PERSONAL EXPOSURES TO TOTAL SUSPENDED PARTICULATES FROM DOMESTIC COAL BURNING IN SOUTH AFRICA

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INTRODUCTION

More than 20 million people in South Africa (60% of the total population) use coal as their primary source of energy (cooking and/or water and space heating). In the majority of cases the coal stoves are unvented or poorly vented. During the winter periods (May - July) the visibility reduces to less than 500 m in these townships. Available data are insufficient and inadequate to provide important information regarding the exposure of South African children to air pollution caused by domestic coal burning. Recent studies performed in two major coal burning areas in South Africa indicated that levels of particulate matter taken at fixed monitoring stations exceeds the USA health standards. A mean PM-10 concentration of more than 200 $\mu g/m^3$ (standard is 150 $\mu g/m^3$) are recorded frequently.[1] The annual average PM-10 concentration measured in Soweto during 1991 was 115 $\mu g/m^3$, more than twice the USEPA standard.[1] Measurements taken from a fixed monitoring station in Sharpeville, a township with more than 200 000 people using domestic coal as primary energy source, a significant increase in the concentrations of fine particulate matter (FPM) (< 2,5 μm in diameter) is recorded during winter. An annual average of 80 $\mu g/m^3$ for FPM is typical for that region.[2]

It is generally accepted that fixed outdoor monitoring stations do not provide accurate human exposure data due to human's activity patterns.[3] Throughout the world individuals are exposed to concentrations of air pollution encountered in a variety of locations and activities. It is therefore important to determine, not only outdoor pollution levels to predict exposure, but also to quantify the contribution of other locations (indoors, transportation) to total exposure.[4,5] Total human exposure can be defined as a function of the time spent in contact with various pollutant concentrations.[3] In order to understand total exposure better, it is important to know how, where and when people spend their time. Personal monitoring is an important method of characterizing the direct exposure of a person to certain air pollutants.[6]

The study on personal monitoring of total suspended particulates (TSP) in a coal burning area in South Africa reported here, was conducted during 1991 and 1992 in the Vaal Triangle (VT). The VT is an area which is known as the industrial heart beat of South Africa and is situated on the South African Highveld. In addition to industrial air pollution, approximately 700 thousand people using low quality coal as primary or secondary domestic energy source, reside in the area. The objectives of the study were to collect personal exposure data on children living in these areas using coal as domestic energy source and to determine factors influencing their exposures. This project is a part of the Vaal Triangle Health Study (VAPS) which investigates the effects of indoor and outdoor air pollution on South African children. The rationale and design as well as some of the preliminary results of the study is presented in separate papers at this conference (paper no: IU-11C.12, IU-21A.07 and IU-23A.05).

METHODOLOGY

Pupils from the Sebokeng area (partially electrified townships in the VT) were solicited through the regional health clinics to participate in the study. The participants were selected from the group who participated in the main health study and for whom a health questionnaire has been completed. Information on parental smoking, household characteristics, location of home, socio-economic status and respiratory tract symptoms were therefore available.

The methodology of the study included the following: Informed consent was obtained from each participant's parents after which participants were trained and informed about the requirements for carrying the monitor. Maximum cooperation was requested and participants were instructed to follow their normal daily activities while carrying the monitor. Light weight monitors (Gill Air model 224-X R) were carried by the participant on various days, during the summer and winter. Monitoring was done on a school day and a weekend day (Saturday) during the summer and on a school day and school holiday (also a week day) during the winter in partially electrified areas (using electricity mainly for lighting while using coal for cooking and heating). The same group of children were used for all the monitoring days except the summer weekend day which was a different group of children. These children were selected randomly from two different areas, a completely electrified area and a non-electrified area close by. Monitoring was done at a flow rate of two litres per minute. Glass fibre filters, housed in open head containers and worn within the breathing zone of the child, were used to sample the particulate matter. Total suspended particulates (TSP) were sampled and not only the respirable fraction. The monitoring period was scheduled for 12 hours starting at 8h30 and ending at 20h30 on each of the monitoring days. The monitors were switched on by field personnel while the participants switched them off at the end of the monitoring period. The monitors recorded the exact monitoring time. Acclimatization of the filters as well as gravimetrical analysis were done according to the standard procedures of the South African Chamber of Mines adopted from NIOSH.[7]

Statistical analysis using Wilcoxon tests were used to compare seasonal and day of the week variations in exposure levels. The following groups were compared: Summer vs winter exposures overall, days of the week

(school vs non-school), boys vs girls and partially electrified vs unelectrified areas.

RESULTS

A total of 45 children (18 boys and 26 girls) aged 8-12 (median age 10) participated in the monitoring programme. Data was collected during different days and 72 individual monitoring sessions with a median duration of 12.2 hours. Of the 72 individual monitoring sessions, 99% recorded exposures which are above 260 $\mu g/m^3$, the original USA 24 hour health standard for TSP.[9] The average TSP concentrations for winter and summer monitoring days are summarized in Table 1, as well as the level of statistical significant difference between the different exposures (95% significance level). From Table 1 it is clear that winter exposures are significantly worse than summer exposures. An interesting observation from Table 1 is also that the winter non-school day was associated with lower exposures than the school day for the total population.

TABLE 1: Comparisons of personal exposures to TSP during different monitoring days in children living in domestic coal burning areas of South Africa.

Monitoring days	N	Average Concentrations µg/m³	P-value 95% sign
Summer school day	13	662,4(294,0 - 1 096,0)	
versus			
Winter school day	13	1 333,5(704,0 - 2 304,0)	p < 0002
Winter school day	13	1 333,5(704,0 - 2 304,0)	
versus			
Winter holiday day	13	880,3(338,0 - 1 917,0)	p < 0,01

Comparison of the results, from the summer weekend day, for the electrified and non-electrified areas indicated a borderline statistical significant difference ($p < 0,05$) for the total population. The average concentrations measured were 387,3 $\mu g/m^3$ (259,0 - 577,0) and 619,8 $\mu g/m^3$ (266,0 - 1449,0) for the electrified and non-electrified areas respectively (Figure 1). However, for boys only, the exposures measured were statistically significantly higher in the group living in the non-electrified (coal burning) environments compared to the ones from the electrified areas (429 $\mu g/m^3$ vs 960 $\mu g/m^3$ respectively, $p < 0.0002$). Although the exposures of children living in non-electrified areas are marginally higher than those from the electrified areas for the group as a whole, 96% of all measurements still exceed 260 $\mu g/m^3$. One has to keep in mind that these measurements were taken in summer when coal burning activities are greatly reduced. It is expected that winter measurements will be substantially higher in the non-electrified than in the electrified areas.

The exposures of boys and girls were compared in the different groups. When comparing boy/girl exposures for all the data together, no difference was observed ($p < 0,7$). However in the different monitoring sessions important variations in exposures of boys compared to girls were documented. For the school days (winter and summer) and the weekend day for the electrified area only, no difference was detected between the exposures of boys compared to those of girls. For the weekend data from the non-electrified area, however, statistical significantly higher exposures were documented for boys living in the non-electrified (coal burning households) compared to girls living in the same environment ($p < 0,0004$). This is depicted in Figure 2. The average weekend exposures of boys and girls living in the electrified area neighbouring the coal burning areas is illustrated in Figure 3.

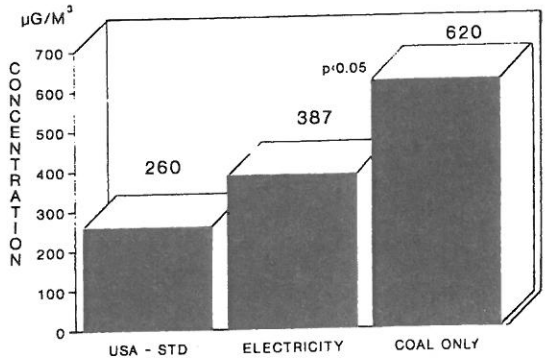

Figure 1: Comparison of personal exposure to TSP concentrations from children living in electrified vs coal burning areas.

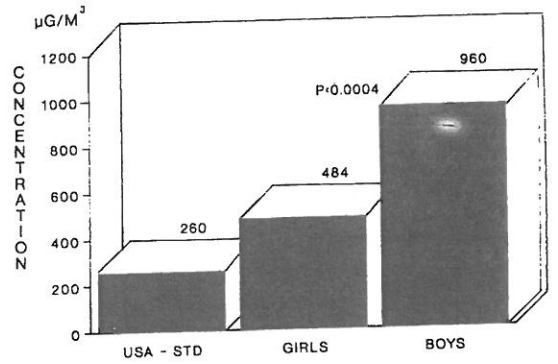

Figure 2: Personal exposures to TSP on a Saturday for boys and girls living in a domestic coal burning environment.

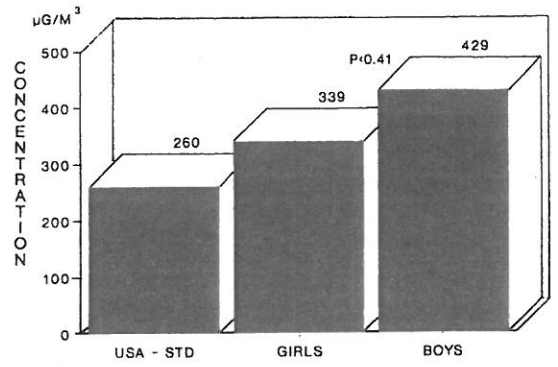

Figure 3: Personal exposures to TSP on a Saturday for boys and girls living in an electrified area neighbouring a coal burning area.

Questionnaire data reporting the use of coal only and coal and electricity together were used to categorize the children. Comparisons were drawn between coal only and coal and electricity as domestic sources of energy during the worse pollution period, namely, winter. The results indicated no statistical significant difference between the two groups, average TSP levels were 1 363 $\mu g/m^3$ for coal only and 1 168 $\mu g/m^3$ for electricity and coal. Partial electrification of townships seems therefore not to be a solution in terms of reducing human exposures to TSP.

DISCUSSION

Coal is the primary source of domestic energy for almost 20 million people in South Africa. Even in most electrified black townships coal is still being used for water and space heating while electricity is primarily used for lighting and cooking. This is due to the lack of resources to create an infrastructure for complete transition to electricity and the lack of money to maintain the system. This is a feature well known in developing countries. It has been documented that the total global population exposure to particulate air pollution varies from 2% in rural areas of developed countries to 55% in rural areas of developing countries.[8]

This study collected data on total human exposures to TSP emitted from domestic coal burning over a 12 hour period. The results illustrated extremely high levels of exposures. These exposures, taken over a 12 hour period, are in 99% of cases higher than the original USA 24 hour health standard of 260 $\mu g/m^3$ and in 100% of the cases above the lowest-observed-effect level of 180 $\mu g/m^3$ documented by the WHO.[9, 10] These measurements are well in range of measurements taken from fixed indoor monitors in Kenya (300 - 1 500 $\mu g/m^3$ overnight), China (2 600 $\mu g/m^3$ all-day in kitchen) and Gambia (1 000 - 2 500 $\mu g/m^3$, 24 hours).[8]

The study reported here, compared seasonal differences in personal exposures to TSP and found, as expected, significantly higher exposures during winter periods compared to summer. The variations in exposures from different monitoring days weekend vs school day or school day vs school holiday is probably not very important in the light of the overall extremely high exposures measured. The lack of statistical difference or week differences between electrified, partially electrified and complete electrified households is important and could be attributable to the close proximity of these areas to each other and the nature of low level coal burning which is classified as an area source and spreads kilometres far without proper dilution or dispersion, as particularly evident during winter. An important finding however, is the higher exposures documented for boys compared to girls during the non-school (weekend) days. This could be related to the specific activities of boys or the micro-environments where they spend their time and will be further investigated.

In conclusion, it was found in this study of personal monitoring of TSP in 45 children living in completely - or partially electrified areas of South Africa that exposures are unacceptably high. The highest risk group for exposures identified in this study is boys on non-school days during winter in the partially or unelectrified areas.

ACKNOWLEDGEMENTS

The support of the Energy Branch of the Department of Mineral and Energy Affairs and EMSA for this project is acknowledged. We would also like to thank Ms Gretel Crowther for biostatistical assistance, the participants, Mr A Kock and the laboratory personnel from ISCOR and the clinic personnel for their cooperation in this study.

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