EXPOSURE CHARACTERIZATION AND POTENTIAL HEALTH IMPACTS OF DOMESTIC FUEL USE IN HOMES IN KHAYELITSHA, WESTERN CAPE

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ABSTRACT

The pattern of fuel use in Lower socio-economic class homes in the Western Cape differs from that in Gauteng province, in that the use of paraffin and gas predominates. The degree of exposure to gaseous and particulate pollutants as a result of the use of these fuels is not well documented. It is against this background that the study to assess the potential health impacts of air pollution emitted from domestic fuel use in the Western Cape area was conducted. The project collected data on exposure to air pollution in households using paraffin and/or gas and wood in comparison to those using electricity. The study consisted of a pollution monitoring survey and the administration of a questionnaire in each of the homes selected. Pollutants were measured. These were sulphur dioxide, nitrogen dioxide, carbon monoxide and total suspended particulates. Co-located sampling was also performed in one home of each group, measuring indoor and outdoor concentrations simultaneously. The results indicate that the homes using mixed fuels had higher levels of indoor air pollution than those which used mainly electricity, or electricity and gas or paraffin. However, these levels were low when compared to coal and wood burning homes in the Gauteng province. This limited exposure assessment study confirms the hypothesis that paraffin (and gas) are cleaner from an air pollution point of view than coal or wood. The respiratory health risks associated with the use of gas and paraffin would therefore be lower than those associated with wood or coal. From an air pollution perspective, the increased use of the former will make a positive contribution. However, promotion of these fuels is constrained by the serious safety concerns around the use of paraffin in lower socio-economic areas.

INTRODUCTION

The World Health Organisation (WHO) has estimated that up to 90% of household energy supplies in sub-Saharan Africa comes from fuels which are low on the energy ladder (low cost, high environmental and health impacts).[1] In South Africa, approximately 60% of the population depend partially or completely on coal or wood for cooking and space heating. Paraffin, however, is also widely used in certain area.

Research in urban and rural areas of Gauteng and the Free State has examined air pollution exposures in communities that use coal and wood as primary energy sources. This information has already contributed to the process of developing provisional household energy policies aimed at reducing the risk to the health. The pattern of fuel use in lower socio-economic homes in the Western Cape differs from that in Gauteng, in that the use of paraffin predominates. The degree of exposure to gaseous and particulate pollutants as a result of the use of paraffin is not well documented.

Electricity is widely accepted as the cleaner and safest from of energy, and electrification is expected to proceed rapidly in the Western Cape. However, many households in smaller towns will continue to rely on alternative fuels for the foreseeable future. It is therefore important that in addition to the known fire and poisoning hazards associated with the use of paraffin, the comparative risks to respiratory health of these fuels should be established. This information will contribute to the formation of a household energy policy for South Africa.

The health effects of paraffin are not well known but are being studied. No association has been found between the use of kerosene stoves and lung cancer in Hong Kong although there was some indication of hazards to asthmatics because of sulphur oxide emissions[2]. It has been reported by Smith that acute exposure to kerosene smoke over three months produces changes in physiological parameters in dogs. Paraffin has 3 times more energy by weight than biofuel and paraffin stoves are more efficient than typical biomass stoves. The emissions per unit task are lower in kerosene stoves than biomass stoves.[2]

AIMS AND OBJECTIVES

This project aimed to collect data on exposures to air pollution in households using paraffin and or gas in comparison to those using electricity. The objectives of the project were thus:

- To measure concentrations of sulphur dioxide, nitrogen dioxide, carbon monoxide and volatile organic compounds emitted from fuels in homes using mainly paraffin in an urban area in the Western Cape winter rainfall region and compare them to measurements of pollutants in homes where mainly electricity is used.
- To assess exposures to total suspended particulates (TSP) in a Western Cape community during winter in the various homes and compare the levels among the various groups of fuel users.
- To compare pollutants concentrations with those measured in the coal and paraffin using homes.

METHOD

The study area was Khayelitsha, Western Cape. The study sample consisted of 72 households. These were stratified into four groups as follows:

Group 1: Formal houses, using electricity almost exclusively. (n=19)

Group 2: Formal houses, using a mix of electricity and paraffin/gas. (n=28)

Group 3: Informal houses (shacks), using a mix of electricity and paraffin/gas and wood. (It was expected that very few informal houses were using electricity exclusively.) (n=18)

Group 4: Informal houses using only paraffin/gas. (n=17)

The study consisted of air sampling and a questionnaire. Survey respondents were asked to specify which fuel was most commonly used for cooking, heating and lighting. Groups 3 and 4 were randomly sampled from an area of informal housing close to Groups 1 and 2. The survey was undertaken during August 1994. The questionnaire which was administered by pre-trained interviewers conversant in Xhosa, English and Afrikaans consisted of questions regarding demographics, fuel usage, and respiratory profile of home occupants. The respondents were selected randomly from a sample as well as a back up sample in case the selected respondents were not available or not willing to participate in the study. The questionnaire survey to determine respiratory health status was conducted at the same time as the pollution survey. Khayelitsha is undergoing a process of rapid electrification of informal dwellings (shacks).

In the month prior to the survey two adjacent area of shack settlements were identified for inclusion in the study. Houses in one of these areas had already been electrified (zone 3), while houses in the second area were not due for electrification until after the date of completion of the survey (zone 4). The two shack areas were selected on the basis of their proximity to an area of formal housing where previous surveys had revealed a pattern of mixed fuel use (as defined above) (zone 2). Each of the zones 2, 3 and 4 contained between 200 and 400 houses. The zones were marked off on maps from the City Engineer's office that identified each housing site with a five digit number. Sampling in each of these zones was systematic with a random starting point. Sample sizes in zones 3 and 4 were 18 houses, and in zone 2 the sample was 26 houses. Where housing sites were unoccupied, or where there was no resident at home after repeated visits, the sites were replaced according to an agreed procedure.

In zone 3, a number of residents were not using electricity despite being connected. Households in this area were therefore only included if they used electricity for either lighting, cooking or heating. Houses not using electricity were replaced according to the agreed procedure.

Previous surveys in Khayelitsha have shown that exclusive use of electricity is more or less confined to the relatively wealthier formal housing area. Such areas are limited in size, and relatively distant from zones 2 to 4 (± 3 km).

Air Sampling

Monitoring and sampling of all pollutants were performed inside the cooking areas, while TSP was also monitored inside the sleeping areas. Monitoring usually commenced between 17:00 - 18:00 and lasted for 12 - 18 hours on average depending on the battery life and filter loading. In order to gain information on the concentrations of ambient pollutants, co-located measurements were taken in selected homes in each group.

Gases

The monitoring periods varied due to the fact that the four instruments being used were not placed simultaneously but one after the other four in the homes studied each day and monitoring times were between 12 - 18 hours. The removal of the instruments followed the same pattern as the placement, hence the different monitoring periods to include peak exposure times associated with cooking processes in the evenings and early mornings. Monitors were removed shortly after the morning cooking period (± 08:00). Due to the unavailability of electricity, battery-operated monitors had to be used, limiting the monitoring period. Sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO) were monitored using an electrochemical Exotox Model 75 continuous monitor. The lowest detection limit of the monitor is 0,1 ppm. The pollutant data were logged and stored every hour to yield averaged concentrations of each gas per hour. These monitors have cross-filters which effectively prevent interference from other gases. The monitors were calibrated prior to and after use in accordance with the manufacturers' specifications.

Co-located sampling was conducted in one home per group on the same day as the indoor sampling for that home. The gas monitors were placed in the early afternoon (15:00 - 16:00) in order to cover the evening cooking period and left overnight to monitor the early morning cooking period. They were removed between 08:00 - 9:00 in the morning. No monitoring was undertaken during the day in the homes except on weekends when the monitors were left until the Monday and then removed. Two sets of ambient data in the Group 3 and 4 homes were obtained over the weekend during the day, as access to the home was not possible during the night.

Total Suspended Particulates

TSP were monitored using a Gill Air model 224-X pump, sampling at 2 /min over a 12-hour period, starting at 18:00 and including the evenings and early mornings. Cellulose filters were used to collect the particulars. Gravimetric analysis was performed using standard procedures. Quality control/quality assurance procedures included careful inspection of filters for irregularities and re-weighing of a statistically significant sample. A specially equipped weighing room with a temperature and humidity control system was used.

Volatile Organic Compounds (VOCs).

Total VOCs were sampled using passive 3M sampling badges over a 1-day period. The samples were analysed by means of gas chromatography. The positioning of the monitors inside the households was standardised as far as possible with respect to their proximity to both the emission source and the occupants of the home.

Health Risk Assessment

The health standards which were used for determining the potential health risks were the USA National Ambient Air Quality standards used by the Environmental Protection Agency and South African Department of Health. It is assumed that exposure to levels below these standards prove little or no threat to health.

RESULTS

Exposure Assessment

The health standards for SO_2 and CO were exceeded in Groups 2 to 4 for below 6% of the total monitoring time. These levels were lower than those recorded in wood, and coal-using households in Gauteng.

The average TSP concentrations measured in each home group showed that there were no exceedances of the standard when averaged out over the full monitoring period, as well as the number of monitoring periods. However, in Groups 2, 3 and 4 single homes were identified where the 24-hour health standards were exceeded in 10.7%; 5.6%; and 11.8% of measurements respectively.

Pollution Profiles - Gases (Indoor Concentrations)

The hourly average results of the gaseous pollution are given in figures 1-4. The profile of pollutants for all 4 home groups are given together for ease of reference. The relevant health standards for each pollutant gas are given on each graph. The outdoor values are reported later. The measurements were taken between the 7-31 July 1994 and 1-7 August 1994.

Outdoor Pollutant Profiles - Gases

The results of these measurements indicate that levels of SO_2 and CO were elevated and exceed the ambient standard on certain days. The results of the ambient measurements are discussed later in this text.

DISCUSSION

A limitation of this type of study is the difficulty in sampling for long periods due to the lack of electricity as well as the lack of a large number of gas monitors to measure in the homes simultaneously. For logistical reasons, the project team carried out gas and TSP measurements in four homes per day and moved through the four sample groups consecutively. The ideal situation would be to conduct measurements in the same type of homes on the same day at the same time. Similarly, sharing a set of monitors in one home in each of the four groups each day would be a good option. However, this causes logistical problems such as the distance between homes, requiring more field workers, and

Figure 1: Indoor Pollution Sulphur Dioxide (SO_2) - Hourly values

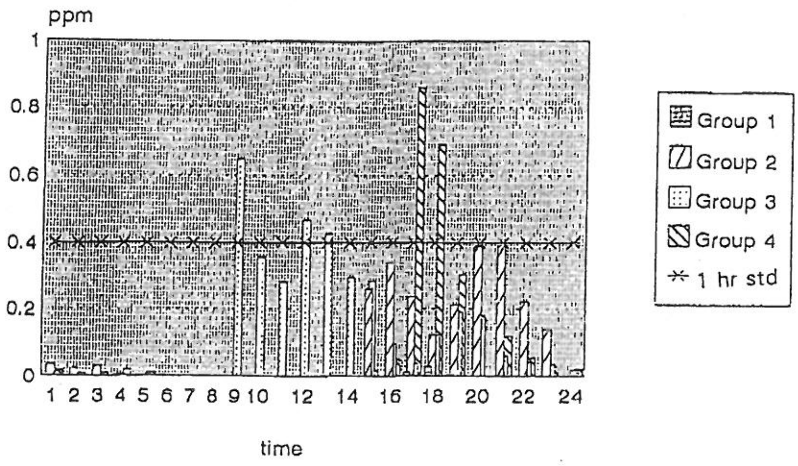


Figure 2: Indoor Pollution Nitrogen Dioxide Measurements For All Groups

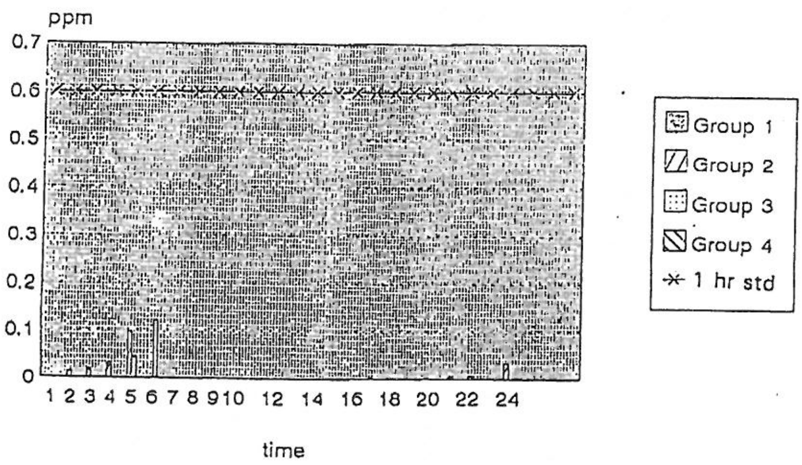


Figure 3: Indoor Pollution Carbon Monoxide Measurements For All Groups - Hourly values

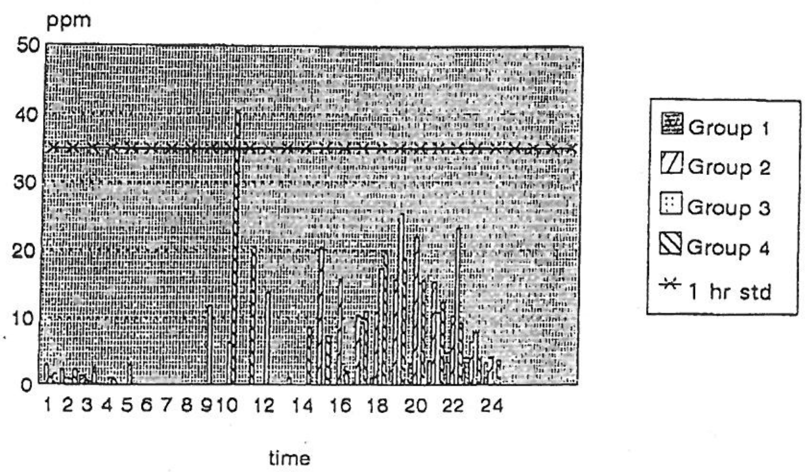
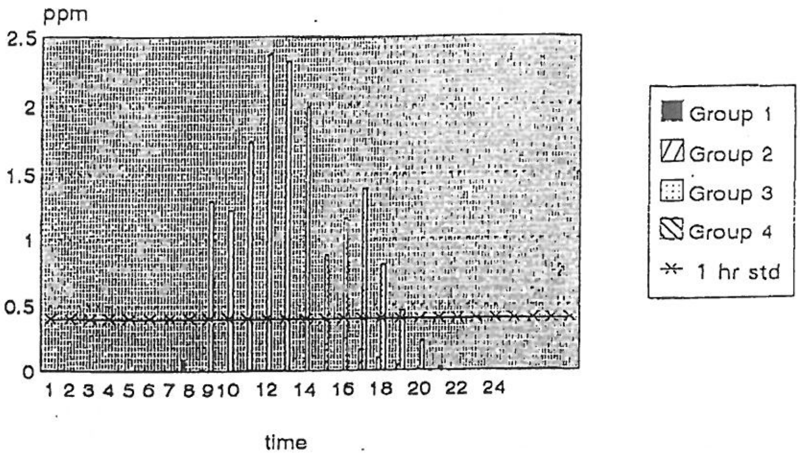


Figure 4: Ambient Sulphur Dioxide Measurements In All Groups - Hourly values



can affect monitoring times. Furthermore, non-electrified homes have to rely on battery power whereas the electrified homes can run equipment for longer periods. These longer monitoring times in the electrified homes could slant the results.

Sulphur Dioxide (SO_2)

SO_2 concentrations were elevated during the day and early evening in Group 3 homes (informal, electricity mixed fuel use) but Group 4 (informal mixed fuel use - paraffin and gas as well as wood) recorded the highest single concentrations of SO_2 in the evening, peaking at 18:00. The day-time measurements were obtained over the weekend and have not been deleted from the data set. These elevated concentrations were possibly from an accumulation of sources due to wind dispersion of geographical topography, but are most likely from wood and other sulphur-containing fuels which are burnt outside the shacks in that area.

In the Group 3 area, the ambient levels were excessive and midday concentrations 6 times above the hourly health standard. The highest ambient and indoor peaks did not occur during cooking times as in the other groups but during the day over the weekend. This could be attributed to various sources, mainly wood burning or industrial activities undertaken by the occupants. A small proportion of Group 3 and 4 home occupants used wood for heating, cooking and lighting. This could possibly be the source of the increased SO_2 concentrations. Inspection by the project team did not reveal any nearby refuse burning. These ambient concentrations were recorded over 3 days: 19, 30 and 31 July 1994. The highest ambient average level recorded by the Cape Town City Council for the day was 0.2 ppm, measured at Goodwood which is approximately 10 kilometres west of the project site. SO_2 poses a health risk to the community from indoor and ambient air pollution in Groups 3 and 4.

Nitrogen Dioxide (NO_2)

Indoor NO_2 sources include paraffin and gas. The NO_2 concentrations in each group were low and in no cases was the hourly health standard of 0.60 ppm exceeded (DOH guideline). The highest indoor concentration was obtained at 06:00 in the Group 3 homes. The majority of Group 4 homes used paraffin yet no significant NO_2 values were measured.

Carbon Monoxide (CO)

CO is a product of incomplete combustion. CO concentrations were elevated in Group 3 and 4 homes, consistent with the mixed fuel use and the small shack-type housing. CO levels were highest in the Group 4 (shacks, no electricity) at 10:00 on a weekend day and then again in Groups 3 and 4 between 18:00 and 19:00 (start-up fires). In the Group 4 area, the highest outdoor concentrations exceeded the hourly health standard at 18:00 on the day of monitoring. This could be due to the lighting of stoves or fires and is a cause for concern.

Total Suspended Particulates

In an area such as Khayelitsha with its unpaved roads and various fuels used for energy, sources of particulates are numerous. In the completely electrified group the 24-hour health standard was not exceeded. In the mixed fuel groups, the standard for TSP was exceeded in about 10% of all measurements. The extent of these exceedances and the maximum concentrations recorded were orders of magnitude below those documented for Gauteng[4-6,8] in the predominantly coal and wood using region of Gauteng. In the studies conducted in Gauteng, pollutants exceeded the recommended health standards by between 2-10 times.

KEY FINDINGS

The pollutant peaks measured in each group were highest in homes where mixed fuels are used, i.e. Groups 3 and 4. Pollutants loads measured reflected the ignition of cooking and heating equipment in the late afternoons and continued into the early evenings. Heating and cooking sources were also used in the early mornings as shown in Group 4. Ambient pollutant levels of sulphur dioxide were high and need further investigation. These elevated peak concentrations may be due to temperature inversions and a large source of fuel burning near the pollution monitor. Industrial activity may also have an impact on the levels.

Carbon monoxide hourly mean levels were high in Groups 3 and 4 homes exceeding the hourly health standard indoors (10:00). Ambient concentrations exceeded the health standard (18:00) (one event). Nitrogen dioxide, commonly associated with use of paraffin and gas, was not found above the health standard and was not found in any significant concentrations indoors or outdoors. Volatile organic compounds, also associated with the use of paraffin and gas were not measured in significant values and pose no health risk.

CONCLUSIONS

Homes in Khayelitsha using mixed fuels in the study area had higher pollution loads than homes using only electricity. However, cumulative or average exposures to indoor pollution in all groups were relatively low and did not pose a significant health risk. When compared with studies of indoor air pollution Gauteng, the average levels of total suspended particulates did not exceed any health standards whereas in the Gauteng studies average TSP values were 3 to 12 times higher than the US EPA health standards. Gaseous pollutants (sulphur dioxide and carbon monoxide) exceeded the relevant standards for short periods (especially in Groups 3 and 4 where some wood burning was reported) and were lower during the measurement period whereas in the Gauteng study the concentrations were higher and exceedances longer. Sulphur dioxide outdoor and indoor levels may pose a health risk to occupants in Group 3 and 4 homes. From this winter cross-sectional exposure assessment study, it is evident that paraffin (and gas) are associated with significantly lower levels of gaseous and particulate pollution compared with wood or coal. However, the levels occasionally exceeded health standards in the case of SO_2, CO and TSP in the informal mixed fuel categories (possibly due to uncontrolled wood usage). The fuels are therefore not as clean as electricity, but are preferable to coal or wood.

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ACKNOWLEDGEMENTS

The Department of Mineral and Energy Affairs is thanked for their sponsorship of this project. The Energy for Development Research Centre, University of Cape Town for its assistance with the sampling of the study sample. The authors also wish to thank Mrs V. Arkley and A. van Dijk for assisting in the typing and preparation of this report.