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Personal exposure to total suspended particulates of adolescents living in Vanderbijlpark, South Africa

Personal monitoring of exposure to air pollution is becoming increasingly important in health studies as a method of characterizing total exposure. We monitored the exposure of 31 teenagers to total suspended particulates (TSP) over a 12-hour period as part of the Vaal Triangle Air Pollution Health Study. Sampling for TSP was performed at 1.9 l min^{-1} and concentrations were determined gravimetrically. A time/activity diary was completed by the participants. The results indicated that the subjects were exposed to unhealthy levels of particulates (more than 50% of measurements exceeded the US and World Health Organisation guidelines), boys had higher exposures than girls and exposures were higher on non-school days than on school days. Additional monitoring was done on 22 of the original 31 teenagers. Each participant carried two monitors simultaneously, one sampling respirable particulates and one total suspended particulates. Sixty-three per cent of suspended particulates found in the 22 co-located samples taken in the Vanderbijlpark atmosphere was respirable. The subjects spent between 58 and 75 per cent of their time indoors. The results also demonstrated that the proposed methodology is feasible and can be used in a larger scale study.

Particulate matter (PM) is generally accepted as the most common air pollutant.[1] The health effects caused by inhalation of particulates are dependent on the size of the particles and their chemical properties.[1,2] The US Environmental Protection Agency (EPA) and the World Health Organization (WHO), amongst others, acknowledge the importance of controlling PM to protect human health and have introduced corresponding health standards.[3] PM is therefore considered as a pollutant which has to be regulated and controlled by law. Standards are available for exposures to TSP (260 μg per m^3 per 24-h US standard and 120 μg per m^3 24-h WHO SA guideline) as well as for respirable PM (150 μg per m^3 24-h US health standard).[2]

Throughout the world, individuals are exposed to air pollution wherever they go. It is therefore important to determine not only outdoor pollution levels to predict exposure, but also to quantify the contribution of other locations to total exposure.[4,5] Total human exposure is a function of the time spent in contact with various pollutant concentrations.[6] A time/activity study can complement those on personal exposure by collecting data on how much time an individual spends in various surroundings.[4,8] This is a relatively new and accurate method of determining an individual's exposure to specific air pollutants.[7] Since the effects of air pollution are dose-related, accurate exposure information is necessary for evaluating its consequences to health.[4]

Available data are insufficient and inadequate to provide much needed information regarding the exposure of South African children to air pollution. A major study, known as the Vaal Triangle Air Pollution Health Study (VAPS), aims to characterize this hazard to children as accurately as possible.[9,10]

The pilot study on personal monitoring of total suspended particulates, respirable particulates (RSP) and time/activity patterns reported here was conducted during November and December 1990 and February 1991 in the Vaal Triangle (VT). This region is known as the industrial heartland of the country and is situated on the South African Highveld.[9,10] High levels of TSP have been reported for the area.[10] The objectives of the study were to: test the methodology; monitor personal exposures to TSP/RSP; determine the TSP/RSP ratio; and identify the logistical problems of personal monitoring and completing a time/activity diary.

Methods

Pupils from the Afrikaans High School Vanderbijlpark were asked to participate in the study. Participants were selected from

the group involved in the main VAPS health study[9,10] and for whom a health questionnaire was completed. Information on parental smoking, household characteristics, location of home, socio-economic status and respiratory tract symptoms were therefore available. Informed consent was obtained from each participant's parents before monitoring began. Subjects were trained and informed about the requirements for carrying the monitor and maximum cooperation was requested. Pupils were instructed to follow their normal daily activities while carrying the monitor. Lightweight monitors (SKC and Gill Air Model 224-43 XR) were carried on three different days, a school day, a Saturday and a holiday (also a weekday) during November and December 1990. Monitoring was done at a flow rate of 1.9 l min^{-1}. Glass-fibre filters, housed in a cassette (carried within the breathing zone of the child), were used to collect the particulate matter. The monitoring period for each session was 12 hours starting at 8:00 and ending at 20:00. The monitors were switched on by the field workers and switched off by the children at the end of the recording period. The exact monitoring time was recorded. Acclimatization of the filters and gravimetric analysis were done according to the standard procedures of the South Africa Chamber of Mines adapted from the National Institute for Occupational Safety and Health (NIOSH).[11] Time-activity diaries were completed during the monitoring period. Each recorded time spent indoors, outdoors and travelling in fixed hourly intervals.[8] Participants also completed a short questionnaire on logistical problems related to the monitoring programme, which addressed: problems experienced while carrying the monitors, whether the child smoked and how the monitors were accepted by their friends and the general public. All participants were acknowledged for their co-operation, and received a T-shirt with the logo 'Vaal Triangle Air Pollution Health Study' on it. The VAPS questionnaires were distributed to collect information on indoor sources of air pollution, respiratory tract symptoms and perceptions about air pollution.[10] The questionnaire was completed by the mother of the participant.

Twenty-two of the 31 teenagers from the school who participated in the first monitoring project were asked to take part in a second study, whose objective was to monitor exposures to TSP and RSP. These pupils were requested to carry two lightweight personal monitors simultaneously for a 12-hour period during a school day. One of the monitors contained a glass-fibre filter which was housed in an open head cassette to sample TSP. The other monitor sampled RSP and was fitted with a cyclone with a 7 μm cut-off point. Glass-fibre filters were also used for the RSP monitoring. Monitoring was done at a flow rate of 1.9 l min^{-1} for both TSP and RSP measurements. The filter containers were worn within the breathing zone of the participant. The monitoring period was scheduled for 12 hours starting at 08:00 and ending at 20:00. The same methodology used in the first TSP monitoring study of 31 participants was used to analyse the filters. The participants were informed about the requirements for carrying the monitors before informed consent was obtained from the parents. The children were encouraged to follow their normal daily activities.

Results

Thirty-one teenagers, 15 boys and 16 girls (median age 16 years), participated in the study. The median monitoring time for the TSP group was 12.1 hours and for the TSP/RSP group 11.9 hours. Two individual monitoring sessions were unsuccessful, one due to pump failure and one monitor was tampered with. Data were therefore collected from over 90% of participants.

Of the 31 children monitored, 15 had been living in the Vaal Triangle for more than 5 years (12 since birth). None of the participants lived in a house where coal and wood were used as primary household energy sources. No usage of humidifiers, air scrubbers or air conditioners was reported. Twenty-eight of the 31 households had natural ventilation — windows were opened daily in 21 of the homes and more than twice a week during the winter season in 6 of them. Twenty-two households had mould and mildew growing on internal surfaces.

Parental smoking was reported in 16 of the households; in four of them only mothers smoked, in 10 only fathers smoked and in two households both parents were smokers. Of all the adult (parent) smokers, 6 reported that they smoke 1 – 19 cigarettes per day, while 7 smoked 20 – 39 cigarettes per day. Three of the 31 teenage participants admitted that they smoked.

Medically confirmed allergies were reported by 6 of the 31 participants. Symptom frequencies reported by the 31 subjects for 'the past year' were: bronchitis 7; pneumonia 2; running nose 20; earache 11; hay fever 4; and sinusitis 8.

General questions on personal views indicated that 29 of the 31 respondents considered the air pollution as serious whereas 2 considered it as 'not critical'. The majority blamed industries and mines for the pollution. Seventeen respondents noticed unpleasant odours regularly in their neighbourhood.

The average TSP concentrations measured on the school day, Saturday and holiday were 126 μg m^{-3} (26 – 248 μg m^{-3}), 168 μg m^{-3} (56 – 537 μg m^{-3}) and 231 μg m^{-3} (119 – 629 μg m^{-3}), respectively. Fifty-one per cent of all measurements indicated exposures above the 24-hour EPA standard of 260 μg m^{-3} after only 12 hours of monitoring, while 57% of measurements exceeded the WHO guideline of 120 μg m^{-3} per 24 hours on average.[3,12,13] Personal monitoring results are however not completely compatible with results of high volume sampling.

Statistical analysis using the Wilcoxon test indicated that the median concentrations measured on the school day were significantly lower ($P < 0.008$) than the measurements taken on the Saturday. Concentrations on the school day were also significantly lower ($P < 0.001$) than those for the holiday. The measurements for Saturday were not statistically different from those of the holiday ($P < 0.5$).

No significant difference was found between the TSP exposure of boys and girls on the school day and Saturday. Girls, however, had a significantly higher TSP exposure during the holiday than boys ($P < 0.02$) (Fig. 1).

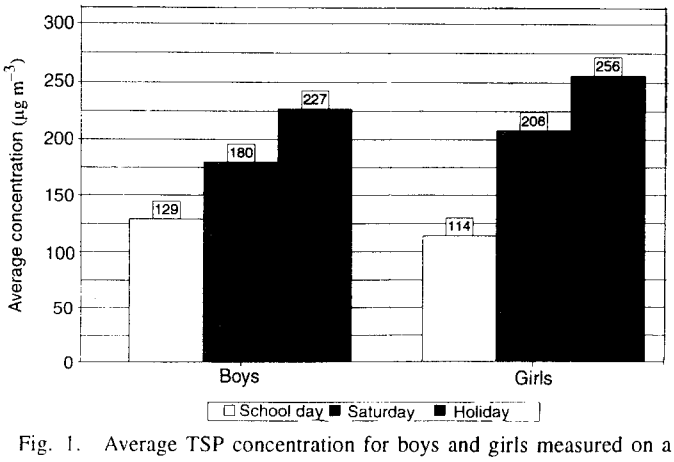

Fig. 1. Average TSP concentration for boys and girls measured on a school day, Saturday and holiday in Vanderbijlpark.

No significant difference was shown between concentrations measured on two of the three days (school day and holiday), when comparing smoker and non-smoker families. However, concentrations measured for households with one or more smokers were significantly higher on the Saturday ($P < 0.038$) compared to non-smoker families; average TSP concentration in smoker homes was 219 μg m^{-3} versus 153 in non-smoker homes. This implies that exposure to cigarette smoking could potentially have an effect on total exposure of children on the Saturday only, due to the presence of parents who smoked (source of air pollution).

When comparing the concentrations measured for non-smoker households only, on the school day versus the Saturday, no significant difference was found. There was, however, a statistically significant lower value measured on the school day versus the holiday ($P < 0.007$) as well as for the Saturday versus the holiday for non-smoker families ($P < 0.03$). In contrast to non-smoker homes, the concentrations measured in households where the parents smoked were significantly higher on the Saturday versus the school day as well as for the holiday versus the school day ($P < 0.02$ and $P < 0.001$ respectively). No significant difference could be found for concentrations measured on the Saturday versus the holiday ($P < 0.2$).

There was no significant difference between the areas in which the pupils lived (i.e. the location of major sources of particulates) and the concentrations measured for the three monitoring days. The average TSP concentration measured was 370 μg m^{-3} (range 120 – 759 μg m^{-3}), while the average RSP concentration measured was 212 (43 – 395) μg m^{-3}. The ratio for RSP (PM-7):TSP was 0.63 (range 0.35 – 0.98). The RSP concentrations exceeded the TSP measurements in seven of the 22 monitoring sessions. These samples were excluded from the ratio analysis; the higher RSP measurements could possibly be attributed to switching of samples during field collections.

The median percentage of time spent indoors on the school day, Saturday and holiday was 75%, 58% and 71%, respectively. The median time spent travelling was 0% (all < 1 hour) on all the different days.

No major problems were experienced during the monitoring sessions except that the pupils sometimes found the running pump too noisy. Although comfortable, the pupils were a little self-conscious about carrying the pump in public and this could have inhibited their normal daily activities.

Discussion

We judge this personal monitoring programme to have been successful and co-operation from the pupils exceeded 90%. The TSP measurements exceeded the 24-hour US health standard of 260 μg m^{-3} after a 12-hour monitoring period in 51% of the monitoring sessions. It has to be kept in mind that the sampling technique used for personal monitoring differs from the high volume sampling methods used for setting the health standard.[12] The WHO 24-hour guideline of 120 μg m^{-3} was exceeded in 57% of the measurements.[1]

Personal exposure to TSP is easily monitored compared to RSP, which requires the use of cyclones and is extremely sensitive to predetermined flow rates. However, particulate matter which is of a size that can deposit deep in the human respiratory tract is of real concern.[1-3] The ratios reported in the literature for PM_{10} and TSP vary between 0.50 and 0.78 for a variety of fixed outdoor samplers.[14] The ratio between PM_{15} and TSP, using high volume samplers, was found to be 0.71 in one study[15] compared to the PM_7 : TSP ratio of 0.63 (0.35 – 0.98) in this project. This ratio corresponds to reports in the literature and is considered useful in the evaluation of potential health risks.

Although this was a limited pilot study, the results indicated that the exposure of the pupils to total suspended particulate matter in the Vaal Triangle was high, which is not surprising in view of the multiple sources of particulates in the area.[9,10] Fixed outdoor monitoring stations have also recorded levels of TSP exceeding the US 24-hour health standard.[10] The difference between exposures of participants living in smoking and non-smoking homes for the Saturday and the school holidays needs further investigation. The results of this study imply that despite the high overall outdoor levels of TSP in Vanderbijlpark,[10] children living in homes where there are smokers have significantly higher total exposure to TSP than those from non-smoking homes. The study demonstrated that the proposed methodology was feasible and applicable to local conditions. Personal monitoring of air pollution exposure is currently being conducted on a larger scale in the VAPS.

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