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Int. J. Hyg. Environ.-Health 208 (2005) 219–225
International Journal of Hygiene and Environmental Health
www.elsevier.de/ijheh

Assessing child time – activity patterns in relation to indoor cooking fires in developing countries: A methodological comparison

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Received 25 August 2004; received in revised form 27 December 2004; accepted 20 January 2005

Abstract

Indoor air pollution, caused by the indoor burning of biomass fuels, has been associated with an increased risk of child acute respiratory infections in developing countries. The amount of time that children spend in proximity to fires is a crucial determinant of the health impact of indoor air pollution. Researchers are reliant on social scientific methods to assess exposure based on child location patterns in relation to indoor fires. The inappropriate use of methods could lead to misclassification of exposure. The aim of this paper is to compare two methods (observations and questionnaire interview) with video analysis (which is thought to offer a more accurate assessment of exposure) in rural South African villages. Compared to video analysis, results show that observations may underestimate the amount of time that children spend very close (within 1.5 m) to fires. This is possibly due to reactivity caused by the presence of an observer. The questionnaire interview offers a more accurate assessment of the amounts of time that children spend within 1.5 m of fires at the expense of a detailed behavioural analysis. By drawing on the strengths and weaknesses of each, this paper discusses the appropriateness of methods to different research contexts.

Keywords: Indoor air pollution; Child acute respiratory infections; Exposure assessment methods; Time–activity patterns

Introduction

Over half the world's population and approximately 75% of households in developing countries are reliant on biomass fuels such as wood, cow dung and crop residues (The World Resources Institute, 1998). When burned indoors in the absence of adequate ventilation, the incomplete combustion of biomass fuels release smoke that contains numerous pollutants such as carbon monoxide, particulate matter and other organic compounds into the living environment (Smith, 1987). Indoor air pollution exposure has been associated with a number of health outcomes, most notably, acute lower respiratory infections (ALRI) such as pneumonia amongst young children in developing countries (Zhang and Smith, 2003; Smith et al., 2000; Bruce et al., 2000; De Koning et al., 1985).

Exposure is defined not only as a function of poor indoor air quality, but critically, the amount(s) of time that children spend breathing in smoke in various locations within burning microenvironments (Ezzati and Kammen, 2001; Albalak et al., 1999). Research has shown that the highest concentrations of pollutants

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1438-4639/$ - see front matter
doi:10.1016/j.ijheh.2005.01.022

tend to occur closest and diminish further away from fires. In addition, peaks in emission of pollutants such as particulates tend to occur at key times during the burning process, for example, during ignition, when pot lids are lifted to stir food and when fuels are added to fires (Ezzati et al., 2000). Exposure to these peaks may be just as harmful as the overall time that children spend close to fires. Thus, in addition to the total amount(s) of time that children spend close to fires, it is equally important to assess when (in relation to key activities that cause peaks in emissions) and how far away from fires they stay.

Researchers are reliant on social scientific research techniques (e.g., interview questionnaires and structured observations) to estimate how much time children spend in various locations within burning microenvironments. When combined with measurements of indoor air quality, time–activity data are an integral part of estimating exposure. The inaccurate assessment of time–activity patterns may lead to misclassification of exposure.

The questionnaire interview, in which researchers interview caregivers and note the responses, has been the most widely used method of exposure assessment (Armstrong and Campbell, 1991; O' Dempsey et al., 1996; De Francisco et al., 1993; Pandey et al., 1989). Although less widely used, structured observations of time–activity patterns are viewed as a more accurate technique of assessing exposure and have often been used as the benchmark to which questionnaires are compared (Engle et al., 1997; Saksena et al., 1992). For example, a study in Highland Guatemala compared the accuracy of two interview questionnaire methods: (a) 24 h recall based on the duration of activities around fires (e.g., 3 h) (durations) and (b) 24 h recall based on the time that each activity started and stopped (elapsed time) – with the 'gold standard' of structured observations. The study found that women could more accurately recall durations compared to elapsed time when compared to findings from observations (Engle et al., 1997).

The relative strengths and weaknesses of observations (compared to other methods) have been discussed extensively in hygiene related topics. However, within the indoor air pollution field, very little comparative methodological information exists. In light of the paucity of information in this regard, the aim of this paper is to compare child time–activity patterns using two methods – structured observations and interview questionnaires – in similar populations in rural South Africa. Results are compared with video footage of child location patterns, which is viewed here as the most accurate assessment technique. In doing so, this paper reflects not only on the question of accuracy, but also the appropriateness of each method to different research contexts and needs.

Methods

The methods described here were used in the design of a behavioural intervention to reduce child exposure to indoor air pollution in rural South Africa. The observational exercise was used during winter 2001 as a formative research method to identify potential behaviours that the intervention could promote. The interview questionnaire was used during winter 2003 to assess behaviours before the intervention was implemented and the video analysis was used as a method to test the validity of the interview questionnaire and observations.

Study setting

The study took place in two poor, rural villages situated in the Tribal-Delareyville magisterial district in the North West Province of South Africa. The observations were conducted in village one while the interview questionnaire and video analysis was conducted in village two. The two villages, situated approximately 20 km apart, had similar socio-economic characteristics and factors that might influence child time–location patterns (see Table 1). Village one, however, was significantly smaller in size (150 households) than village two (634 households). The area is generally characterised by high unemployment (37.9%), low income (over 30% of households earn less than the equivalent of 42 British Pounds per month) and low education levels (only 27% of caregivers have a primary school education with the rest having very little, or no formal education). The predominant language is seTswana (Statistics South Africa: Census in Brief, 2003).

Preliminary investigations showed that the villages were unelectrified and there was a high reliance on solid fuels for cooking and heating particularly during the cold winter months. Fuels were burned in old, dilapidated wood stoves or open fires, ventilation in the form of windows and doors leading to the outside were available in most kitchens, children were often present in the kitchen while fires were burning and respiratory ill health was a concern expressed by both mothers and health care workers.

Sample selection

The observational exercise involved 40 families (out of a total of 150 households) in village one. Families were purposively selected to include all families who had a child less than 5 years of age and were burning solid or liquid fuels indoors. The interview questionnaire involved 324 families (out of a total of 634 families in the village) in village two. Families were also purposively selected to include all families who had one or more

Table 1. Background characteristics of the study sample

Variable	Village one	Village two
Mean child age (months)	24.3	25.2
Child sex	Female = 51.2%	Female = 50.4%
Mean number of household occupants	6.5	8
Mean number of children less than 5	1.55	1.78
Child shares a bed with someone else	100%	100%
Fuels burned indoors	Solid only = 72%[a]	Solid only = 73%
	Liquid only = 8%[b]	Liquid only = 6%
	Mixed = 20%	Mixed = 21%
Volume of burning room (mean)	34 m^3	36 m^3
Number of windows in room used for burning (mean)	1.49	1.52
Dwelling construction	Bricks (62%)	Bricks (61%)
	Traditional mud (38%)	Traditional mud (39%)

[a]Wood, cow/donkey dung and maize cobs.
[b]Kerosene.

children less than 5 years old and were burning solid or liquid fuels indoors. Thirteen families were randomly selected from the sample of 324 for video analysis. The youngest child was selected as the study participant for each method.

Procedure

For the observational exercise, trained first language seTswana speaking researchers spent time with families the day before the observations in an attempt to reduce reactivity to the researchers observing their behaviours. Before the observations began, observers reassured families of their anonymity, that they were not there to judge them and that they will not require any special attention such as food or drinks. Researchers sat in the corner of the kitchen (out of the way of normal household activities) and observed household occupants' behaviours for a 1-day period, from the first fuel activity (06.30) to approximately 18.30, using a pre-structured observation sheet. This instrument included sections on household structural information, a diagrammatic layout of the house and a diagrammatic layout of the kitchen or room used for burning (which researchers were required to draw). In addition, the instrument had sections on the location of burning, the appliance used for burning, the purpose of burning and the fuel used. The diagrammatic layout of the kitchen allowed observers to figuratively subdivide the length of the kitchen (or room used for burning) according to letters of the alphabet (A, B, C, D) and breadth according to numbers (1, 2, 3, 4) resulting in 16 figurative quadrants. Once a fire was burning, researchers completed sections on child location practices, child activity, ventilation practices, and location of caregiver and other persons during the burning. The time each event occurred was also recorded.

Using the quadrant system, observers assigned a spatial descriptive to each behaviour. For example: "At 16.58 the child moved from B3 to A1 (where fire is located) and stayed there for 1 minute 25 seconds. Here she warmed herself next to the fire. She then moved to A2 where she sat on the floor and played with a plastic cup. After 40 seconds she moved to A3 and sat on a chair."

The interview questionnaire involved researchers completing a structured questionnaire whilst interviewing caregivers of children less than 5 years old. The questionnaire included items on the structural information of houses; burning, child location and ventilation behaviours using 24 h recall; and child respiratory health using 2-week recall. To obtain child location data specifically, a section of the questionnaire included columns with 10 min time slots (from 06.00 until 20.00), fuels burned (solid or kerosene), ventilation data (one source open/two or more sources open) and the location of the study child (within 1.5 m of the fire, further than 1.5 m of the fire or outside the kitchen). Mothers were asked: "If you can think back to yesterday, can you please tell me…" Based on mothers' answers, researchers shaded in the relevant cells of the questionnaire (Fig. 1).

The video analysis entailed leaving a small digital video recorder (with night vision capabilities) with 13 families overnight. The device was set up discreetly in a corner of the kitchen, covered (except the lens) with a cloth and focused to capture footage of the fire and surrounds. One member of the family, usually an older adult, was taught how to switch the camera on when evening fires were ignited. The first 5 min of footage was excluded from analysis because this is when reactivity was most likely to occur. To further reduce reactivity, the camera was left for a day before filming to allow families, particularly children, to become accustomed to it. Due to power limitations (the villages

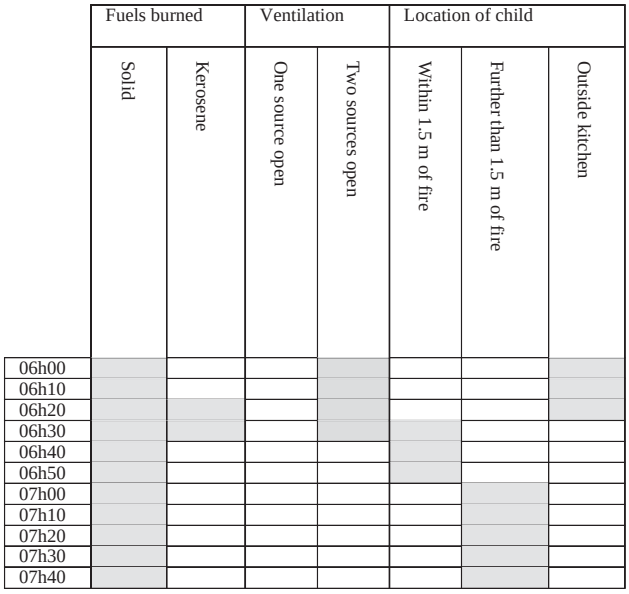

Fig. 1. Proportion of completed interview questionnaire.

are unelectrified) only the first 60 min of each family's burnings were captured.

Analysis

The observational, questionnaire and video data were captured and analysed using Statistics Package for Social Sciences (SPSS). Much of the data violated the assumptions of normality. In addition, there were large discrepancies in sample sizes – 324, 40 and 13 families for the interview questionnaire, observations and video analysis, respectively. This made the use of statistical tests based on comparisons of central tendency inappropriate. Thus, the study employed non-parametric tests (Kruskal Wallis) to test the significance of the differences.

Results

All three methods showed similar results in terms of the time that children generally spent within the room used for burning (52–61% of the time that a fire was burning) ($p = 0.39$). However, they differed markedly in terms of the time that children spent indoors within 1.5 m of fires compared to indoors but further than 1.5 m from fires. Video analysis showed that children spent very little time (5%) further than 1.5 m away from fires. Instead, time was spent either within 1.5 m of fires (47%) or outside the room used for burning (48%). The interview questionnaire showed similar results to the video analysis – children spent longer periods of time within 1.5 m of stoves (44%) than further than 1.5 m of fires (17%). Observations, however, showed that children spent more time further than 1.5 m (38%) compared to within 1.5 m (14%) from fires. This was significantly different to results obtained from the interview questionnaire and video analysis ($p < 0.001$) (Table 2).

Fewer children were present within 1.5 m of fires when structured observations were used compared to the interview questionnaire over a 12 h period. The interview questionnaire showed that up to 90% of all children were situated within 1.5 m of stoves during both morning and evening burnings. By comparison, when observations were used, only 58% and 70% were within 1.5 m of stoves during morning and evening burnings, respectively. During the middle of the day when very few fires are lit, observations and the questionnaire showed similar results (Fig. 2).

The observations and video analysis allowed researchers to identify important behaviours including children's proximity in relation to peaks in exposure such as during ignition or when fuels are added to fires. Observations and video footage also identified the way young infants were handled (in a crib or carried on their caregivers' backs) as well as burning-related behaviours such as the use of pot lids (the use of which hastens the cooking process and reduces the need for prolonged burning), the size of the fuels that were added to fires, the duration of burning and so forth. Because of space limitations, the interview questionnaire could not capture as much detailed behavioural information as the observations and the video.

In addition, the video analysis allowed them to identify contextual behaviours that researchers did not initially consider to be important. For example, footage revealed that 87% of children observed were not warmly dressed during the coldest parts of a winter day. As a result children, once cold, will return to fires from the outside (where they usually play with other children) to warm themselves. Children will spend short periods of time (usually less than 1 min) very close to fires and, once sufficiently warm, return to the outside. Another notable behaviour identified from video footage was the use of flammable materials (for example, mixtures of used cooking oil and diesel or plastic shopping bags) to ignite or increase the intensity of fires. Supplementary indoor air pollution monitoring of particulate matter of less than 2.5 μm in diameter showed these behaviours to be associated with uncharacteristically high emission peaks.

Discussion

Previous indoor air pollution studies have viewed structured observations as the most accurate method of

Table 2. Proportion of time child spent in relation to fires by method

	Within 1.5 m of fire	Further than 1.5 m of fire	Outside room used for burning	Total
Observation ($n = 40$)	39[a] (14%), 7–108, 29	107 (38%), 17–314, 84	139 (48%), 34–641, 148	285 (100%)
Interview Questionnaire ($n = 324$)	128 (44%), 24–456, 128	52 (17%), 24–446, 84	113 (39%), 31–580, 128	293 (100%)
Video ($n = 13$)	28 (47%), 16–47, 11	3 (5%), 1–10, 3.9	29 (48%), 10–42, 12	60 (100%)

[a]Results are shown as mean number of minutes, percentage of burning time, 95% confidence intervals and standard deviation.

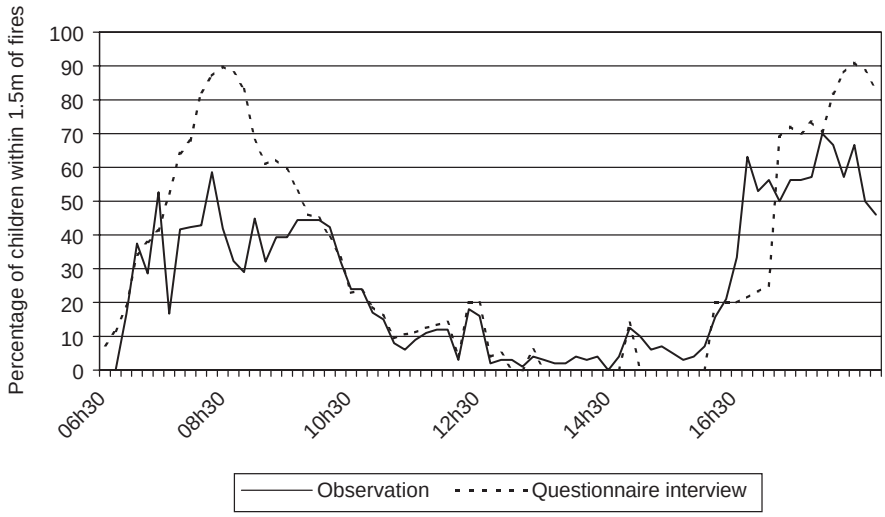

Fig. 2. Percentage of children within 1.5 m of fires over a 12 h period.* *Video analysis was excluded from this figure as this method only captured 65 min of footage.

assessing child exposure and the method to which other techniques should be compared (Saksena et al., 1992; Engle et al. 1997). No published studies, however, have questioned the accuracy or appropriateness of observations in relation to other methods in similar contexts. Findings from this study suggest that there may be problems with the view that structured observations should be viewed as the gold standard to which other methods should be compared. Results showed that once-off observations underestimated children's exposure close to fires by as much as 70%. This may be due to reactivity caused by the presence of a human observer in the kitchen.

As much as observers attempted to reassure families that they were not there to judge them, the fact that families were informed that the researchers were observing children's proximity to fires (for ethical reasons) may have resulted in caregivers not allowing their children to be too close to fires while observers were present. In addition, even though observers spent a few hours with families the day before the observations, the children nonetheless viewed them as strangers. This may have affected how much time children spent in proximity to the observers and, consequently, fires.

In addition to the high human resource cost, observations also rely extensively on the skills of observers. Skills could include the ability to concentrate for long periods of time, knowledge of what to observe and when as well as note-taking abilities. In addition, observers need to constantly make decisions about their role along a continuum from 'observer' to 'participant' depending on the situation. Although researchers were trained to be as unobtrusive as possible (i.e. more 'observer' than 'participant'), anecdotal experiences suggest that not only did their presence disrupt 'normal' daily routines, it was often necessary for researchers to adapt their position from 'observer' to 'participant' to facilitate the observation process. For example, caregivers often left children unattended in the kitchen with the assumption that the observer will watch over them. Observers had to temporarily stop the observation process to look after the child. In addition, many families invited observers to participate in domestic activities such as cooking and eating. Whilst meaningful data is obtained through participating in household activities, the accuracy of time–location data may be compromised.

Results obtained from the questionnaire interview showed strong correlations to the results obtained from

video footage. Specifically, both methods highlighted the fact that children tend to spend most of their time either very close to fires or completely out of the room used for burning. Children spend proportionally very little time in the room but further than 1.5 m away from fires. A well-designed questionnaire, therefore, may offer a reasonably accurate assessment of the amount(s) of time that children spend in various locations around fires in this context. The interview questionnaire is relatively cost effective, can be completed in a short period of time and allows for an analysis of child location patterns over a longer period of the day (for example, early mornings and late evenings) when observations are often not feasible. However, the questionnaire interview might be weakened by recall bias and does not allow for detailed behavioural analysis.

It is recommended that methods should be selected based on their appropriateness to different research needs. Structured observations, for example, may be useful for formative research in contexts where little is known about burning and exposure behaviours. Coupled with qualitative interviews, information obtained from structured observations can be used to inform the design of questionnaire interviews. In addition, information obtained from structured observations could also be used in the design of much needed interventions to reduce exposure. For example, in this exercise, results from the observations were used to identify four potential behaviours that a potential intervention could promote (see Barnes et al., 2004). This comparison suggests that once-off structured observations, however, may be limited in terms of the accuracy of assessing child location patterns. Increasing the duration of observations could overcome the effect of reactivity. Indeed, it was observed that 12% more children were close to fires during evening compared to morning burnings which might be explained, in part, by the fact that children were becoming accustomed to the presence of a researcher. However, the prohibitive cost may limit the feasibility of structured observations in developing contexts.

A weakness of the questionnaire interview is the bias for respondents to over-report 'good behaviours.' This was not evident in this analysis as caregivers tended to report children being very close to fires (a 'bad' behaviour) for longer periods of time than children being further away from fires. In addition, the interview questionnaire technique is relatively cost effective and can be applied to large research populations. This makes it appropriate to large-scale epidemiological or field evaluation studies. The questionnaire, however, needs to be well designed and appropriate to the research context. Structured observations may assist in this process. In addition, decisions about assessing 'durations' that children spend close to fires or 'elapsed time' needs to be considered in the design of the questionnaire interview. This study used 10 min time slots to assess child location patterns. Future research may consider testing the usefulness and accuracy of a variety of recall time options (for example, 30 min, 1 h and so forth). The questionnaire is also weakened by the inability to capture behaviours in detail.

Before proceeding, it is important to note the weaknesses of this analysis. This paper viewed video analysis of the burning process as the most accurate method of assessment. Results from observations and interview questionnaires were compared to video analysis. Reactivity due to the presence of a video camera is worth noting. However, researchers attempted to reduce this by using a small recording device that was set up discreetly in a corner of the room. In addition, the camera was left for a day before filming to allow families to become accustomed to it. During the first stages of recording, some evidence of reactivity was observed especially since an adult was asked to switch it on (when a fire was lit) and make sure that it was recording. This meant that others, including children, were made aware of the camera at this point. Because of this, the first 5 min of recording were excluded from the analysis.

In addition, because of power limitations, video equipment was only able to record for an average of 65 min. This made comparison of prolonged exposure to the results of the two other methods difficult to achieve. Nonetheless, video analysis offers researchers useful insights into time–activity patterns in relation to indoor cooking fires. An assumption, however, is that behaviours noted in the first 60 min of burning is representative of entire burning durations. This may be problematic.

A further limitation is the fact that the methods were not used concurrently in the same research populations. In addition, all methods were 'once-off' and did not monitor patterns over extended periods of time e.g. a number of weeks. Indoor air pollution exposure behaviours are known to change based on a number of contextual factors such as season and availability of fuels. Future studies need to take this into account and compare methods in the same populations concurrently over extended periods of time.

This comparison reflects on the accuracy and appropriateness of the methods to assess child time–activity patterns in relation to indoor cooking fires. When compared to video analysis, structured observations were found to underestimate child exposure to indoor air pollution possibly due to reactivity. A well-designed interview questionnaire may offer a more accurate assessment of child exposure within the burning micro-environment at a relatively cheaper cost. Observations, however, are useful in obtaining rich qualitative data that could be used in the formative phases of intervention research and/or in the design of questionnaires. It is

hoped that this discussion will serve to instigate more comparative studies in impoverished contexts where indoor air pollution remains a public health concern. Findings from such studies, together with current developments in indoor air quality measurement techniques, might serve to improve the overall quality of indoor air pollution exposure assessments in developing countries.

Acknowledgements

Funding for this project from the United States Agency for International Development through the CHANGE project (implemented by the Academy for Educational Development with the Manoff Group) and the South African Medical Research Council is gratefully acknowledged.

References

Albalak, R., Keeler, G.J., Frishncho, A.R., Haber, M., 1999. Assessment of PM10 concentrations from domestic biomass fuel combustion in two rural Bolivian highland villages. Environ. Sci. Technol. 33, 2505–2509.

Armstrong, J.R.M., Campbell, H., 1991. Indoor air pollution exposure and lower respiratory infections in young Gambian children. Int. J. Epidemiol. 20, 424–429.

Barnes, B.R., Mathee, A., Shafritz, L.B., Krieger, L., Zimicki, S., 2004. A behavioral intervention to reduce child exposure to indoor air pollution: identifying possible target behaviours. Health Edu. Behavior 31, 306–317.

Bruce, N., Perez-Padilla, R., Albalak, R., 2000. Indoor air pollution in developing countries: a major environmental and public health challenge. Bull. World Health Organisation 78, 1078–1092.

De Francisco, A., Morris, J., Hall, A.J., Armstrong Schellenberg, J.R.M., Greenwood, B.M., 1993. Risk factors for mortality from acute lower respiratory tract infections in young Gambian children. Int. J. Epidemiol. 22, 1174–1182.

De Koning, H.W., Smith, K.R., Last, J.M., 1985. Biomass fuel combustion and health. Bull. World Health Organization 63, 11–26.

Engle, P.L., Hurtado, E., Ruel, M., 1997. Smoke exposure of women and young children in highland Guatemala: prediction and recall accuracy. Hum. Organization 56, 408–416.

Ezzati, M., Kammen, D.M., 2001. Quantifying the effects of exposure to indoor air pollution from biomass combustion on acute respiratory infections in developing countries. Environ. Health Perspect. 109, 481–488.

Ezzati, M., Saleh, H., Kamen, D.M., 2000. The contributions of emissions and spatial micro-environments to exposure to indoor air pollution from biomass combustion in Kenya. Environ. Health Perspect. 108, 833–839.

O' Dempsey, T.J.D., Mcardle, T.F., Morris, J., Lloyd-Evans, N., Baldeh, I., Laurence, B.E., Secka, O., Greenwood, B.M., 1996. A study of risk factors for pneumococcal disease among children in a rural area of West Africa. Int. J. Epidemiol. 25, 885–893.

Pandey, M.R., Neupane, R.P., Gautam, A., Shrestha, I.B., 1989. Domestic smoke pollution and acute respiratory infections in a rural community of the hill region of Nepal. Environ. Int. 15, 337–340.

Saksena, S., Prasad, R., Pal, R.C., Joshi, V., 1992. Patterns of daily exposure to TSP and CO in the Garhwal Himalaya. Atmos. Environ. 26A, 2125–2134.

Smith, K.R., 1987. Biofuels, Air Pollution and Health. Plenum Press, New York.

Smith, K.R., Samet, J.M., Romieu, I., Bruce, N., 2000. Indoor air pollution in developing countries and acute lower respiratory infection in children. Thorax 55, 518–532.

Statistics South Africa: Census in Brief, 2003, second ed. South African government, Pretoria, 2003.

The World Resources Institute, 1998. World resources: a guide to the global environment 1998–99. WRI, Geneva, 1998.

Zhang, J., Smith, K.R., 2003. Indoor air pollution: a global health concern. Br. Med. Bull. 68, 209–225.