RESPIRATORY HEALTH STATUS OF CHILDREN IN THE EASTERN TRANSVAAL HIGHVELD

S Zwi, H I Goldman and J M Kallenbach
Pulmonology Division, Department of Medicine, University of the Witwatersrand and Johannesburg Hospital, Johannesburg, South Africa

J C A Davies and M R Becklake
Department of Community Health, University of the Witwatersrand and the National Centre for Occupational Health, Johannesburg, South Africa

S G Reinach
Institute for Biostatistics, South African Medical Research Council, Johannesburg, South Africa

SUMMARY
To determine if there are detectable effects on the respiratory health status of children resident in the Eastern Transvaal Highveld (ETH) as a consequence of their exposure to community air pollution, we compared them to children in areas ostensibly less polluted. We conducted a prevalence study in white school children from 11 schools in the ETH (1031 children) and from 11 schools in "non-polluted" towns in the Transvaal (978 children). A questionnaire was completed by the child's mother, height and weight were measured and spirometry was recorded on a Vitalograph. Cough, wheeze, asthma and chest illnesses were more frequently reported from polluted areas compared to non-polluted areas taking into account parental smoking and home cooking fuel (odds ratios 1,34, 1,20, 1,15, 1,88 respectively). After correcting for age, children in the polluted area were 0,83 cm shorter (p = 0,035). However, there were no significant differences in forced vital capacity and forced expiratory volume in 1 second after standardizing for height, age, parental smoking and home cooking fuel. We conclude that, in children, exposure to pollution in the ETH may cause respiratory symptoms and chest illness and may affect height but does not measurably affect lung function as assessed by spirometry.

Environmental pollution has been identified as a source of ill health in man.[1] A perception that levels of environmental pollution are rising in certain regions of South Africa such as the Eastern Transvaal Highveld (ETH) has become a cause of public concern. The ETH is the main coal producing region in the RSA where 80% of the country's electrical power requirement is generated by coal-fired power stations. It also contains petrochemical plants, numerous industries, smouldering discard coal dumps and usual sources of pollution. The ETH has climatic conditions which are highly adverse for the dispersion of atmospheric pollutants including temperature inversions and lack of rain in winter. For 1983/84 the average annual combined emissions of pollutants over the area exceeded 125 million tons of which 123 million tons were carbon dioxide.[2]

A study in the Sasolburg area carried out in 1984 showed that there was a significant difference in the forced expiratory volume in 1 second (FEV_1) between primary school boys in the study area and those in neighbouring negligibly polluted rural towns.[3] An investigation of possible health effects associated with air pollution in the greater Cape Town area concluded that there are not any gross short-term public health hazards associated with air pollution in the areas studied and that they had no information of any possible chronic long-term trends.[4]

The harmful effects of pollution (as detected by increased symptom prevalence or impaired lung function) are likely to be modest, and possibly less than those of other environmental exposures (eg, smoking, passive smoking and home gas range emissions) and/or host factors (eg, age, size, socio-economic status, previous respiratory illness). Children are probably more susceptible than adults to the effects of inhaled airborne materials, and many researchers seeking to determine whether community air pollution in a given location has in fact affected human health, have confined their observations to young persons. In the present study we concentrated on respiratory health status, and focused on children of school going age. Such children are fully capable of co-operating in lung function testing but most have not yet started their pubertal growth spurt. Confounding factors such as cigarette smoking, occupational exposure and changing residential areas are minimized by studying children.

The principal objective was to determine whether there are detectable effects on children resident in the ETH as a consequence of their exposure to community air pollution.

METHODS

Respiratory health status is defined in terms of (i) respiratory illness, past and present; (ii) respiratory symptoms (obtained using a respiratory symptom questionnaire answered by the child's mother); and (iii) spirometric /lung function tests. Exposure to community air pollution is defined on the basis of area of residence.

Prevalence (cross-sectional) studies were carried out on children in primary schools from areas selected because of presumed heavy environmental pollution on the one hand and minimal on the other hand.

Air pollution data from all available sources concerning the ETH were examined to try to define the geographical limits of the polluted area and to select suitable control areas. Climatological and wind pattern data were studied to select control areas unlikely to be polluted from the study area. Altitude above sea-level, annual temperature, rainfall and relative humidity in the control areas were matched with the study area as closely as possible.

Eleven schools in the control area form two groups well outside the study area - one composed of six schools located to the north and east and the other comprising 5 schools to the west and south-west (Figure 1).

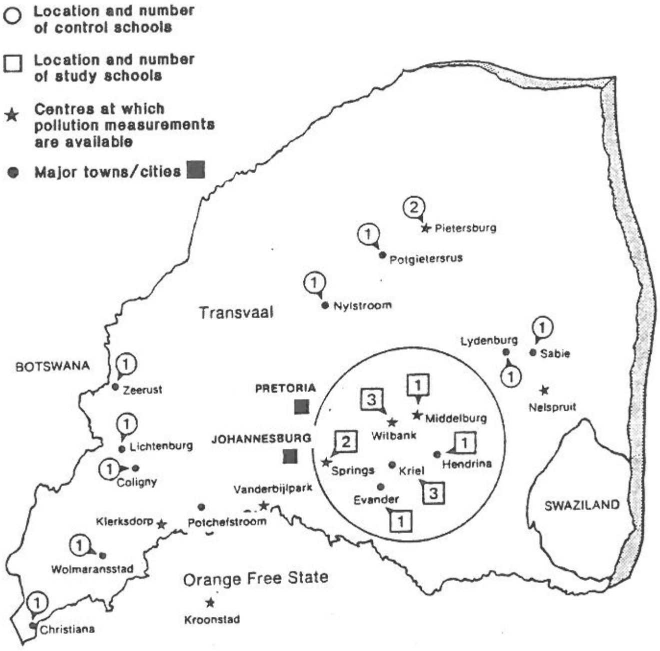

Figure 1

The test subjects chosen were primary school children of both sexes in Standards 2 and 3.

Taking into account the biologic and instrumental variability involved in spirometric assessment of lung function, a sample size calculation was made for which published figures for biological variations and intraclass correlation coefficients obtained in a similar previous study of South African children[3] were utilized.

We used the strategy of cluster (school) sampling rather than random sampling of all school children in the areas selected. The calculations (using an A value of 0,05 and a B value of 0,10) indicated that a difference in mean value of approximately 0,09L in forced expiratory volume in 1 second (FEV_1) would be detectable as statistically significant if 10 clusters (schools) of 100 children each were tested from the study (or "polluted") and control (or "unpolluted") areas ie. 1000 children from each area. We tested 1031 children from 11 schools in 6 towns in the polluted area (exposed children) and 978 children in 11 schools in 10 towns in unpolluted areas (unexposed children). Testing alternated between study and control areas to avoid any effects associated with changing climatic conditions or technical drift. No epidemics occurred during the survey. White children only were studied.

A questionnaire was developed in both English and Afrikaans, the respondent being the child's mother. Questions were asked concerning duration of residence and schooling in the area, respiratory symptoms of the child, economic factors and smoking habits of the parents. The questionnaire was issued a few days prior to spirometry and had to be signed by a parent if permission was given for the child to participate in the study. A response rate of more than 90% was achieved.

The vitalograph (Model S, Vitalograph Ltd, Buckingham, England) was used for lung function measurements while standing and provided a hard copy of the expiratory spirogram as well as a print-out of several indicators of respiratory function calculated by a microprocessor. The best results out of a minimum of 3 attempts and a maximum of 5 were used for analysis. All tests were performed by one experienced technologists. Height and weight of children were measured without shoes, jacket or jersey and recorded to the nearest 0,5 cm and 0,1 kg, respectively, using one Detecto commercial scale. The survey of children commenced on 8/5/85 and was completed on 3/10/85.

For categorical data in 2 x 2 tables, initially Fisher's exact test was applied; when the numbers were large, the chi-squared test using Yates' correction was applied. A p-value < 0,05 was regarded as indicative of possible differences. Bonferroni's correction for multiple tests was not applied in this probing investigation. A stepwise logistic regression analysis was used to evaluate the risk factors for the various symptoms and the corresponding odds ratios were calculated (Table III). The 2 groups (exposed, unexposed) were tested for lung function differences by means of a covariance analysis with those variables which could affect lung function as independent variables, namely, duration of residence and schooling in the area and cigarette smoking and fuel used in the home (Table V). The BMPD package was used in the calculations which were done on the IBM 4381 computer of the SA Medical Research Council. In the text and the tables, children from schools in the study area in the ETH are referred to as "exposed" children, and those from schools in the control areas as "unexposed". The former area is also referred to as "polluted".

RESULTS

These are tabulated (Tables I to VI). After correcting for age, children in the exposed area were 0,83 cm shorter than those in unexposed areas (p = 0,035). Cough, wheeze, asthma and colds involving the chest occurred significantly more often in exposed than unexposed girls. In answer to the question, "has your child ever had asthma?" there were more affirmative responses for exposed than unexposed children but this was significant for boys only.

In Table III data are shown for boys and girls separately and for both sexes combined (total) but only if the odds ratio is greater than one. The independent variables were a) resident in the area for more than 2 years; b) attended schools in the exposed area; c) came from homes where there were cigarette smokers; d) came from homes where electricity was used for cooking. Earache and hay fever were less common in exposed than unexposed boys ($p = 0{,}01$ and $p = 0{,}004$ respectively). Mothers of children in the exposed group were more often cigarette smokers than mothers in the unexposed ($p = 0{,}0005$) but amongst the smokers there was no difference in the number of cigarettes smoked/day. The smoking habits of the husband/breadwinner were similar in both groups, as were the number of people in the household and the number sleeping in the same bedroom as the child. On this basis and the nature of the husband's occupation socio-economic status was similar in both groups. In the homes of the exposed children, electricity was used for cooking almost exclusively, but in 18% of homes of unexposed children other fuels were used.

Table IV shows the results of the lung function tests (spirometry). There are no statistically significant differences between exposed and unexposed children except for the vital capacity and the peak expiratory flow rate both of which are lower in the exposed boys, and the vital capacity which is lower in exposed girls. However, when the results are standardized and adjusted for sex, height, weight and age, as well as other confounders (duration of residence and schooling in the area, fuel used and cigarette smoking in the home), (Table V), these differences are abolished.

Pollution data available for South Africa have been collated and analysed in a series of reports from the National Physical Research Laboratory of the Council for Scientific and Industrial Research for the period October 1980 to September 1986.[5-7] As at September 1986, smoke was measured at 146 sites by 37 municipalities and sulphur dioxide (SO_2) at 108 sites by 24 municipalities. Over the total survey period, 1980-1986, smoke pollution was decreasing at 56% of sites, unchanged at 39% and increasing at 5%. SO_2 was decreasing at 33% of sites, unchanged at 53% and increasing at 14%.[6] With the exception of an increase in smoke pollution in the central city area of Pietersburg and an increase in the sulphur dioxide level in a low density residential area of Witbank, all centres in the study area or adjacent areas show a decrease or no change.

A detailed analysis of the published measurements for 1980-82 and 1982-84 (ie, the 4 year period immediately preceding the study) indicates that within the study area measurements are available for three towns, Springs, Witbank and Middelburg. Only for Middelburg are there measurements for both smoke and SO_2 in both residential and industrial areas of the town. For Witbank only residential area measurements are available for the complete four year period. For Springs measurements are confined to the industrial area (Table VI).

In the control area measurements are available for only one town, Pietersburg, and these are for smoke only. Measurements for Nelspruit (smoke only) may with caution be extrapolated to represent Sabie and Lydenburg and with somewhat greater caution the measurements of smoke at Klerksdorp might be taken to represent the levels at Wolmaransstad (Figure, Table VI). However, atmospheric pollution tends to be local rather than general and even within each town there is considerable variation in pollution levels. Note that there is no clear difference between the measurements available for the study and control areas, although both visible smoke and smell suggest otherwise.

DISCUSSION

In the ETH, the levels of air pollution by smoke and SO_2 are not high by international standards. In the European Community Survey on the relationship between air pollution and respiratory health in primary school children[8] the smoke and SO_2 ranges were 5-60 $\mu g/m^3$ abd 20-160 $\mu g/m^3$, respectively. In their study of 22 337 children aged 6-11 years no consistent relationship between air pollution levels and respiratory health could be demonstrated, and by their criteria our pollution levels are low.

Our study was not ideal. We lacked measurements of pollution in most of our control areas and correlated symptoms and lung function with smoke and SO_2 only. Other pollutants such as oxides of nitrogen, ozone and acidity and peaks rather than mean levels may be more relevant to health but this is controversial. It is possible that an increased awareness of the pollution problem by residents in the ETH led to more positive responses to questions about symptoms.

We found that respiratory symptoms were significantly commoner in exposed children, particularly girls. This was also true for colds involving the chest where cigarette smoking in the home was a contributing factor. The European Community Survey[8] found that "there was some evidence for an increase in respiratory symptoms resulting from tobacco smoking in the home". In a recent review of the health effects of environmental tobacco smoke[9] it is stated that the incidence of pneumonia and bronchitis in children showed a positive gradient with smoking by parents but more studies are required.

The facts that mothers of children in the ETH were more often cigarette smokers than in the control areas ($p = 0{,}0005$) might tend to exaggerate the differences due to community air pollution. On the other hand, the fact that in the households in the ETH electricity was used almost exclusively, while in about 18% of homes in the control areas gas, coal or other fuels were used, would tend to decrease the differences due to community air pollution. Melia *et al*[10] reported that respiratory illness in white primary school children in England was significantly associated with the combined use of gas cookers and paraffin heaters at home. These cause indoor air pollution, particularly with nitrogen dioxide. Our study showed an increased risk of chest illness in boys from homes where fuel other than electricity was used.

In our study, earache and hay fever in boys are commoner in the control areas. Possibly the latter is related to the more rural environment with more allergens. Asthma is slightly more common in exposed than unexposed children, particularly boys, and is more common in boys (6%) than girls (4%) (Table II), as has been widely reported.[11] It seems possible that children with a predisposition to asthma might manifest the condition in a polluted area whereas it might go undetected in an unpolluted area.

We found that children in the exposed (polluted) area were shorter than those in the control areas. There are many possible reasons for this difference besides a possible adverse effect of air pollution, including exposure to cigarette smoke in the home.[12] We did not ask about ethnic origin as this might be a sensitive subject, but we speculate that the population in the heavily industrialized ETH includes many immigrants from Southern Europe, whereas the control, more rural areas, consist mainly of the taller indigenous population. Growth is a product of the continuous and complex interaction of heredity and environment; and different factors may affect the rate or tempo of growth and size, shape and body composition of the child.[13] The difference in height that we noted between exposed and unexposed children confirms a similar observation by Coetzee *et al*[3] and warrants further investigation.

Although our control areas were carefully selected using available data, information on air pollutants in these areas is sparse. It is possible that differences in pollution between the study and control areas were less than anticipated during planning, thus making it more difficult to detect differences in respiratory health status.

Nevertheless, we conclude that respiratory symptoms and illnesses are commoner and stature is shorter amongst children in the ETH than in the control areas but the differences between the groups are slight. Monitoring of air quality needs to be extended to cover more areas in the Republic of South Africa and more pollutants need to be measured including ozone and acidity. Longitudinal studies would be valuable in order to assess the long term effects of air pollution. Black children who tend to be exposed to much indoor and community pollution should be studied.

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TABLE I

		BOYS			GIRLS		
		Exposed	Unexposed	P-value	Exposed	Unexposed	P-value
AGE (Years)	n	504	445		527	533	
	x	10,5	10,6	0,006	10,4	10,5	0,001
	sd	0,71	0,72		0,67	0,68	
WEIGHT (kg)	n	504	445		527	533	
	x	34,51	35,57	0,016	34,55	35,66	0,012
	sd	6,95	6,52		70,01	7,22	
HEIGHT (cm)	n	504	445		527	533	
	x	140,63	141,45	0,002	139,82	141,45	0,001
	sd	6,72	6,61		7,59	7,52	

TABLE II
RESPIRATORY SYMPTOMS : POSITIVE ANSWER

	BOYS			GIRLS		
Question	Exposed	Unexposed	P-value	Exposed	Unexposed	P-value
Morning cough usually	33/504	24/444	0,55	29/527	10/531	0,002
%	6,5	5,4		5,5	1,9	
Day/night cough usually	57/500	33/442	0,05	63/523	36,531	0,005
%	11,4	7,5		12,0	6,8	
Wheeze ever	66/503	45/445	0,15	49/526	33/531	0,08
%	13,1	10,1		9,3	6,2	
Wheeze often	22/63	18/45	0,69	28/49	7,32	0,003
%	34,9	40,0		57,1	21,9	
Colds involve chest	170/502	161/443	0,47	191/525	140/530	0,001
%	33,9	36,3		36,4	26,4	
Asthma	38/503	19/443	0,05	24/527	19/532	0,51
%	7,6	4,3		4,6	3,6	
Bronchitis	82/502	79/445	0,62	83/527	69/533	0,22
%	16,3	17,8		15,7	12,9	
Pneumonia	2/500	5/444	0,26	10/524	7/528	0,48
%	0,4	1,1		1,9	1,3	
Other chest illness	26/501	17/441	0,41	25/524	16/531	0,19
%	5,2	3,9		4,8	3,0	

Slight discrepancies in numbers answering positively are due to a few incomplete or illegible replies.

TABLE III

ODDS RATIOS AND CONFIDENCE INTERVALS FOR SYMPTOMS IN RELATION TO RISK FACTORS

Dependent Variable	Group	Independent Variable	Categories	Odds Ratio	95% C.I.
Morning cough usually	Boys	Fuel	Elec : Other	2,44	0,90 - 6,59
	Girls	School	Exp : Unexp	1,72	1,20 - 2,49*
	Total	School	Exp : Unexp	1,33	1,07 - 1,64*
Day/night cough usually	Boys	Fuel	Elec : Other	1,76	0,98 - 3,17
	Girls	School	Exp : Unexp	1,38	1,11 - 1,72*
	Total	School	Exp : Unexp	1,34	1,14 - 1,56*
Wheeze ever	Girls	School	Exp : Unexp	1,22	0,97 - 1,54
	Total	School	Exp : Unexp	1,20	1,03 - 1,39*
Wheeze often	Girls	School	Exp : Unexp	2,14	1,29 - 3,65*
	Total	Fuel	Elec : Other	1,66	0,86 - 3,18
Colds involve chest	Girls	School	Exp : Unexp	1,23	1,08 - 1,40*
	Girls	Cigs	Yes : No	1,16	1,00 - 1,33*
	Total	School	Exp : Unexp	1,09	0,99 - 1,19
Earache	Boys	Durres	2Y : 2Y+	1,28	1,07 - 1,54*
	Boys	School	Unexp : Exp	1,24	1,06 - 1,46*
	Total	Durres	<2Y : 2Y+	1,15	1,02 - 1,30*
Toothache	Boys	Cigs	Yes : No	1,25	1,07 - 1,46*
	Girls	Cigs	Yes : No	1,21	1,06 - 1,39*
	Total	Cigs	Yes : No	1,23	1,11 - 1,37*
Eczema	Boys	Cigs	No : Yes	1,24	0,95 - 1,63
	Girls	Cigs	No : Yes	1,35	1,04 - 1,75*
	Girls	Fuel	Elec : Other	1,47	0,93 - 2,34
	Total	Cigs	No : Yes	1,30	1,08 - 1,57*
Hayfever	Boys	School	Unexp : Exp	1,27	1,08 - 1,498
	Total	School	Unexp : Exp	1,15	1,03 - 1,298
Asthma	Boys	Fuel	Elec : Other	2,42	0,89 - 6,54
	Total	School	Exp : Unexp	1,26	1,02 - 1,55*
Pneumonia	Boys	School	Unexp : Exp	2,38	0,81 - 6,99
	Total	Cigs	Yes : No	1,48	0,97 - 2,26
Chest Illness	Boys	School	Exp : Unexp	1,40	0,97 - 2,01
	Boys	Fuel	Other : Elec	1,88	1,18 - 3,00*

All symptoms enquired for are listed as dependent variables, except eye irritation and bronchitis for which there were no significant differences between groups.

Total = boys and girls combined;
Elec = electricity;
Exp = exposed;
Unexp = unexposed;
Cigs = cigarettes;
Durres = duration of residence;
<2Y = 2 years or less;
2Y+ = more than 2 years;
* = statistically significant.

E IV

TION TESTS

[illegible]	GIRLS		
	Exposed	Unexposed	P-value
	527 2,12 0,40	533 2,19 0,39	0,01
	527 2,29 0,42	533 2,31 0,41	0,31
	527 2,01 0,37	533 2,04 0,37	0,25
	527 88,13 5,27	533 88,27 5,23	0,67
	2,39 0,64	527 2,45 0,68	533 0,14
	0,49 0,13	527 0,49 0,15	533 0,85
	527 0,96 0,40	533 0,98 0,41	0,38
	253,58 57,15	527 257,18 55,30	533 0,30

TABLE V

LUNG FUNCTION VALUES ADJUSTED FOR VARIOUS CONFOUNDERS

Test	Group		N	Adj Grp Mean	Sex	Height	Weight	Age	Dur Res	Dur Sch	Fuel	Cigs	Grp Prob
					P-values								
VC (ℓ)	Boys	Exp	496	2,36		0,0	0,0	0,048	0,351	0,700	0,396	0,630	0,861
		Unexp	436	2,36									
	Girls	Exp	522	2,15		0,0	0,0	0,063	0,343	0,199	0,455	0,094	0,813
		Unexp	519	2,16									
	TOTAL	Exp	1018	2,25	0,0	0,0	0,0	0,008	0,946	0,204	0,283	0,418	0,947
		Unexp	955	2,25									
FVC (ℓ)	Boys	Exp	496	2,51		0,0	0,0	0,009	0,898	0,839	0,318	0,750	0,098
		Unexp	436	2,48									
	Girls	Exp	522	2,31		0,0	0,0	0,047	0,943	0,084	0,136	0,246	0,025
		Unexp	519	2,28									
	TOTAL	Exp	1018	2,41	0,0	0,0	0,0	0,002	0,989	0,229	0,093	0,525	0,004
		Unexp	955	2,37									
FEV_1 (ℓ)	Boys	Exp	496	2,16		0,0	0,0	0,004	0,990	0,583	0,213	0,011	0,118
		Unexp	436	2,14									
	Girls	Exp	522	2,03		0,0	0,0	0,014	0,753	0,201	0,159	0,295	0,061
		Unexp	519	2,01									
	TOTAL	Exp	1018	2,09	0,0	0,0	0,0	0,000	0,836	0,538	0,077	0,380	0,012
		Unexp	955	2,07									
FEV_1/FVC %	Boys	Exp	496	86		0,464	0,014	0,396	0,620	0,311	0,626	0,0	0,965
		Unexp	436	86									
	Girls	Exp	522	88		0,734	0,013	0,159	0,700	0,955	0,850	0,006	0,608
		Unexp	519	88									
	TOTAL	Exp	1018	87	0,0	0,970	0,000	0,151	0,579	0,520	0,928	0,005	0,732
		Unexp	955	87									
FMEF (ℓ/s)	Boys	Exp	496	2,42		0,0	0,081	0,048	0,871	0,412	0,671	0,001	0,439
		Unexp	436	2,39									
	Girls	Exp	522	2,42		0,0	0,013	0,029	0,814	0,841	0,553	0,775	0,929
		Unexp	519	2,41									
	TOTAL	Exp	1018	2,42	0,454	0,0	0,002	0,005	0,986	0,469	0,521	0,038	0,516
		Unexp	955	2,40									
FMFT(s)	Boys	Exp	496	0,53		0,137	0,261	0,238	0,910	0,683	0,943	0,0	0,866
		Unexp	436	0,53									
	Girls	Exp	522	0,49		0,290	0,322	0,092	0,152	0,332	0,605	0,785	0,773
		Unexp	519	0,48									
	TOTAL	Exp	1018	0,51	0,0	0,119	0,123	0,061	0,319	0,634	0,651	0,001	0,777
		Unexp	955	0,51									
FEF (ℓ/s)	Boys	Exp	496	0,93		0,0	0,072	0,168	0,349	0,086	0,439	0,003	0,439
		Unexp	436	0,92									
	Girls	Exp	522	0,96		0,0	0,255	0,167	0,950	0,662	0,428	0,219	0,858
		Unexp	519	0,96									
	TOTAL	Exp	1018	0,95	0,015	0,0	0,047	0,082	0,660	0,472	0,327	0,485	0,510
		Unexp	955	0,94									
PEF (ℓ/m)	Boys	Exp	496	271		0,0	0,002	0,002	0,597	0,777	0,049	0,169	0,420
		Unexp	436	273									
	Girls	Exp	522	257		0,0	0,001	0,0	0,997	0,517	0,806	0,253	0,258
		Unexp	519	253									
	TOTAL	Exp	1018	263	0,0	0,0	0,0	0,0	0,721	0,503	0,136	0,090	0,752
		Unexp	955	263									

N = number of subjects; Adj Grp Mean = adjusted group mean; Cigs = cigarette smoking in the home; Dur Res = duration of residence in area; Dur Sch = duration of attendance at present school; Fuel = fuel used for cooking in home; Grp Prob = group probability; Total = boys and girls combined. Other abbreviations as in Table IV.

TABLE VI

ROUNDED WINTER MEANS FOR ATMOSPHERIC POLLUTION IN SELECTED TOWNS IN THE TRANSVAAL

		1980-81	1981-82	1982-83	1983-84
Smoke (S/m^3)					
Study area					
Witbank	Residential	6	5	4	5
	Industrial	12	nd	nd	nd
Middelburg	Residential	7	8	10	5
	Industrial	8	65	5	6
Springs	Industrial	17	15	11	11
Control area					
Pietersburg	Commercial	nd	nd	3	3
	Industrial	nd	nd	5	4
Klerksdorp	Commercial	nd	nd	4	4
Nelspruit	Residential	nd	nd	3	3
	Industrial	nd	nd	6	9
Sulphur Dioxide ($\mu g/m^3$)					
Study area					
Witbank	Residential	21	22	21	22
	Industrial	18	nd	nd	nd
Middelburg	Residential	14	14	13	26
	Industrial	18	13	12	14
Springs	Industrial	38	41	31	43
Control area		nd			

nd = no data available

S/m^3 = soiling index, defined as darkening potential of smoke and soot suspended in 1 m^3 of atmospheric air and collected on a circular area 32 mm in diameter of Whatman No. 42 filter paper. The concentrations are measured by comparing the light transmission through the clean and then exposed paper.

Conversion factor: Smoke $\mu g/m^3$ = S/m^3 x 5 (approximately).[17]