors?

P3: Maybe some people thought that if they burned indoors, then you will tell ESKOM that they don't deserve electricity.

In exploring *why* participants need to impress the study team, another respondent indicated, after an uncomfortable four second pause, that she had heard from someone else in the village that the researchers were from the national electricity supplier (ESKOM) and were there to check whether the villages *deserved* electricity – which, of course, was not the case. Later in the chapter it is revealed that there was a strong perception that indoor burning was shameful, neglectful and a sign of lower social standing. Selected respondents could have interpreted the study team as there to judge them and burned outdoors to create a good impression in the hope that they will receive electricity sooner. The question of why ESKOM or the study team for that matter would bother whether they burned indoors or outdoors speaks to a broader issue of how caregivers perceived who was deserving of state driven service delivery – a point I will return to in the discussion chapter.

In addition to the need to create a good impression, interviews also highlighted the fact that a short term reaction could have occurred through a misunderstanding of the workings of the indoor air pollution monitoring equipment. In particular, respondents reacted to the Gillair pumps used to monitor PM_{10} levels. The Gillair pumps are small machines that were mounted approximately 1.5 metres from fires. They emit a low level noise as they pump air through the pre separator and filter. Extracts four and five are taken from two interviews conducted with the control group.

Extract 4

P1: I did not want the machine to block. I did not bring the fire indoors.

Interviewer: Where did you burn?

P1: I was burning in the segotlo

P2: I also burned in the segotlo because there was a day (last year) when the machine stopped by itself in my house and what came into my mind was the smoke in the house made the machine to stop. I was so heart broken because I just made conclusions that it is the smoke in my house that made the machine to stop... so this year I burned outdoors. I don't want to break your machines.

Interviewer: So does that mean when we left, you burned indoors again?

P1: Yes

Interviewer: When other members of the community were asking you about the machine what was your response?

P1: I told them it was the machine to capture the smoke.

P2: Nobody has ever asked me but I was going to say it reduces the smoke in the kitchen but if it gets too full it stops.

Extract 5

P3: We told the children to be careful because the machine was recording everything they said. They were told so because we wanted to keep them away from the machine. They were afraid of it.

Interviewer: Were you afraid of it?

P1: We were afraid that the children even ourselves will get burned by this machine because we understood why it was installed but sometimes we were doubtful.

P2: We did not want them to touch the machine because one day one girl forgot to switch the iron off and the whole house burned down so I was thinking the same thing will happen if they touch the machine. So I locked the door of the inkwe (where the machine was placed) and burned outdoors for that day.

In the above extracts, one participant highlighted the fact that the pump stopped on its own during baseline assessment when she burned indoors and she interpreted this to mean that the smoke from the indoor fire had caused it to 'break'. In fact, the pumps were programmed to stop sampling after 24 hours and this was the more likely explanation for the pump stopping. Responses later in the extract suggest that participants (mis)understood that the machine sucks the smoke into them and do not let the smoke out and this is the reason that the pumps stop when they get to full. To prevent machines from blocking during follow-up, some caregivers reported that they burned outdoors where the smoke would not reach the machines but burned indoors as soon as the pumps were removed. These misunderstandings of the pumps could have arisen from the (necessary) participant information process (see Appendix 1) which, given the ethical obligations of the study, had to explain the working of the pumps in a simplistic manner (explored in more detail in the discussion chapter). In addition, in one focus group, participants indicated that they believed that the machines may cause fires, which will burn children and cause property damage. They also indicated for fear of children touching the pumps, they attempted to keep children away from them and, by implication, fires by for example telling the children that machines were recording everything they said. This could have resulted in lower indoor air pollution exposure for children whose time was limited in the vicinity of fires.

The second type of reaction (a learning effect) occurred as a result of participants in the control group becoming more interested in indoor air pollution and child health and taking steps to reduce child indoor air pollution exposure. As mentioned previously, most participants knew that indoor air pollution was associated with poor health before the study commenced. Observations of health effects, however, were limited to short term symptoms such as coughing and dizziness in the vicinity of fires with very little understandings of more serious health consequences. Many participants were not fully aware of the seriousness of exposure, that is, that children can die from it. Participants in both groups were made aware of that the study focused on biomass fuels, indoor air pollution and (poor) health through the participant information process at the beginning of the study. It is reasonable to expect, therefore, that participants in the control group would have concluded that the problem of indoor air pollution must be serious enough to warrant a study. If it was serious to warrant a study, therefore, then steps should be taken to reduce exposure to it. Extract 6 is taken from a control group interview in which participants took an interest in the health effects of indoor air pollution.

Extract 6

Interviewer: I'm trying to understand why some people in your community burned indoors last year but outdoors in the segotlo this year.

P2: I burn outside but in winter I used to bring the embers inside until one day my child started coughing and vomiting. After you visited last year and asked us about where we burn and our children's health. I thought before it was because of the smog. Now I now only burned outdoors and my child seems better.

Interviewer: So what you are telling me is that since we visited last year you started thinking about smoke from fires and your child's health and decided to burn outdoors.

P2: Yes…

Interviewer: But why outdoors?

P2: The smoke is not so strong. I would like to find out more from you about the study and these diseases.

The extract highlights how one participant in the control group concluded, through her own experiences of her child's illnesses together with the questions that were asked of her in the study, that indoor air pollution may be dangerous to her child's health. After the initial question about why people who were not exposed to the intervention burned outdoors at follow-up but not at baseline, the participant indicated that she had brought a fire indoors until her child became sick (coughing and vomiting). She mentions that her understanding of the link between air pollution exposure and her child's sickness was confirmed by the study team visit when they asked her about where she burns and her children's health. She concluded that the air pollution ('smog') from the fire was causing her child's sickness. A few participants in the control group took an interest in the study and were keen to understand more about it.

6.2.3 Reduced drudgery

Some caregivers in both groups reported that a key motivation for outdoor burning was a reduction in the dirt and odour generated fires when fires were burned indoors.

In the following extract, for example, participants highlighted the fact that smoke causes clothes to smell, leaves black soot on the walls and ceilings and that condensation caused by (the often many) people that sleep in the *inkwe* during winter leads to soot droplets that stain clothes and linen and which are very difficult to get out. In addition, ash and burned embers end up on the floor creating a mess. The inconvenience in terms of time and effort needed to clean their homes, therefore, was viewed by some caregivers as a motivation for burning outdoors. Extract 7 is taken from a focus group in the control group.

Extract 7

P6: It is also better to burn in the segotlo because when you burn indoors the house fills with smoke. It is very easy to make an outdoor fire because there is no smoke in the house.

Interviewer: I see. Why don't you want smoke in the house?

P3: It stinks awful! Most of the time we try to avoid the smoke. We don't want our clothes to smell of smoke from the fire especially from cow dung. You know you can tell the difference?! Wood smoke is bad especially Morutlwana (type of wood) but cow dung is worse! ***I feel sorry for all those children who go to school with their clothes smelling of smoke. The other children tease them. Their mothers don't care.***

P4: I also don't want the walls and ceiling in my house to be black =

P2: = uhm sometimes when we used to sleep in the inkwe at night, water forms on the ceiling. You know what I mean (2) like from people breathing and black drops would fall on us and stain our clothes and blankets. ***It is hard to get those stains out.***

Interviewer: I see.

P4: ***The ash from the fire also dirties the floor of the house. It blows all over when you open the door. You have to sweep and sweep.***

After the interview:

P1: I am sorry for not being at home when you arrived, I thought you were coming on Monday. I have to apologise for the house being so dirty when you came to visit me. I was in Mafikeng and the girls brought a fire inside. They don't do this when I'm there. The girl was at school so there was no one to clean the house, I am sorry it wasn't cleaned when you got here. One of the children told me there was ash all over the floor and the dishes were not washed.

<u>Interviewer</u>*: It is not a problem, I am grateful that there was someone there when I arrived and they were able to answer my questions while you were not here.*

It is relatively easy to understand that some caregivers would want to burn outdoors to reduce the drudgery associated with having to clean after fires were burned indoors. However, there were also elements of prestige related to outdoor burning evident in the above extract.

6.2.4 Prestige

Outdoor burning was viewed as a symbol of prestige in the villages. Outdoor burning and a clean and organised domestic environment was viewed as symbolic of higher social standing. In contrast, indoor burning and the negative effects thereof were often couched in terms of shame, neglect and lower social standing. In extract 7 above, for example, P3 speaks about the smell associated with cow dung. She distinguishes between the smell of different fuels and highlights, in particular, the fact that the smell of cow dung is particularly pungent. Dried cow dung was often couched in the qualitative interviews as the least desirable fuel and mostly used by people of lower social standing. It was often suggested that it was also the easiest fuel to collect because cows roam freely and defecate along the village roads and within homesteads and dry thus making it popular amongst ‘lazy’ people who do not wish to collect wood, which involves a longer walk. She comments on the fact that it is possible to ‘smell’ children whose families use cow dung indoors and that these children generally stand out and are teased by other children. Caregivers of such children are positioned as neglectful – “their parents don’t care.” In contrast, caregivers who use wood and who burn outdoors were positioned as putting in more effort to keep their homes and children clean in their homes and generally of higher social standing.

Similarly, P1 approaches the interviewer after the focus group (but while the tape recorder was on and the other participants had left) and apologises for the poor state of her house when the interviewer visited. She mentions that she does not allow a fire to be brought indoors but when she is not home her teenage daughters disobey her and bring a fire indoors. She also mentions that one of the younger children told her that there was ash from the fire on the floor and that the dishes were not washed. P1’s apology is framed within a context of the indignity of having a dirty house particularly in the context of the discussion that focused on the shame of bringing a fire indoors and having an unkempt living environment.

Similarly, the shame of indoor burning was evident in earlier extracts when participants felt shame for smoke from indoor fires ‘blocking’ the indoor air quality monitoring machines and pity for children whose clothes smelled of cow dung smoke. At the end of extract 3 earlier, one participant, who herself burned indoors, believed that outsiders might think that those who burn indoors are lazy and do not ‘deserve’ to be beneficiaries of development projects such as electrification. Outdoor burning, therefore, was often represented in interviews as progressive, symbol of personal development and ‘the right thing to do’. In contrast, indoor burning was represented as backward and neglectful given the negative health and domestic implications. A shift from indoor to outdoor burning, therefore, was viewed as a symbolic *process* of personal development from ‘backward’ to ‘progressive’.

Interestingly, a shift to outdoor burning was also contextualised against the backdrop of broader development processes that were underway or due to commence in the near future. Both rural villages were without electricity, running water and flush sanitation at the start of the study in 2003, but these projects were due to be implemented in 2005. At the time the South African government was also promoting access to state grants such as child support and old aged grants in the study areas. There were high expectations among participants of what these projects were going to achieve. In extract 8, the interviewer initiates a discussion about what participants think is the solution to indoor air pollution in their context. The discussion turns towards participants expectations of the role of the impending electrification process in alleviating indoor air pollution.

Extract 8

Interviewer: What do you think is the answer to this [indoor air pollution] problem?

P2: We all dream of electric stoves ((laughs))

All: ((laughter))

Interviewer: Let’s not talk about electricity for now because if you had it, it would be a choice.

P3: But we will get it. We are going to get it soon. They are putting up the poles.

Interviewer: I know, but you don’t have it now. What I’m trying to get at is what can we do about it until we can get electricity? Besides, electricity is expensive to cook with =

P1: = the only thing that can help us is electricity, because if there is electricity then we won't need to make fires and there will be no more smoke affecting our children. ***We've suffered for a long time****.*

Interviewer: But if you had electricity, how would you be able to afford it especially to cook with? You know what I'm saying. Some people won't be able to afford it. That is why we are talking about other things that people can do like opening windows. But it's okay if you want to talk about it.

P2: For me it's like this. We all agree that people should not be in a house that is full of smoke, especially children. ***But things are getting better for us. We are getting electricity in a few months, water pipes, even i.d's (identity documents) now. We can't still be cooking indoors. That's in the past, in Mangope's time ((laughs))****.*

P3: ((laughs)) we have to improve ourselves, we are not backwards. *Even if we can't afford electricity now, one day we will. Then we can cook even heat ourselves when it is cold. You can even bake with electricity. Eh, I can bake and sell cakes. Even if it is out of our hands now, we can still do small things to* ***develop ourselves****.*

Interviewer: what do you mean small things?

P3: Like cook outside. It is not right to cook inside. Like all the things we've been talking about. You have to take pride in yourself. No one will lift us out this situation. We have to do it on our own. ***Because one day we will have electricity, but until that time, I will cook outdoors. I want a better life. I don't want my children sick and smelling of smoke. I want them to see that there is a better life.***

After the initial question about what can be done to solve the indoor air pollution problem, the interviewer attempts to steer the discussion away from electrification as the solution to indoor air pollution. This is in keeping with the key justification of the project, that is, that electrification is unlikely to be sustainable in contexts like the study communities because of the high costs. Thus, even with access to electricity, households will not necessarily be able to afford to use it for domestic activities such as cooking and heating that are likely to have the most significant impact on indoor air quality. The interviewer tried her best to convince the participants (particularly P1 and P2 who were convinced that electricity was the answer) that electricity is not a meaningful discussion from an indoor air pollution perspective.

At critical point in the discussion, P3 suggests that it is not possible to separate impending electrification and people's desire for a better life from the reasons that people shifted to outdoor burning. She suggests that, like her, it is precisely *because* of development projects that many caregivers chose to burn outdoors. The anticipation of development projects stimulated people to engage in behaviours that were deemed as symbolic of lifting themselves out of poverty. P3 jokingly mentions indoor burning is associated with past ways of thinking such as in Mangope's time (referring to the previous leader of the independent Bophuthatswana state). She notes that *"we have to improve ourselves, we are not backwards"* and goes on to mention that even if they cannot afford electricity when they get it, they can 'do small things to develop themselves' like cook outdoors.

An important first step in lifting oneself out of poverty, she suggests, is to take responsibility for one's actions. In contrast to "lazy" people who do things (like cook indoors and let their children smell of smoke) that suggests that they do not take responsibility for lifting themselves out of poverty, people who are interested in developing themselves out of poverty do 'small things' like burn outdoors, are motivated to keep their homes clean and keep their family's healthy and presentable. This is reflected in P3's comments in extract 8: *"You have to take pride in yourself.*

No one will lift us out this situation. We have to do it on our own. Because one day we will have electricity, but until that time, I will cook outdoors. I want a better life. I don't want my children sick and smelling of smoke. I want them to see that there is a better life."

The onus on the individual to engage in behaviours that suggest their willingness to lift themselves out of poverty is reinforced by the government's commitment, through improving access to basic services, to doing the same. The assumption, however, is that the government can only do so much, for example, provide electricity, the rest is up to the individual to improve their lives. This is reflected in P2s comments that *"…things are getting better for us. We are getting electricity in a few months, water pipes, even i.d.s (identity documents) now. We can't still be cooking indoors."* Caregivers' rhetoric about taking responsibility mirrors government stance on 'shared' responsibility for community development. That is, the poor need to take some responsibility in ensuring poverty alleviation (explored in more detail in the discussion section). In this case, outdoor burning fell squarely as a practice that showed poor people's intention to improving their lives.

The extracts above highlight a critical point in relation to behavioural change for environmental health promotion in developing countries. *While intrapersonal perceptions of health may play a role in determining why people may change their behaviours, it is not possible to ignore poor people's experiences of poverty and their desire to achieve a better quality of life as a factor that may influence behavioural change.* The need to show that they were engaging in behaviours that were symbolic of self development in the expectation that they would get electricity may have also played a role in why members of the control group burned outdoors in order to create a good impression for the research team.

Thus, the qualitative study highlighted a number of motivating factors that could explain the results of the quantitative study. Equally important to this study, however, was to identify the barriers to outdoor burning. The fact that the remainder of the study sample (approximately 50% of households), were unaffected by the intervention suggests that a number of factors might have served as barriers to behaviour change. The following section highlights barriers to outdoor burning that were reported to influence caregivers' decisions to burn indoors despite having received the intervention or been part of the control group participating in the study.

6.3 Barriers to behavioural change

6.3.1 The need for space heating

Caregivers who reported to burn indoors at both baseline and follow-up (hereafter referred to as the indoor burning group) identified a number of factors that influenced their decision to burn indoors during the study. As expected, an important barrier to outdoor burning was the cold winter temperatures. Winter temperatures at follow-up were significantly lower compared to baseline making it very difficult to burn outdoors. While the quantitative study showed no statistical association between lower ambient temperatures and the likelihood of outdoor burning, the qualitative study showed that the colder winter temperatures were a major barrier to outdoor burning. In the following extract, participants describe the familiar winter pattern of outdoor burning during warmer parts of the day in winter but bringing fires indoors during the early evenings when the ambient temperatures drop. In response to the interviewer's questions about concerns about their children's health, participants suggested that the warmth of fires for space heating outweighed the health benefits of outdoor burning.

Extract 9:

Interviewer: Why do you bring a fire inside the house and not outside?

P1: We make the fire in there when it is cold. We only sit next to it in winter when it is cold, in summer we just burn outdoors.

I: What about your children's health? Are you not concerned about them inhaling smoke?

P5: Yes, but what can we do? We have to live with smoke in our homes because it's cold outside. I don't want my children to be cold.

I: I understand, but is there nothing you can do to reduce smoke?

P7: I suppose we can keep them away from fires or open a door. But it is hard.

While many participants in the indoor burning group (in both the intervention and control groups) generally agreed that smoke was harmful to their children's health and could identify steps to reduce exposure, they suggested that the cold made it very difficult to change their behaviours during winter. P5 in extract 9 suggests that there was nothing they could do about the fact that they were reliant on solid biomass (and by implication the smoke generated by them) until they had access to electrification: "*what can we do? We have to live with smoke in our homes because it is cold outside*." In addition, many caregivers believed that it was non-nurturing to allow their children to be cold when they could bring a fire indoors to heat the inkwe. The immediate benefit of space heating outweighed the health consequences of indoor air pollution exposure. At the end of the extract, P7 suggests that she could open windows or keep children away from fires but this is very difficult to do so.

How did people keep warm during winter when they burned outdoors? In extract ten, the interview explores how caregivers kept warm while cooking outdoors particularly the follow-up winter when winter temperatures were lower than the baseline winter. Respondents indicated that they warmed themselves outdoors sitting next to a fire in the segotlo during winter during the day. At night, outdoor fires are normally extinguished as soon as the sun sets. Participants reported that they dress warmly and prepare for bed soon after dusk (approximately 18h00). When asked about how children warmed themselves, participants indicated the (older) children only spend short periods of time sitting next to fires to heat themselves and leave to play outdoors anyway. Caregivers highlighted the fact that children spend short periods of time close to fires regardless of whether the fires were indoors or outdoors and that it was difficult to dress them warmly. As P6 explains, "children just want to play it doesn't matter where the fire is they only sit next to fires for a little bit."

Extract 10

Interviewer: This winter was much colder than last winter, how did you heat your home if you only burned outdoors?

P4: We warmed ourselves in the segotlo. We always do. We sit around the fire outside when it gets cold.

Interviewer: Even before we came last year?

P4: Yes.

P2: It is a cultural influence because when I grew up we were burning in the segotlo.

P3: I learned it from my parents because the smoke from segotlo is not too strong like the smoke from indoors. So you can sit next to the fire a long time.

P5: We also sit next to the fire in the segotlo during the day.

Interviewer: And at night?

P5: By the time the sun sets, we go to bed. There is nothing else to do here in the night. We sleep early.

Interviewer: What about the children, how did you keep them warm?

P5: My child ((pointing to her child)) usually plays outside with the other children. It is better just in case I'm busy with boiling water or something that might burn him in the segotlo.

Interviewer: Does he ever leave the other children and want to be with you?

P5: He does come back. They all come back and warm themselves next to the fire for a little bit but then goes to play again.

Interviewer: And then what does he do if there are not any children?

P5: He usually plays with the chairs, and then he gets bored like he is now and goes back to play outside ((child singing in the background)). Tshepiso stop that, you are making a noise! He gets bored easily.

P6: ((laughs)) Children just want to play it doesn't matter where the fire is they only sit next to fires for a little bit. It is hard to even get them to dress warmly.

Interviewer: And the smaller children, the babies?

P3: I get an older girl to look after my little one inside the house when I'm busy in the segotlo. Sometimes I strap her to my back when there isn't anyone to look after her. When she falls asleep I make a bed for her in the corner of the segotlo. She is usually dressed warmly.

Some caregivers reported, therefore, that it was better to allow their children to heat themselves outdoors in the segotlo where the smoke from fires was "less strong" than indoors. In addition caregivers suggested that children do not mind where they heat themselves as children do not spend long periods of time close to fires as they get bored easily. To emphasize the point that children get bored if they spend long periods in one location, one mother pointed out how her son was getting bored while sitting on the floor waiting for her to finish with the focus group discussion. In addition, many caregivers indicated that they prefer it when children play outside of the segotlo for fears of burn injuries resulting from contact with the fire or boiling water. For younger children, caregivers, if possible, got someone else to look after the children indoors while they burned outdoors. If additional caregivers were not available, caregivers usually strapped their children to their backs while they engaged in outdoor burning activities.

6.3.2 Indoor air pollution and rural existence

Many indoor burners in both groups questioned the link between indoor air pollution exposure and adverse health effects. These participants were also more likely to draw on the notions that indoor air pollution is an acceptable part of rural existence and that their ancestors were exposed to indoor air pollution with no noticeable health effects. In extract 11, R8 (the only male respondent) suggests that *"smoke is part of our culture. Our grandmothers all burned fires inside and they lived to an old age."* Drawing on his 'first hand' observations that smoke did not harm her ancestors, he makes it difficult to counter his claims that indoor air pollution is an acceptable part of rural existence.

He goes on to suggest that not only is behavioural change very difficult (*"even keeping children away from fires is difficult, they want themselves around fires")* but even if it were possible, the fact that people were still reliant on biomass fuels means that there is still likely to be smoke. Similar to previous extracts, he questions the value of behavioural change if the source of the pollution is not removed for example, through the use of electricity for cooking and space heating. He criticises the interviewer's question about the value of outdoor burning and notes that *"everything we use makes smoke, so I don't understand what we can do about it."*

Extract 11

Interviewer: Do you think cooking outdoors might be a solution to smoke?

R8:No. Why should we? ***Smoke is part of our culture. Our grandmothers all burned fires inside and they lived to an old age. We can't get rid of fires, until we get electricity there is nothing we can do. Even keeping children away from fires is difficult, they want themselves around fires.***

R4: I agree electricity will be the answer.

All: Yes.

R8: Everything we use makes smoke, so how can we reduce it if we still have to use them. ***Everything we use makes smoke, so I don't understand what we can do about.***

R3: Also, even if we wanted to, sometimes our families don't want to. ***If my husband wants to bring a fire indoors then there is nothing I can do. He will just make it inside.***

The end of the extract reveals a gendered issue in relation to burning location. R3 points to the fact that even though she wished to burn outdoors, sometimes her family members wanted to burn indoors. She suggests that if her husband (in particular) wished to bring a fire indoors, then she was usually powerless to influence his actions. Similarly, in extract 7 above, one caregiver mentioned that while she was home, she did not allow fires indoors but when she had been away (in this instance to Mafikeng) her children brought a fire indoors which resulted in her home being dirty when the interviewer visited. Gendered roles in relation to domesticity were also highlighted as a determinant of burning location. The following section describes how gendered perceptions of women's time were a barrier to behavioural change.

6.3.3 Gender and women's time

An important factor for why family members (mostly men) did not consider the inconvenience of indoor burning is the low value attached to women's unemployed labour. In the study context, unemployed women are mostly considered responsible for domestic and childcare duties because they are thought to have the 'free time' to do so. In reality, of course, women's 'chores' are labour and time intensive and as highlighted above, they would prefer to keep their homes cleaner through, for example, burning outdoors. Extract 12 is taken from the intervention group.

Extract 12

Interviewer: As a woman, do you feel that it is your responsibility to perform household work?

*P1: Yes, as a woman it is your responsibility to perform household duties **especially when you are unemployed.** When you are working you can always tell other family members to do what. When you a woman who is unemployed, you don't rest. If you did not finish with your today's work, you can always finish it tomorrow. But you can't really finish.*

Interviewer: Do you feel sometimes that it is too much for you?

P1: Yes, but there is nothing you can do. As a woman, you have to do everything because men are too lazy even to do the garden. I collect wood and cook but I even have to renew the segotlo because my husband can't do it.

P2: We were advised by our elders to do things for ourselves. Husbands can't cook but they also don't do the garden. Women are instead expected to perform heavy duties in the house *especially the garden.* ***When people come to visit and find the grass in the yard, they are asking why the woman is not removing it and not mentioning the man.***

P3: ***As a man I help my wife at home but only if she is not around, not when she is home. I can't wash the dishes when my wife is there ((laughs)).***

In extract 12, P1 while accepting a degree of responsibility for domestic chores because she was unemployed and at home during the day (*"Yes, as a woman it is your responsibility to perform household duties especially when you are unemployed")*, goes on to suggest that there is little trade-off between chores traditionally assigned to women and those by men. She suggests that men are lazy and women end up doing both men's duties (gardening and house maintenance) as well as duties traditionally assigned to women (domestic and child care responsibilities). She mentions that husbands *"can't cook but they also don't do the garden. Women are instead expected to perform heavy duties in the house especially the garden."* P3, one of two men in the focus group interview, concurs with the idea that it is a women's responsibility to maintain the home. He suggests that he helps out with domestic duties only if his wife is not available. When she is available, it is her responsibility to clean the house. Men such as P3 are likely to be less supportive of outdoor burning and will bring a fire indoors if they perceive women as having the responsibility and, because they are unemployed, the 'free' time to clean up after them. In addition, gender inequalities are reinforced through social expectations placed on women. P2, for example, suggests that when people visit and the grass is long, visitors usually question why the woman (and not the man) of the house has not cut the grass. Social pressure on women to maintain a clean and healthy domestic environment reinforces the low value attached to women's time and labour. Although issues of gender are highlighted in one extract, the theme emerged in many of the focus group interviews.

6.4 Concluding remarks

This chapter has highlighted a number of factors that influenced caregivers' decisions to shift their burning location (summarized in Table 6.1 below). These findings were not only important in their own right, but also provided possible explanations for the results of the quantitative study (for example, why people in the control group changed their behaviours despite not having received the intervention). Thus in line with objective 4 of this thesis, the qualitative study contributed to the understanding of why people changed their behaviours or not. It provided evidence of a more complex picture of behavioural change for indoor air pollution reduction compared to previous studies. The following Chapter 2 brings together the results of both the qualitative and quantitative study with the literature reviewed in chapter and the objectives of this work.

Table 6.1 Factors that influenced burning location

Outdoor burning	Indoor burning
• Health concern (adults and children). • Self presentation. • Reduced drudgery. • Outdoor burning symbolic of higher social standing. • The prospect of macro-development such as electricity.	• Space heating benefits outweigh any other motivations. • Indoor burning is an acceptable part of rural existence. Ancestors burned indoors with no apparent health consequences, why should they? • Gender relationships. Even if female caregivers wanted to only burn outdoors, they had very little choice if husbands believed that fires should be brought indoors.

CHAPTER 7: DISCUSSION

7.1 Introduction

As described in chapter two, indoor air pollution from the indoor burning of biomass fuels remains one of the most important environmental health risks for young children in poor rural contexts in developing countries. Results from this study underscore the problem of high household reliance on solid biomass fuels and the resultant indoor air pollution in poor rural contexts of South Africa. In 2003 and 2004, 98% of households in the study communities were reliant on biomass fuels (wood, cow and donkey dung) with the remaining 2% reliant on kerosene used by wealthier households and obtained at considerable additional cost from Mafikeng approximately 40 kilometres away. Three quarters of households brought fires indoors during winter leading to elevated levels of indoor air pollution.

The true value of this study, however, was that it evaluated the role of a behavioural change intervention to reduce the practice of indoor burning. This study was the first of its kind in Africa and compared to two previous behavioural intervention studies (Tun et al. 2005 & Ezzati and Baris, 2006), was more informed by health and behavioural change theory, adopted a different implementation strategy (face-to face meetings where the degree of behavioural change was negotiated) and, importantly, use mixed methods to identify the factors that influenced behavioural change. The current chapter discusses the results of this study in relation to the literature and objectives presented in chapter two. It summarizes the strengths and limitations of the study and highlights the implications of this study for future intervention studies, theory and policy. In relation to objective one set out in section 2.7, the following section discusses the results of the behavioural changes documented in this study in relation to previous studies.

7.2 Behavioural change

Despite barriers such as colder weather at follow-up, the percentage of households in the overall sample that burned indoors during winter decreased from 75% at baseline to 56% at follow-up. Improvements were similar in the intervention and control group with the percentage of households that burned indoors decreasing from 75.5% to 54.1% (21.4% improvement) in the intervention group and from 74.4% to 57.9% (16.5% improvement) in the control group. Importantly, approximately 30% of households in both groups shifted from indoors to outdoors while fewer households shifted from outdoors to indoors (8% in the intervention group and 14% in the control group). Differences between groups at baseline and follow-up, however, were not significant.

A behavioural intervention study in Tibet (Tun et al. 2005) found that the proportion of households cooking indoors (living room or kitchen) at baseline decreased by 15.1% in the intervention group and decreased by 4.2% in the control group (that did not receive the intervention) six months after receiving a health education intervention. The study, however, experienced a high attrition rate (32% and 25% in the intervention and control groups respectively) and did not take into account loss to follow-up in the analysis. As such, no firm conclusions could be made about the impact of the intervention. Thus, although the study reported behavioural change and there was difference of 10.9% between the two groups, it was not clear whether behavioural change occurred amongst the same caregivers or not.

In the Chinese intervention trial there was evidence of behavioural change in certain provinces. In Inner Mongolia (the only province that only received a health education intervention only with no improved stove component), for example, women that received the health education intervention were found to be statistically more likely to change their behaviours compared to women in control group that did not receive the intervention (Ezzati and Baris, 2006). However, there were no significant differences in indoor air pollution measurements between the two groups as a result of reported behavioural change indicating perhaps an over-reporting of behavioural change by participants in the intervention group. In addition, in other provinces there were no significant differences in reported behavioural change between the group that received the health education intervention alone and the control group that did not receive the intervention. In all provinces the group that received the health education intervention *together with* improved stoves showed greater improvements in indoor air pollution compared to those that only received the health education intervention leading the authors to conclude that health education on its own does not lead to behavioural change (Ezzati and Baris, 2006).

Nonetheless, participants in all three studies (including the current study) did show evidence of behavioural change following exposure to the intervention. Whether that behavioural change was attributable to having received a health education intervention or other factors, however, is discussed in more detail in section 7.4 below. However, it is important to acknowledge the fact that some participants *did* change their behaviours in the current study and that behavioural change was evident 12 months following the intervention. This raises an important question that is reflected in objective two of this thesis: was behavioural change associated with reductions in indoor air pollution and child exposure to indoor air pollution? The following section discusses the impact of behavioural change on indoor air pollution in the current study in the context of findings of other indoor air pollution intervention studies.

7.3 Indoor air pollution and child exposure

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 (1300-2100 μg/m^3), South Asia (2000-2800 μg/m^3) and Latin America (520-870 μg/m^3)(Smith, 1999). The study also 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 and Röllin et al. 2004) that have highlighted the problems of household energy, indoor air pollution and health.

Importantly, a shift from indoor to outdoor burning was associated with significant improvements in indoor air quality and child personal exposure. Median PM_{10} levels were reduced by 94-96%, CO by 85-97% and child CO exposure by 83-95% when fires were moved from indoors to outdoors. The study also found that when fires were brought indoors, the intervention group showed larger differences (by 33% for PM_{10}, 31% for CO and 33% for child CO exposure) compared to the control group – possibly due to improvements in behaviours such as ventilation and child location in the indoor environment (this is explored elsewhere).

Differences in indoor air pollution associated with a shift from indoor to outdoor burning in this study are comparable to those documented in studies of improved cook stoves and cleaner energy sources documented elsewhere (Budds et al. 2001; Ballard-Tremeer and Mathee, 2000). Albalak et al. (2001), 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 $PM_{2.5}$) and by Reid et al. (1986) (66% reductions in TSP).

In terms of the impact of burning location on indoor air pollution, the cross-sectional study by Albalak et al. (1999b) that compared infant exposure in a predominantly indoor burning village with a predominantly outdoor burning village in Bolivia provides a useful comparison to the current study. Amongst others, results showed that infants living in the outdoor burning village had 62.5% lower daily personal exposure to PM_{10} compared to infants living in the indoor burning village. There are differences in context though. In the Bolivian study, burning location was observable at the village level (one village burned outdoors and one indoors) while in this study burning location was determined at the household level. The Bolivian study also estimated PM_{10} personal exposure while the current study measured CO exposure.

Nonetheless, both studies highlight the potential effectiveness of outdoor burning in rural contexts (where it is feasible) in reducing child indoor air pollution exposure.

The results of this study can also be compared to cross sectional and/or laboratory studies that have focused on differences in indoor air pollution associated with behaviours. Surridge et al. (2005) 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 PM_{10} 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 documented differences were achieved by simply opening a door during burning under test conditions (Still and MacCarty, 2006). Opening a door for the duration of burning showed 94% lower PM and 97% lower CO compared to concentrations measured in an unventilated closed kitchen. Figure 7.1 summarizes the differences in indoor air pollution associated with different behaviours in comparison to open fires in unventilated burning conditions.

A comparison of these figures should be interpreted with caution however. As mentioned above, studies have focused on different pollutants measured using different methodologies and have been conducted in a variety of settings (laboratory, field and so forth). In addition, the figures presented 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 pollutions values documented in developing countries, which means that well tended and ventilated indoor fires may have lower emissions than badly tended outdoor fires located close the living environment which may increase pollution levels in the indoor environment. Lastly, except for Albalak et al. (1999b) and the current study, behavioural studies have ignored personal exposure, which is influenced by the amount of time that people spend breathing in the polluted air and is considered a stronger predictor of health impacts than stationery indoor air pollution levels (Bruce et al, 2000).

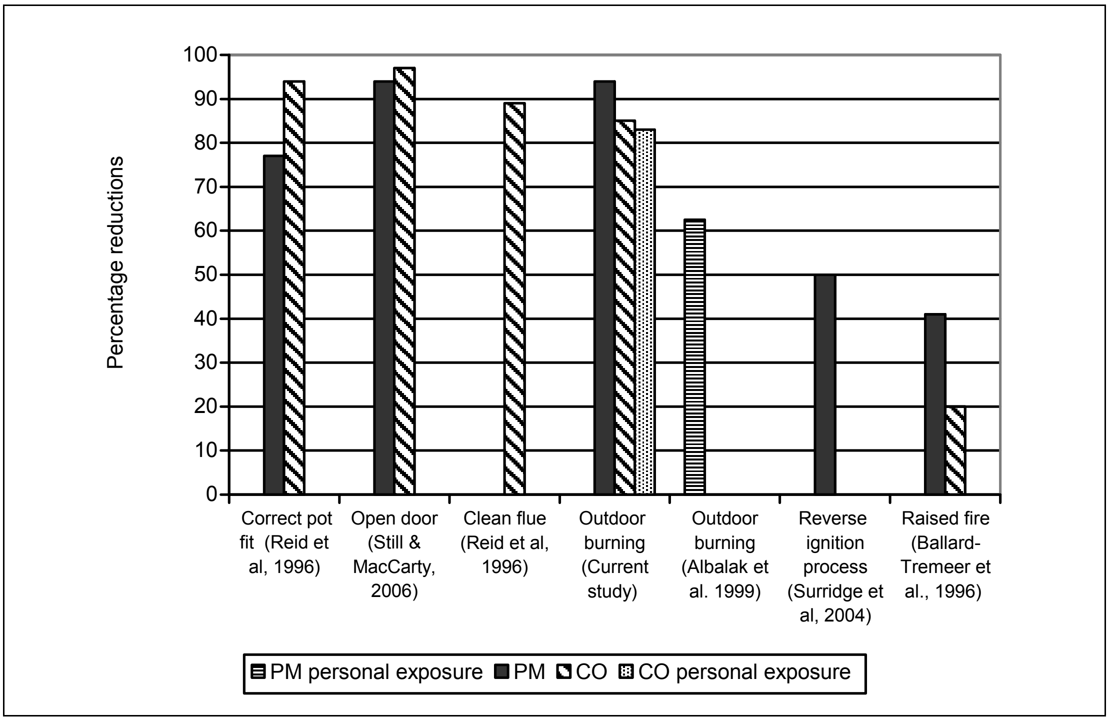

Figure 7.1 Percentage reduction in indoor air pollution associated with selected behaviours

The large differences in exposure (83-95%) associated with a shift from indoor to outdoor burning documented in this study raises the important question: is a shift from indoor to outdoor burning protective of child ALRI? Understanding the impact of behavioural change on child ALRI, however, was not possible in this study. The high attrition rate meant that the study design was not powerful enough to adequately determine the impact of the intervention on child ALRI and the limited resources meant that the study could not measure ALRI at the level that is required from such studies (for example, weekly visits by highly trained staff). Nonetheless, it is possible to discuss the exposure reductions in this study in relation to what is known about the association between indoor air pollution and child ALRI in the literature. The following section discusses whether the differences in exposure documented in this study have the potential to be protective of child ALRI.

7.4 Potential health impacts

While it is reasonable to expect that a shift from indoor to outdoor burning may have a protective effect on child ALRI (Fidelis et al. 2006), it is important to be cautious about assuming that the exposure reductions documented in this study are necessarily of the magnitude to be *statistically* protective. The indoor air pollution and child ALRI exposure-response curve (Ezzati and Kammen, 2001b) suggests that a reduction from the PM category of 500-1000µg/m3 (mean concentrations amongst indoor burners in this study fall within this category) down to 0-200 µg/m3 (mean concentrations of outdoor burners fall within this category) will reduce the mean fraction of child weeks per year with ALRI from 0.04 to 0.035 – a relatively small gain given the percentage of reductions. Similarly, unpublished results from the Guatemala stove trial - the only trial thus far to specifically focus on the health outcomes of exposure reduction and the most robust in terms of health outcome measurement - suggested that even though there were significant reductions in indoor air pollution and exposure in households that received the improved stoves (over 80%) over a 12 month period, the impact on child ALRI was in a positive direction but not significant (Bruce et al. 2006). There are a number of reasons to hypothesize a positive yet relatively modest impact of exposure reductions documented in this study on child ALRI.

First, even though indoor air pollution was significantly reduced by shifting indoor burning to outdoors, the intervention did not completely remove air pollution in the indoor environment. For example, child CO values amongst outdoor burning households were still evident albeit at significantly lower levels than when fires were burned indoors. Exposure possibly occurred through sitting next to outdoor fires to warm themselves as suggested by Nel et al (1993) or through smoke from outside fires entering the indoor environment (as evidenced by the finding that even outdoor burning households had levels of indoor smoke where the air quality monitoring took place). It is important, therefore, to acknowledge that a shift to outdoor burning did not result in 'air pollution free' living environments and that even low levels of exposure together with other confounding factors described below could still contribute negatively to child ALRI in this context.

Understanding the impact of behavioural change on child ALRI is also based on the assumption that behavioural change is sustained. In other words, households who burned outdoors following the intervention will continue to do so over a long period of time. Given that a number of caregivers reported in the qualitative interviews to change their behaviours only when the study team were present, it is not known how many participants reverted back to indoor burning after the study team had left the villages.

It is also important to remember that the relationship between indoor air pollution and child ALRI is complex and, as outlined in chapter two, a number of confounding factors (including nutrition, low birth weight, crowding, a family history of respiratory concerns, environmental tobacco smoke and incomplete immunization history) are thought to influence the association. 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). The current study took place under severely deprived conditions that could serve to undermine the impact of exposure reduction on child ALRI. For example, background information collected at baseline suggested that in terms of:

- *Nutrition*: 41% of children over six months of age were fed pap (maize porridge) alone with nothing else. Poor nutrition, particularly poor vitamin A intake is likely to be major risk factor for ALRI in this study context.
- *Crowding*: children shared a bedroom with up to 11 people with the average bedroom occupancy being 3.7. High levels of crowding in poorly ventilated rooms may also contribute to ALRI.
- *Immunization history*: over 21% of children had missed one or more scheduled vaccinations - particularly measles vaccinations.
- *Environmental tobacco smoking (ETS)*: 46% of children lived in a household that had one or more people who smoked tobacco. ETS may also contribute to

indoor air pollution and may serve to undermine exposure reductions gained by a shift to outdoor burning.

- *Family history of respiratory concerns*: 21% of children had one or more family members with a history of respiratory health concerns.

In short, given the exposure reductions documented in this study, it is expected that a shift from indoor to outdoor burning is likely to have a protective effect on child ALRI particularly for children living in households with higher concentrations of pollution at baseline. However, given the magnitude of the potential confounding variables in the study area, it is unclear whether exposure reductions will have a *statistically significant* impact on child ALRI after adjusting for confounders. More powerful intervention studies are needed to investigate the impact of exposure reductions on child ALRI of similar quality as the Guatemala stove study. Recommendations for future studies are discussed in section 7.6.2 below.

As highlighted in chapter two the indoor pollution prevention field is characterised by an inherent dilemma: interventions often show evidence of indoor air pollution reduction in initial testing but their effectiveness deteriorate considerably over time under actual field conditions. It was crucial to understand, therefore, the factors that influenced the uptake and sustainability of the indoor air pollution intervention in the current study. In response to objectives three and four (that is, to understand the factors that influenced behavioural change) set out in section 2.7, therefore, the following section focuses on the factors that influenced behavioural change in the current study.

7.5 Factors that influenced behavioural change

Chapter two summarized the fact that health education has been widely purported to be the most effective option to induce protective indoor air pollution behaviours in developing countries. However, health education has had limited success in two indoor air pollution studies (Ezzati and Baris 2006; Tun et al. 2005) as well as in the broader environmental health literature (Cave and Curtis, 1999; Loevinsohn, 1990; Favin et al. 1999). Similarly, health education (even though it was more theoretically informed) played a relatively minor role in influencing behavioural change in the current study. Because the control group showed similar improvements in burning location as the intervention group, it was not possible to attribute shifts to outdoor burning with having received the health education intervention and, by implication, because of an improvement in the way in which caregivers thought about the health effects of indoor air pollution exposure.

This is not to suggest that health education was entirely ineffective, however. Results from the qualitative interviews indicated that participants in the intervention group spoke more concretely about the health effects of child indoor air pollution exposure and behaviours to reduce indoor air pollution compared to participants in the control group. The intervention also improved caregivers' perceptions of the seriousness of their children's exposure to indoor air pollution. Thus, compared to previous studies, this study found improvements in specific types of health perceptions (for example, the seriousness their children's exposure) rather than in improvements in general knowledge of indoor air pollution.

In addition, the quantitative study showed two areas in which the intervention group faired better than the control group and, by implication, where health considerations may have played a role. First, compared to the control group, households in the intervention group that burned outdoors during baseline were less likely to bring a fire indoors at the much colder follow-up (see page 98, section 5.3.1). Second, when fires were brought indoors, the intervention group showed larger reductions in PM_{10} (33%), CO (31%) and CO (child) (33%) compared to the control group (see page 114, section 5.4). This finding suggests that improved perceptions of health could have had more influence on behaviours in the indoor environment (where indoor air pollution levels and resulting sensory discomfort was higher) compared to influencing caregivers decisions to shift to outdoor burning. Because the intervention attempted to link sensory experiences with more serious 'down the line' health effects, caregivers reportedly took more care to reduce indoor air pollution levels. In addition, improved health considerations may play a role in getting caregivers to 'think twice' before bringing a fire indoors when it became colder.

The quantitative study, therefore, confirmed an important point conveyed in the broader health and behavioural change literature (Nettleton and Bunton, 1995; Kloos, 1995) – that improving health considerations alone may have a relatively minor contribution to sustained behavioural change. Health education should not be entirely rejected in future indoor air pollution interventions however. There are contexts in developing countries where people may have limited knowledge of the link between child exposure to indoor air pollution and child respiratory health (Iyun and Tomson, 1996; Stewart et al. 1994; Denno et al. 1994). Health education may be a useful starting point in a process to encourage behavioural change in such contexts.

Furthermore, even in contexts (such as the study area) where people have a basic understanding of the association between indoor air pollution and child ALRI, improving understandings of the seriousness of indoor air pollution exposure and their children's susceptibility to it may play a stronger role in inducing behavioural change than merely educating caregivers of the health effects and of alternative behaviours.

The quantitative study yielded a poor predictive value with no statistically significant associations between the likelihood of outdoor burning at follow-up and characteristics of the youngest child (older than 18 months old and male), characteristics of the caregiver (older than 40 and some formal education), dwelling type (formal) and warmer ambient temperature on the day of measurement as postulated in the literature. Contrary to two hypotheses put forward in the literature, findings from this study suggest that households with a child younger than 18 months old (Mathee et al. 2000) and caregivers younger than 40 years old (Balakrishnan et al. 2004) were more likely to burn outdoors. Differences, however, were not significant. There was an elevated association between higher household income and the likelihood of outdoor burning. This could be explained by having more resources to, for example, afford to dress more warmly and be able to burn outdoors. It could also be explained by the influence of prestige (associated with having more money) on outdoor burning that was identified in the qualitative study (explored below). The non-significant findings from the quantitative study encouraged the qualitative study to explore, in more detail, the question of why caregivers engaged in behaviours to protect their young children from indoor air pollution.

The qualitative study found that a key motivation for caregivers to burn outdoors was the reduced drudgery associated with maintaining a clean(er) domestic environment. Having a dirty and smelly home was viewed in a negative light by participants who burned outdoors. Indoor burning caregivers were often positioned as lazy and neglectful by outdoor burners. The 'indoor burners as lazy and neglectful' sentiment, however, was somewhat contradictory given that indoor burners often had to work harder to clean their homes after fires were brought indoors and, for the most part, burned indoors to keep their young children and families warm during winter, which is hardly lazy or neglectful. Nonetheless a move to outdoor burning was viewed in positive light not only because of the decreased burden associated with outdoor burning, but also because of the social stigma attached to indoor burning. Outdoor burning was viewed as symbolic of higher social standing (prestige) and, importantly, of increased *effort* in maintaining a clean domestic environment. The shame and perceived lack of domestic pride associated with indoor burning together with misplaced expectations of the study (explored in more detail in the following section) may explain why so many participants changed their behaviours to create a good impression.

At a broader level, outdoor burning was symbolic of a move away from the perceived backwardness of indoor burning towards a more progressive way of living. In addition, the promise of macro-level development projects such electrification provided the behavioural momentum for individuals to engage in behaviours such as outdoor burning to achieve a better life. Despite valiant attempts to convince participants of the need to change their behaviours because they are unlikely going to be able to afford electricity, participants in some focus groups suggested that it was precisely because of impending electrification that they changed their behaviours. Expectations of improvement in one aspect of their lives (for example, electricity), influenced them to change their behaviours (outdoor burning) to fit in with expectations of a better quality of life.

These findings are similar to a recent study in rural Benin. Jenkins and Curtis (2005) found that motivations for poor people to want latrines had very little to do with health considerations. One of the strongest motivations included *prestige* – to avoid the shame of having to defecate in open fields; to experience a new, more progressive kind of lifestyle, that is, 'wanting a better life', to leave a lasting legacy for descendants and to aspire to upper class ways of living. Similarly, caregivers in this study wanted to avoid the shame (odour and dirt) of indoor burning, believed that outdoor burning was symbolic of aspiring to a better quality of living; did not want their children to experience the health consequences and shame of indoor burning and aspired to higher classes who are perceived to burn outdoors and who are not perceived as lazy or neglectful. Similar to this study, the Jenkins and Curtis (2005) study also found that improved cleanliness and smell as well as convenience were reported to be key motivators for behavioural change.

Many caregivers, however, intended to engage in protective behaviours for the reasons cited above but lacked the 'enabling factors' (Hubley, 1988) such as time, money or familial support to do so. A key enabling factor was the need to address the need for space heating during winter. Although the quantitative study did not find a statistical association between ambient winter temperature and indoor burning, the qualitative interviews highlighted that the colder winter temperature at follow-up made it extremely difficult to only burn outdoors. Caregivers of young children found it cruel and non-nurturing to let their children get cold during winter by not bringing a fire indoors. Indeed some caregivers found the advice to burn outdoors contradictory as they believed that their children had a higher risk of developing respiratory infections if they were exposed to the cold compared to if they breathed in polluted air but were warmer. There were, however, households that found alternative ways of keeping warm, for example, heating themselves outdoors or dressing more warmly. Nonetheless, keeping warm during winter was reported to be a significant barrier to behavioural change. Future interventions in cold climates should be sensitive to the need to balance indoor air pollution reduction with the comfort of warmth.

Familial support for outdoor burning may play a key role in whether intentions to change behaviours are translated into actual behavioural change or not. In particular, some families disregarded women's intentions to burn outdoors because of the perception by some men that it was unemployed women's obligation to clean up after them because they had the 'free' time to do so. In reality, of course, the labour burden on rural women is large. For example, studies have found that rural women in developing countries work considerably longer than men (11-14 and 8-10 hours respectively) and that these tasks, for example, walking large distances and collecting wood that weighed up to 35 kilograms, were incredibly labour intensive (Bembridge and Tarlton, 1990; Cecelski, 1987). Many female participants reported that there was significant social pressure on women to respect the wishes of their male counterparts, for example, to burn indoors, but with little or no support from them to contribute to reducing the labour burden to, for example, clean up the ash and soot afterwards.

Gendered roles in relation to household energy have been reported in a number of studies. Jeffrey et al. (1989), for example, found that men in rural India refused to collect and dry cow dung for fear of being labelled as lower class. The obligation to collect and dry cow dung fell on women, not only because of their perceived lower social status, but importantly because they were perceived to not contribute to the household economy and had the free time to do so (Jeffrey et al. 1999). Similarly, a study on the social determinants of energy use in low income urban settlements in South Africa also found that one of the reasons that men were opposed to electrification was the perception that women would become lazy, through for example, the purchase of domestic appliances such as electric irons and stoves (Mehlwana and Qase, 1999). Such perceptions also falsely imply that women are naturally more inclined carers of families and their domestic environments and therefore do not mind the hard work.

In short, results from this study support a growing body of evidence that suggests that health considerations played a relatively minor and quite specific role in influencing selected behaviours. Caregivers of young children burned outdoors because perceptions of convenience, social standing and a desire for a better quality of life. Even if caregivers intended to burn outdoors, a number of enabling factors needed to be in place in order to act on those intentions: alternatives for space heating (dressing warmly or heating outdoors) and familial support to burn outdoors (a belief that the advantages of outdoor cooking outweigh the disadvantages and there was high value attached to women's labour). Figure 7.2 summarizes the factors that influenced behavioural change in the current study.

MOTIVATIONS → **INTENTIONS** → **BEHAVIOURAL CHANGE**

MOTIVATIONS

Perceptions of the seriousness of the health effects of exposure.

Convenience

- *Cleaner less smelly living environment.*
- *Reduced drudgery*

Prestige

- *Symbol of higher social standing.*
- *Desire for a better life.*

Anticipation of macro development projects e.g. electricity.

↑ **ENABLING FACTORS** (→ INTENTIONS)

Alternatives for space heating.

- *Dress warmly.*
- *Outdoor heating.*

Household support.

- *Household belief in the positive impacts of behavioural change.*
- *Respect for women's labour.*
- *Assistance with domestic chores and childcare.*

Figure 7.2 Factors that influenced outdoor burning in the current study

The study highlighted a number of insights in relation to the potential effectiveness of the intervention as well as the factors that influence behavioural change in the study context. Before proceeding to the implications of the study, however, it is important to discuss the strengths and limitations of the study.

7.6 Strengths and limitations

A notable strength of this work was that the study included a before-after component with a similar control group to understand the effectiveness of the intervention, adjusted for confounding variables, took into account seasonality (winter) when exposures were highest; had an adequate sample size, a period of evaluation of twelve months or more (Cave and Curtis, 1999) and included components (such as the indoor air quality data) to test the validity of the design.

A further strength of this study was that it drew on a combination of qualitative and quantitative methods to provide an overall picture of behavioural change and indoor air pollution exposure in a poor rural context. The quantitative data offered a picture of *what* and *how much*, while the qualitative data provided data on questions related to *why*. Without the qualitative component, the study would have been unable to explore in any detail the results obtained in the quantitative study. Conversely, a qualitative investigation on its own would have been unable to quantify the impact of the intervention in terms of behavioural change and indoor air pollution. In itself, the qualitative component represented an acknowledgement that the quantitative study (despite notable planning effort to identify factors) on its own is unable to provide the 'rich' data sought in trials of this nature (Brown, 2003).

Weaknesses of the study design included the fact that it only captured two 'snapshots' of exposure (one day before and one day after the intervention) and was therefore unable to capture variability in child exposure (daily, weekly and monthly). It was also unable to quantify short term impacts of the intervention although the longer term impacts were of particular importance to this study.

A major weakness of the study was the large attrition rates between baseline and follow-up. The sample size calculations did not take into account the loss to follow-up that the study experienced. While the sample size (n=98 in the control and n=121 in the intervention group) and resulting behavioural improvements provided reasonable estimated power (0.74) (although less than 0.80 suggested by Cohen in (Lipsey, 1998; Lenth, 2001) for an analysis of improvements in the behavioural outcome, the resulting power was less than previously hoped for. In addition, the large attrition rate had a negative impact on the potential to understand the impact of exposure reduction on child respiratory health. Although self-report data were collected on child respiratory health indicators (see Appendix A), the sample size was too small at follow-up to offer any meaningful interpretation of the impacts of exposure reduction. The study *did*, however, take into account loss to follow-up in the analysis of behaviours and indoor air pollution unlike previous studies (Tun et al. 2005).

A further weakness related to the statistical 'one-to-one comparison'. The one-to-one comparison refers to inclusion of households in one group (usually assigned at the village level) which is compared to households in a control group (also at the village level). The household was defined as the unit of analysis within each village. From a statistical perspective, however, a one village to one village comparison is analogous to comparing two individuals with the resulting sample size in each category equal to one (Blum and Feachem, 1983).

Despite the limitations, the study design offered sufficient rigour and depth that, to date, has been absent on the role of behavioural change in the indoor air pollution literature. The following section discusses the implications of these findings of this study on three levels: methodology, theory and policy.

7.7 Implications of the study

7.7.1 Methodological implications

There is a need for larger more detailed studies to explore the association between behavioural change, indoor air pollution reduction and health impacts. Future studies need to 1) monitor indoor air pollution and exposure for longer periods of time and in much more detail than the current study (possibly continuously over the study period), 2) need large enough sample sizes to be able to detect impacts on indoor air pollution as well as child ALRI, 3) a clear case definition and robust methodology for diagnosing ALRI, 4) and adjust for the myriad of confounding variables that may influence the impact of exposure reduction on child ALRI. If ALRI cases are to be measured at healthcare 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.

Future studies should include an experimental or, by the very least, a quasi experimental design. Such studies should include long enough periods of monitoring of behaviours, indoor air pollution and health outcomes both before and after the intervention to address the daily, weekly and seasonal variability of these outcomes. Single group designs (for example, randomised control trial within a single village) should be aware of the possibility of message contamination, that is, the control group indirectly receiving the intervention while two or more group designs need to ensure that the study populations have similar socio-economic and demographic characteristics at baseline. It is important to note, however, that such studies if done correctly are complex and very expensive to conduct.

Future intervention studies should also take into account possible attrition similar to what occurred in the current study. It is crucial that future intervention studies expect and plan for potential loss to follow-up (as much as 30% in this case). It is important that planners pay careful attention to site selection (possibly select sites where populations are relatively stable), understand migration and the characteristics of those who migrate in the study area before study commencement and ensure that sample sizes are large enough to absorb such losses without compromising power.

The control group also showed evidence of behavioural change through participation in the study. Control groups are an essential feature of future indoor air pollution experimental designs to assess the true effect of an intervention. However, given that behavioural change due to participating in the study was documented, to varying degrees, in the current study as well as the Guatemalan (Bruce et al. 2006), Tibetan (Tun et al. 2005) and China (Ezzati and Baris, 2006) intervention studies, it is important to discuss ways to minimise it in future intervention studies.

Misunderstanding(s) of the current study may have been reduced through being clearer about why the study was being conducted. The qualitative interviews showed that the control group were unclear about the justification of the study, who the study team represented (for example, some participants believed that the study was being conducted by the national electricity provider) and the functioning of the air pollution monitoring equipment. Given the invasive nature of the air quality monitoring equipment, future studies should pay careful attention to how participants' understand the operation of the indoor air quality equipment (particularly the larger and noisier Gillair pumps that measured particulates). For example, some believed that the pumps sucked smoky air into them and broke if they became too full; and if children touch them (which they were likely to do) they would also break and burn.

The participant information process may have played a role in creating misunderstandings (see Appendix A). As part of the (necessary) ethical obligations of the study, the objectives of the study as well as the working of the monitoring equipment were explained to participants in an easily understandable fashion. Participants in both the intervention and control groups were informed that the study was about fuels, smoke, ventilation and child location practices as well the respiratory health of their children. Further in the participant information sheet, interviewers explained in a simple manner about the operation of the Gillair pumps. The interviewers explained that the pump and cyclone is "a small machine that tells us how much smoke your fires are making" and that it "sucks air into it and captures the amounts of pollution that are made by fires." These two sentences, while at the simplest level are correct, could have led to the misunderstandings about the air quality equipment mentioned in the qualitative interviews. Based on certain caregivers' perceptions of the shameful aspect of indoor burning (highlighted above), it is easy to see how, for example, participant could view the machines as operating to give researchers information about indoor burning practices or will break if they became too full.

The participant information process is a necessity in any study. However, if oversimplified, the participant information process could influence short term reaction to the study. The institutional (ethical) review of this study suggested that the original participant information sheet was too complex, gave too much information to participants and by implication may have influenced behavioural change amongst the control group. On the contrary, the over simplification of the process could have a similar, if not stronger, effect in influencing people to burn outdoors.

A noteworthy strength of this study is that it used both quantitative and qualitative methods to evaluate the intervention. The quantitative study, by its very nature adopted a deductive approach in that it attempted to measure predetermined categories that might have influenced outdoor burning (for example, ambient temperature). On the contrary, the qualitative study adopted an inductive approach that was flexible in its design and that primarily aimed to answer questions that arose from the quantitative study. Although the qualitative study included a number of predetermined questions to begin the investigation, the study evolved as themes emerged and proved useful in highlighting factors that were not previously considered in the study. It is highly recommended that future quantitative studies include a qualitative component to better understand the role of behavioural change in relation to indoor air pollution in developing countries.

7.7.2 Theoretical implications

The current study came at a historical point in the indoor air pollution literature where not much was known about 'behavioural' aspects and the little that was known, was represented in a simplistic manner. It was intended, therefore, to further the current theoretical understandings of indoor air pollution interventions in developing countries. Results from this study highlighted the potential for behavioural change to reduce child indoor air pollution exposure in a context that was highly unlikely (from an indoor air pollution perspective) to benefit from technical interventions in the short to medium term. However, this study showed that behavioural change is far from the 'simple' and 'cheap' alternative represented in the indoor air pollution literature.

The results from this study suggest that health education, on its own, may have a limited and specific role in indoor air pollution reduction - even when informed by health and behavioural change theory. This raises an important question: should future intervention studies continue to promote behavioural change for indoor air pollution reduction in developing countries?

Answers to this question depend almost entirely on what is meant by 'behavioural change'. If behavioural change is conflated with health education as is currently represented in the indoor air pollution literature, then the answer to the question is a definitive no. If, however, behavioural change is defined as an *outcome* that most indoor air pollution interventions (including technical interventions[6]) should aim to realize, and that behavioural change can be influenced by a number of factors that operate on a number of levels beyond intrapersonal health considerations, then opportunities exist for further behavioural intervention studies in the indoor air pollution literature.

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[6] Even if not framed as such, the overall aim of cleaner fuel and ICS interventions, for example, is to change people's behaviours in relation to cooking and space heating.

There are no, nor should there be, any easy definitions of behavioural change in the indoor air pollution field. If anything, it is hoped that this study will stimulate debate about the role of the 'behavioural' in indoor air pollution prevention. It is important, however, that these debates should be located within a theoretical framework that extends beyond discussions of effectiveness; or of simplistic notions of why people may protect their young children from indoor air pollution. I set out by locating this study within the health and behaviour change literature in developing countries that focused on improving intrapersonal perceptions of *health*. The boundary of my focus was limited to individual perceptions of health, characteristics of the individuals and, at most, to that of the households in which children lived. The findings of this study, however, led me to widen my initial theoretical focus to take into account factors that operate at a broader level. An ecological understanding of indoor air pollution may be a useful framework to guide future interventions (Howze et al. 2004).

Figure 7.3 proposes a framework for understanding behavioural change based on the findings of this study. The inner circle (adapted from Ballard-Tremeer and Mathee, 2000) represents how behaviours, pollution source and ventilation characteristics of the living environment interact to influence exposure. The model also highlights the levels (presented as widening concentric circles) at which factors that influenced behaviours in the current study were thought to operate. The model implies that interventions can be targeted at multiple levels, which as several key texts suggest (Krieger, 2001; Howze et al. 2004) *may* strengthen the effect of intervention on behavioural change. Factors are represented at the intrapersonal (knowledge of health effects and the seriousness of exposure), household (familial support and assistance for behavioural change), community (norms around burning location and gendered perceptions of women's roles) and macro-development level (the promise of electrification could influence behavioural change) and policy level (clean air policy).

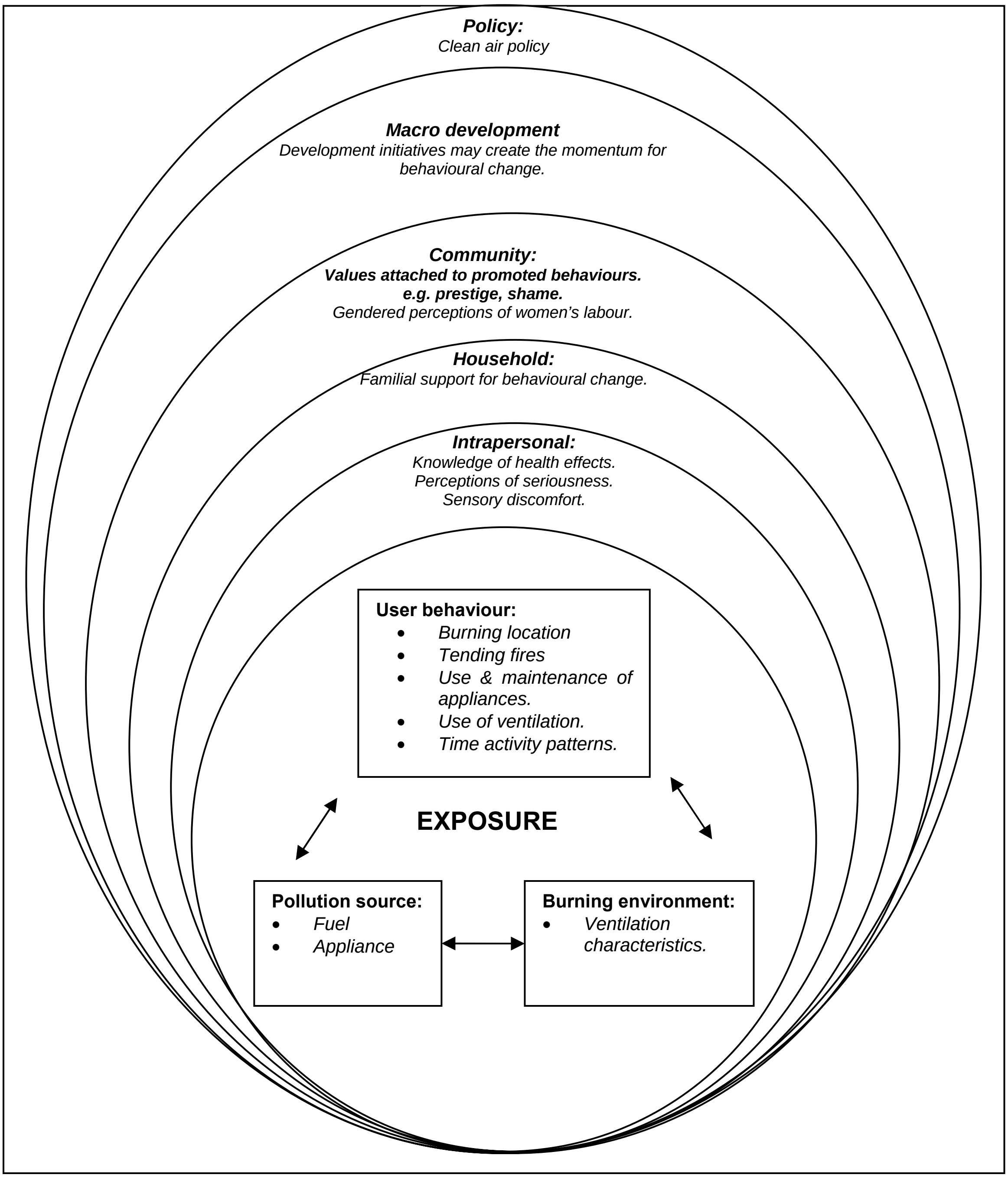

Figure 7.3 Model of behavioural change for indoor air pollution reduction

The proposition of an ecological framework also stems from the question: with the benefit of hindsight, how could the intervention have been improved to be more effective? Based on the findings of this study, the intervention would have probably been enhanced by being pitched at each of the levels highlighted in Figure 7.3. At the intrapersonal level, the intervention would have still *negotiated* behavioural change with families but would have not spent as much effort in promoting the health benefits as the primary motivation for change. At the household level, the intervention could have made more effort to include more family members (particularly husbands/partners who were less likely to be supportive of behavioural change) into the discussions about behavioural change. At the community level, the intervention could have been pitched at community meetings and organisations (for example, faith organisations and committees) and with aim of influencing community norms around indoor burning. At each of these levels, the intervention could have emphasized why behavioural change fits in with broader discourses of a 'better life' linked with macro development projects that were underway in the study communities. Having said this, however, such an approach would have required significantly more resources than were available.

Health and behavioural change theory is an important but a neglected aspect in framing behavioural change interventions in developing countries (Cave and Curtis, 1999; Aboud, 1998). An ecological framework allows for existing health and behavioural theoretical models to be adapted to each of the levels (see, for example, Parker et al. 2004; Krieger, 2001). However, it is important that health and behavioural change theories should be applied cautiously to indoor air pollution, not only because they were mostly developed in western contexts to address non communicable health concerns but also because very little is known about the behavioural determinants of many environmental health concerns in developing countries (Favin et al. 1999). Interventions could be designed to adopt a middle ground by applying selected aspects of theories while also including other factors (not considered in theoretical models) that may facilitate behavioural change. To do so, it is imperative that planners gain a thorough understanding of the context through formative research (a point I will return to in the following section) as well as an understanding of the health behavioural change literature as has been applied in developing countries.

It is important to note, however, that the proposed framework was informed by a small number of qualitative interviews and has yet to be applied and evaluated under actual field conditions. It is recommended that future studies test the approach proposed for behavioural change to reduce child exposure to indoor air pollution. In addition, this thesis did not discuss the effectiveness of communication channels in influencing behavioural change. The current study relied on face to face discussions with individual caregivers of young children based on the assumption that, because of the one-to-one element where change was negotiated, this was likely to be the most effective channel. It is not possible, however, to discount the fact that communicators visiting homes in person may have contributed to the reactivity documented in the study. Other studies, however, have relied on printed materials such as posters and pamphlets (Tun et al. 2005). Although the question of the effectiveness of communication channels was beyond the scope of this study, more work is needed to test the levels of effectiveness of different communication channels in the hope of improving behavioural interventions for indoor air pollution reduction in developing countries.

Policy is a critical aspect of air pollution alleviation (Williams, 2004) and current intervention efforts are often located within broader policy frameworks that aim to reduce indoor air pollution. In addition to theoretical implications, the following section discusses the implications of this study for the implementation of clean air policy in South Africa.

7.7.3 Clean air policy implications

In South Africa, chapter three (section 15) of the recently promulgated National Environmental Management: Air Quality Act No. 39 of 2004 calls for air quality management plans at the national, provincial and municipality level. At the local level, each municipality needs to appoint an Air Quality Officer who, amongst other tasks, will develop a plan to "address the effects of emissions from the use of fossil fuels in residential applications (Chapter three, section 16, point iv). The focus of current policy is on reducing indoor air pollution associated with coal usage in *urban* and *peri-urban* townships with two strategies in place: the promotion of low smoke producing coal and the Basa Njengo Magago (a behavioural intervention that promotes the reverse ignition project described in chapter two).

However, except for household electrification (which households find difficult to afford and so continue to use biomass for cooking and space heating) (Mathee et al. 2000), the South African government has no strategy for indoor air pollution reduction in poor rural households - particularly those poor rural areas that are unlikely to benefit from improved technologies in the short to medium term. Given the high household reliance on biomass fuels in poor rural areas and the unacceptably high indoor air pollution levels documented in this study, it is imperative that the problem of rural indoor air pollution (and ways to mitigate it) enter the policy dialogue within the framework of the new Act.

Results from this study suggest that a behavioural change approach that promoted a shift from indoor to outdoor during winter burning significantly reduced indoor air pollution and child exposure to it. Such reductions may be of the magnitude to be protective of child respiratory health (although the health impacts need to be confirmed by more powerful studies). Results also (tentatively) suggest that the intervention may have influenced alternative behaviours, for example, open windows and keeping children away from smoke, which reduced indoor air pollution in the indoor environment. The role of behaviours in the indoor environment needs to be further analysed in the dataset as well as in future studies.

However, one of the most important findings of this study is that policy makers and planners should not assume that health education is necessarily the most effective way to induce behavioural change. In particular, policy makers should recognise the fact that for rural people, indoor air pollution reduction represents more than health benefits but is inextricably linked to poor people's desire for a better life that fits into a broader development discourse. Planners could integrate these motivations into future interventions while being sensitive to the need to address potential barriers such as space heating and familial support for behavioural change.

In addition, it is important for policy dialogue to include an acknowledgement of the context-specific nature of indoor air pollution exposure. In a climate where there is an increasing demand to generalize specific practices to other settings; given the large variation in the types, manner, location and appliances in which solid fuels are burned, generalizing specific practices (for example, outdoor burning or ventilation) to other contexts may be mischievous. Important lessons have been learned from the failures of the ‘one size fits all’ approach adopted in cleaner energy and ICS projects of the past (Goldemberg, 2004). For example, outdoor burning was effective in reducing indoor air pollution in this context and a major motivation in the adoption of outdoor burning was that it was symbolic of higher social standing. However, in high density urban settlements, outdoor burning might not be effective (where community pollution might be high) or feasible (outdoor burning is viewed as a sign of lower social class because poorer households cannot afford to have an indoor separate kitchen). It is crucial, therefore, that prevention interventions consider *context* specific factors to plan not only for effectiveness but for adoption and sustainability over time.

The importance of formative research in order to understand the context cannot be underestimated. Formative research should include identifying all potential target practices, understanding the potential effectiveness of those behaviours (this thesis has summarised potential behaviours and their demonstrated effectiveness in section 7.4 which can assist planners with this process) and understanding the participants’ ability (can they perform the behaviours) and willingness (are they able to perform the behaviours) to try the target behaviours. Planners are likely to be faced with a complex trade-off between effectiveness and sustainability when planning the key message(s) of the intervention. In other words, behaviours that are likely to be the most effective are probably also likely to be the most difficult to change.

Furthermore, a critical aspect of the policy dialogue should involve the training of the Air Quality Officers and Environmental Health Practitioners (EHPs) in indoor air pollution management within the context of air quality management plans. Lessons learned from this study informed a week long EHP training course in indoor air pollution interventions in the North West province in December 2005, the author will facilitate a training course at national level in 2007 and results of this study have been communicated to the Department of Environment Affairs and Tourism's clean air strategy.

7.8 Concluding remarks

In terms of the overall thesis, this chapter discussed the results of the study in relation to the study objectives set out in chapter two. Based on this discussion, it highlighted the implications of the current study for future intervention studies, theory and policy. In summary, it suggested that behavioural change is possible and associated with differences in child exposure to indoor air pollution; but that health education on its own may play a specific and limited role in certain contexts. However, much more work is needed to a) determine the impacts (if any) of behavioural change (particularly outdoor burning) on child ALRI, b) to further the current theoretical understandings of behavioural change for indoor air pollution reduction and c) the effectiveness of various communication channels for implementing interventions. The following section concludes the work.

CHAPTER 8:CONCLUSION

"So, did your study work?" asked Mr. Oliphant when I visited him in July 2006. Three years had past since I had met him. I had spent a large proportion of time in the rural villages particularly with the Oliphant family. I had experienced the harsh contradictions of rural existence which affected me deeply: on the one hand there was the incredible beauty, serenity, security and friendliness of the people; but on the other hand the incredible hardships and indignities of not having running water to drink or bath in, lights to flick on at night, private toilets to defecate in and not having anything to eat for days at a time.

At the beginning of the study I was primarily interested in the effectiveness of behavioural change in relation to child indoor air pollution exposure – moving fires outdoors, opening windows, keeping children away from fires and even pointing fingers at fires. By the time the study ended I was equally, if not more, interested in *why* people did what they did in relation to indoor fires and how events at a broader scale influenced behaviours within the household. During my time with the Oliphant family, I witnessed their daughter graduate to become a traditional healer and open a practice in the village; their excitement at impending electrification and piped water supplies; as well as Mr. Oliphant receiving an identity document and an old age pension. In all of this, I witnessed how the family's anticipation of a better life influenced how they did things in and around their home. I felt frustrated that the 'scientific' environmental health community with a focus on cause and effect did not allow the space for such important yet complex stories to be heard; but also (reluctantly) recognised the need for simple messages that decision makers can use to inform future interventions.

"I'm not sure," I replied to Mr. Oliphant's question. In one respect, this reply was an acknowledgement of failure of the study. I *had* no easy answers as to the role of behavioural change to reduce child indoor air pollution exposure. I could not be the defender of behaviour change as the cheap, simple alternative to improved technology in poor rural contexts as I and others had hypothesised. On a personal level, I battled to come to terms with not having a definitive (positive) answer on the role of behavioural change, which I had, at least partially, hoped that this study would have yielded. In the spirit of doctoral research, however, these findings forced me to think through what this meant for the broader indoor air pollution and behavioural change literature.

It has been suggested that an evaluation should strive to do one or both of two things: to make the *'obvious obvious'* and/or the *'obvious dubious'* (Patton 1991). In terms of making the 'obvious obvious', the results of this work confirm two points that have been already highlighted in the literature. First, indoor air pollution is a daily reality for poor rural households in developing countries and, second, that people's behaviours in relation to biomass fires can have a significant impact on child indoor air pollution exposure and possibly health. In terms of making the 'obvious' dubious, this work critiques the health education approach to behavioural change and, importantly, highlights opportunities for factors that may be stronger determinants of behavioural change.

As the indoor air pollution field enters an era of assessing potential effective and sustainable interventions to reduce indoor air pollution exposure in developing countries, practitioners can no longer afford to assume that behavioural change is simple and involves merely educating the poor of the associated health consequences and of behaviours to reduce their children's exposure. In this study, how and why people protect themselves from smoke was influenced by factors that operated on a number of levels and was deeply embedded in poor people's experiences of poverty and rural development.

In conclusion, people (albeit a relatively small number) can and do change their behaviours in relation to their use of biomass fires following intervention, which in turn, can have a significant impact on their children's indoor air pollution exposure and possibly health. Behavioural change, however, is complex and requires significant effort. Unfortunately, this means is that there is no one 'quick-fix' solution to the problem of indoor air pollution in developing countries – even in the short to medium term until technical interventions become sustainable. It is important for discussions about indoor air pollution interventions to move beyond simplistic notions of how and why people may protect themselves from smoke to reflect debates in the broader behavioural change literature. One way to do this, I believe, is to encourage social scientists to work more closely with technical disciplines such as environmental engineering in designing context-specific indoor air pollution interventions.

This is not the first, nor hopefully the last, word on behavioural change for indoor air pollution reduction in developing countries. My intention was not to denigrate health education but to offer insights into a potentially more meaningful and effective approach to behavioural change and, indeed, indoor air pollution interventions in general. It is hoped that this study will inform further debate about the role of behavioural change to reduce child indoor air pollution exposure in developing countries.

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APPENDIX A

INFORMATION SHEET, CONSENT FORM AND QUESTIONNAIRE

PARTICIPANT INFORMATION SHEET

Good morning/afternoon,

I am [name] from the Medical Research Council of South Africa. We are conducting a study on smoke from fires, behaviours and child respiratory health and would be grateful if you could assist us to fill out a questionnaire. Specifically, we wish to have one person interview you once this winter and once next winter to find out about your understandings smoke, which fuels you use, when and for how long you open windows and doors, the location of your children in relation to fires and the respiratory health of your children.

The interview should take between 30-45 minutes but may take longer. This may cause you some discomfort by taking you away from your normal daily activities. The interview may also ask you to reveal any health problems your child has experienced.

We *may* also ask your permission to leave an air pollution monitor (the size of a small shoe box) in your kitchen or wherever you make fires for 24 hours - once this month, again in August and once next winter. The air pollution monitor is a small machine that tells us how much smoke your fires are making over a one-day period. It sucks air into it and captures the amounts of pollution that are made by fires. One person will install it in the morning, leave it overnight and then collect it the next morning. It will take approximately 20 minutes to install. The monitor will create a low level sound that may cause you some discomfort – particularly during the night.

We also wish to attach a small, lightweight patch (the size of a large coin) to your child's clothing for 24 hours. One person will attach it to your child in the morning and remove it the following morning. This will have no side effects but may irritate him/her.

You don't have to participate if you don't want to. Although I will write down your address, no one except the researchers will see this. We will write the results in a report, but no one will know which is yours. By participating the study, you will be helping us to plan ways to prevent children from becoming sick from smoke, not only in your community, but also in similar communities in South Africa. Would you like to participate? IF NO, thank you for your time! IF YES, is this a good time for you or can I come back at another time to see you?

If you have any queries, please do not hesitate to contact:

Brendon Barnes (project co-ordinator), Medical Research Council, Health and Development Research Group, P O Box 87373, Houghton, 2041, Tel: (011) 643 7403, Fax: (011) 642-6832, Email: bbarnes@mrc.ac.za

study consent form

I give my consent to participate in the smoke, behaviours and health study as explained to me in the participant information sheet and by the researchers.

I agree to participate in the study and understand that I am free to withdraw this consent at any time. I understand that any questions I have will be answered and that my identity will not be revealed.

Signed: ____________ Date:_________/______/04

INTERVIEWERS, IF THE RESPONDENT IS UNCOMFORTABLE WITH WRITING, PLEASE OBTAIN VERBAL CONSENT AND SIGN ON THEIR BEHALF BELOW.

I, ______________________(name of interviewer), certify that I have explained the information sheet to the research participant who has given verbal approval to participate in the smoke, behaviours and health study.

Signed: ____________ Date:_________/______/04

QUESTIONNAIRE

[INTERVIEWERS PLEASE GREET THE PERSON AND EXPLAIN THE PURPOSE OF YOUR VISIT AGAIN IF NECESSARY].

SECTION A: BACKGROUND

Household identity number:

____

Assessment number:

1	2	3	4

Date of assessment:

____

Interviewer name:

____

Age and sex of children less than 4 years old.

	Age (in months)	Sex (M/F)	Twins [tick]
Youngest			
Next youngest			
Next youngest			
Next youngest			
Next youngest			

Education level of mother

None	Primary school	Secondary school	Tertiary

Education level of father

None	Primary school	Secondary school	Tertiary

Age of mother:

Age of father:

SECTION B: SOCIO-ENVIRONMENTAL CONDITIONS

How many rooms (including kitchen) does this dwelling consist of?

____

How many windows does the burning room have?

____

How many of these are not able open e.g. are broken or covered?

____

How many doors leading to the outside does the burning room have?

____

How many people are presently living in this house?

____

How many people are present during the daytime?

____

How many people do the study children share a room with?

Youngest child	
Next youngest	
Next youngest	
Next youngest	
Next youngest	

Wall material

Bricks	Concrete blocks	Mud Bricks	Corrugated iron

Roof material

Corrugated iron	Thatch	Roof tiles

Floor material

Concrete	Cow dung	Bare earth

Burning appliances used

Wood stove	'Mbawula'	Paraffin stove	Gas stove	'Senke'

Condition of appliance 1: [PLEASE SPECIFY WHICH APPLIANCE] _______________

Poor	Reasonable	Excellent

Condition of appliance 2: [PLEASE SPECIFY WHICH APPLIANCE]_______________

Poor	Reasonable	Excellent

[PLEASE SPECIFY THE DIMENSIONS OF THE ROOM USED FOR BURNING]

Length = m	Breath = m	Height = m

Do you think this household has a problem with dust?

Yes	No	Don't know

Do you think this household has a problem with dampness?

Yes	No	Don't know

How many people in this home smoke?

____

How many people in this home smoke more than 20 cigarettes a day?

____

What is this home's combined monthly income?

Less than R500	R500-1000	R1000-1500	Greater than R1500

Which of the following does this house own? [plz tick more than 1 if necessary]

Colour TV	Black & white TV	Radio	Microwave	Electric iron	Electric fridge

SECTION C: BEHAVIOURS

If you can think back to <u>yesterday</u>, please can you tell me:

Where did you start fires [PLEASE TICK MORE THAN ONE IF NECESSARY]?

Kitchen	Separate room attached to dwelling	Outside

If started outside, was the fire brought into the house?

Yes	No	Don't know

Which fuels did you burn [PLEASE TICK MORE THAN ONE IF NECESSARY]?

Wood	Cow dung	Mielie cobs	Paraffin	Gas	Electricity	

Which appliances did you use to burn [PLEASE TICK MORE THAN ONE IF NECESSARY]?

Wood stove	Brazier	Paraffin stove	Gas stove	Open fire	Electric stove	

If burning took place indoors, please can you help me to fill in the following?

[INTERVIEWERS USING A PENCIL, PLEASE SHADE IN THE RELEVANT SECTIONS]

	Fuels burned		**Ventilation**		**Location of youngest child: Age________**				**Location of next youngest child: Age: _________**				**Location of next youngest child: Age: _______**				**Location of next youngest child: Age: _________**			
	Solid	Kerosene	One source open	Two sources open	Within 1.5m of fire	Further than 1.5m of fire	Segotlo	Elsewhere	Within 1.5m of fire	Further than 1.5m of fire	Segotlo	Elsewhere	Within 1.5m of fire	Further than 1.5m of fire	Outside fire	Elsewhere	Within 1.5m of fire	Further than 1.5m of fire	Segotlo	Elsewhere
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	Fuels burned		Ventilation		Location of youngest child: Age________				Location of next youngest child: Age: _________				Location of next youngest child: Age: _______				Location of next youngest child: Age: _________			
	Solid	Kerosene	One source open	Two sources open	Within 1.5m of fire	Further than 1.5m of fire	Segotlo	Elsewhere	Within 1.5m of fire	Further than 1.5m of fire	Segotlo	Elsewhere	Within 1.5m of fire	Further than 1.5m of fire	Segotlo	Elsewhere	Within 1.5m of fire	Further than 1.5m of fire	Segotlo	Elsewhere
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SECTION D: STUDY CHILD

Have any of your children died in the past 12 months? If so, what of? [Please ask to check death certificate if available].

How would you describe your children's health? [Please tick]

Youngest child INDEX CHILD	Poor	Average	Good
Next youngest	Poor	Average	Good
Next youngest	Poor	Average	Good
Next youngest	Poor	Average	Good
Next youngest	Poor	Average	Good

Please describe any <u>respiratory health</u> problems that family members (apart from study children) have had in the past year?

In the past two weeks, have any of your children experienced the following symptoms:

[TICK IF YES, LEAVE BLANK IF NO. PLEASE NOTE DOWN THE NUMBER OF DAYS THE SYMPTOM PERSISTED. REMEMBER TO EXPLAIN THE VARIOUS SYMPTOMS TO MOTHERS]

Symptom	Youngest child	Days	Next youngest	Days	Next youngest	Days	Next youngest	Days	Next youngest	Days
Productive cough										
Dry cough										
Fever										
Chest indrawing										
Rapid breathing										
Blocked nose										
Runny nose										
Sore ears										
Sore throat										
Sneezing										
Teary/watery eyes										
Wheezing										
Skin rash										

[IF AVAILABLE, PLEASE ASK THE MOTHER IF SHE COULD GET HER CHILD'S HEALTH CARD]

In the past 6 months, how many times have your children visited a health care facility (e.g. a clinic or hospital) for respiratory problems? [TICK IF YES, LEAVE BLANK IF NO. PLEASE VERIFY BY CHECKING HEALTH CARD]

	How many times?
YOUNGEST	
Next youngest	
Next youngest	
Next youngest	

In the past 6 months, have any of your children been diagnosed with following? [TICK IF YES, LEAVE BLANK IF NO. PLEASE VERIFY BY CHECKING HEALTH CARD]

Diagnosis	Youngest child	Next youngest	Next youngest	Next youngest
Pneumonia				
Bronchitis				
Tuberculosis				
Asthma				

[INTERVIEWERS, IF 'SUSPECTED' PNEUMONIA, PLEASE WRITE DOWN THE SYMPTOMS LISTED ON THE CHILD'S HEALTH CARD AND THE ASSESSMENT DATE]

____

____

____

____

Have these children received all due vaccinations? [VERIFY BY CHECKING EACH CHILD'S HEALTH CARD & TICK THE APPROPRIATE BOX]

	Yes	No	Not sure
Youngest child			
Next youngest			
Next youngest			
Next youngest			

Which health care facility do you take your children to?

How much money do you spend to get there and back home?

What was your children's weight at birth? [Please tick appropriate box]

	<2.5kg	>2.5kg
Youngest child		
Next youngest		
Next youngest		
Next youngest		
Next youngest		

Are the children: [PLEASE CHECK EACH CHILD'S LAST HEIGHT & WEIGHT MEASUREMENT IN THE HEALTH CARD & TICK THE APPROPRIATE BOX]

	Underweight	Average	Overweight	Health card not available
Youngest child				
Next youngest				
Next youngest				
Next youngest				

How are your children's nutritional needs fulfilled? [PLEASE TICK MORE THAN ONE IF NEED BE].

	Breast	Bottle	Solid	Not sure
Youngest child				
Next youngest				
Next youngest				
Next youngest				

If any of your children are still breastfeeding, how many times a day is each child breastfed?

	3	4	5	6 or more
Youngest child				
Next youngest				
Next youngest				
Next youngest				

If any of your children are bottlefed, how many times a day is each child given a bottle?

	1	2	3	4 or more
Youngest child				
Next youngest				
Next youngest				
Next youngest				

If any of your children are on solid foods, please list what each child ate yesterday?

Youngest child	
Next youngest	
Next youngest	
Next youngest	

[ASK IF SHE HAS ANY QUESTIONS AND THANK HER FOR HER TIME BEFORE LEAVING]

FOR OFFICE USE:

Temperatures on the day before interview:

Minimum = ^{o}C	Maximum = ^{o}C

APPENDIX B

FOCUS GROUP INFORMATION SHEET, CONSENT FORM AND INTERVIEW GUIDE

FOCUS GROUP INTERVIEWS INFORMATION SHEET

Hello,

We are researchers from the Medical Research Council conducting a study to find out what people thought of the indoor air pollution campaign that took place in your village last winter. We would be grateful if you could help us by participating in a focus group discussion where you, together with about 8 other members of your community, will discuss the campaign with us. The focus group discussion will take between 1hour 30 minutes and 2 hours to complete but may extend for a little longer. Because what you have to say is important to us, we want to tape record the interview.

Participating in the focus group interview may cause you discomfort by taking you away from your normal daily activities. You are free to leave at any stage of the interview. You are also invited to bring your children to the interview as someone will be available to look after them.

Having the interview tape-recorded may also cause some discomfort for you. Except for the researchers, no one will know who is speaking because when we transcribe the interviews you will be given a 'fake' name. The tapes will also be destroyed 2 months after being transcribed. Your participation is entirely voluntary and in no way are you compelled to participate. In addition, the results of the focus groups will be published in a report but only as a group. The names of individuals and households will not be released. By participating in the study, you will be helping us to understand what you thought of the campaign thereby helping us to improve it.

If you have any queries, please do not hesitate to contact:
Brendon Barnes (project co-ordinator)
Medical Research Council, Health and Development Research Group
P O Box 87373, Houghton, 2041, Tel: (011) 643 7403, Fax: (011) 642-6832,Email: bbarnes@mrc.ac.za

FOCUS GROUP INTERVIEWS CONSENT FORM

Focus group interviews

I give my consent to participate in the focus group discussions. I understand that I am free to withdraw this consent at any time. I understand that any questions I have will be answered and that my identity will not be revealed.

Signed: ____________ Date:________/______/03

INTERVIEWERS, IF THE PARTCIPANT IS UNCOMFORTABLE WITH WRITING, PLEASE OBTAIN VERBAL CONSENT AND SIGN ON THEIR BEHALF BELOW.

I, ______________________(name of interviewer), certify that I have explained the information sheet to the research participant who has given verbal approval to participate in the smoke, behaviours and health questionnaire.

Signed: ____________ Date:________/______/03

Tape recording:

I give my consent to allow researchers to tape-record and transcribe the focus group discussion in which I will be participating as explained to me by the researcher and information sheet. I understand that I am free to withdraw this consent at any time. I understand that any questions I have will be answered, that my identity will not be revealed and that the tapes will be destroyed 2 months after transcription.

Signed: ____________ Date:________/______/03

INTERVIEWERS, IF THE PARTCIPANT IS UNCOMFORTABLE WITH WRITING, PLEASE OBTAIN VERBAL CONSENT AND SIGN ON THEIR BEHALF BELOW.

I, ______________________(name of interviewer), certify that I have explained the information sheet to the research participant who has given verbal approval to participate in the smoke, behaviours and health questionnaire.

Signed: ____________ Date:________/______/03

FOCUS GROUP INTERVIEWS INTERVIEW GUIDE

Can you tell me about indoor air pollution?

What diseases does indoor air pollution cause?

How difficult was it to perform the suggested behaviours (INTERVENTION GROUP ONLY)?

What made it difficult?

Probes: Cold? Other family members complained? Affected fires?

Did you find anything encouraging about burning outdoors?

What?

Did anything else happen by burning outdoors that you think we should know?

Were the key messages of the campaign clear?

If I had to ask you now, what would you tell me were the key messages? If you had to tell your friends about the study what would you tell them?

Do you think you will continue practicing the behaviours?

If so, why?

If no, why not?

How courteous were the counsellors?

How clearly were issues explained?

Did they make you feel compelled to perform the behaviours?

Did they negotiate with you the extent you will perform the behaviours?

Did they discuss the possibility of performing other behaviours? Did you perform other behaviours? If yes, what?

Can you tell me why some people burned outdoors this winter and not last winter?

Can you tell me why some people burned indoors this winter and not last winter?

Where did you think the study team were from?

APPENDIX C

ETHICAL APPROVAL CERTIFICATE

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

COMMITTEE FOR RESEARCH ON HUMAN SUBJECTS (MEDICAL)
Ref: R14/49 Barnes

CLEARANCE CERTIFICATE PROTOCOL NUMBER M03-05-43

PROJECT The Evaluation of a Behavioural Intervention to Reduce the Impact of Indoor Air Pollution on Child Respiratory Health

INVESTIGATORS Mr B Barnes

DEPARTMENT Medical Research Council, Medical Research Council

DATE CONSIDERED 03-05-30

DECISION OF THE COMMITTEE Approved unconditionally

Unless otherwise specified the ethical clearance is valid for 5 years but may be renewed upon application
This ethical clearance will expire on 1 January 2008.

DATE 03-06-25 CHAIRMAN (ProfessorP E Cleaton-Jones)
* Guidelines for written "informed consent" attached where applicable.
c c Supervisor: Dr A Mathee
Dept of Medical Research Council' Medical Research Council
Works2\lainO015\HumEth97.wdb\M 03-05-43
===:====
DECLARATION OF INVESTIGATOR(S)
To be completed in duplicate and ONE Copy returned to the Secretary at Room 10001, 10th Floor, Senate House, University.
I/we fully understand the conditions under which I am/we an~authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with trlese conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. I agree to a completion of a yearly progress form. I/we agree to inform the Committee once the study is completed.

DATE 27/06/03 SIGNA TURE

PLEASE QUOTE THE PROTOCOL NO IN ALL QUERIES: M03-05-43