Original article

Dust exposure levels among treet sweepers in Bole Sub-City, Addis Ababa, Ethiopia

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Abstract

Background: Intensive manual street sweeping has been performed over the last three years in Addis Ababa to optimize the cleanliness of the surface of the street and make it convenient for public use. Street sweeping is a job, but it is a job that also has a direct link with the health of the sweepers. Street sweepers are severely exposed to street dust. Yet, the level of dust exposure among the sweepers has not been documented in Ethiopia.

Objective: The aim of this study was to assess the level of exposure of dust to street sweepers in Addis Ababa city.

Methods: An exposure study was conducted among 10 street sweepers, measuring exposure levels for four working days. The measurements were performed by total dust samplers (37 mm Millipore plastic cassette with a PVC filter) attached to the breathing zone of the workers. Gravimetric analysis of the filters was done using a Mettler Toledo XPE105 micro-balance (detection limit 0.01mg). The sampling cassettes with filter were conditioned in desiccators for 24 hours before weighing. A survey data sheet and an observational checklist were used to record exposure attributes. Data were analyzed using SPSS Version 20. The exposure levels were compared with the threshold limit value for total dust recommended by the American Conference of Governmental Industrial Hygienists of 10 mg/m^3.

Results: The study participants covered a total of 1km, and were sweeping from 6:00-9:00 am. The participants were assumed to constitute one similar exposure group as all sweepers covered four operations in performing the street sweeping: sweeping the street surface, collecting dust and litter in one place, putting it in a container and then disposing it at a disposal site designated for this purpose. The median dust exposure level (n=19 samples) was 10.71 mg/m^3 (IQR=7.43). This is above the threshold limit value of 10 mg/m^3. Eleven of the samples exceeded the occupational exposure level. The exposure level did not vary significantly between sampling days. This indicates that the exposure variability is consistent across the four sampling days.

Conclusion: The studied street sweepers were exposed to dust levels that exceeded the recommended exposure level. Additional comprehensive research in a larger exposed population is suggested to further identify the most important determinants for high exposure levels among street sweepers. Studying characteristics of the street dust is another suggested area for future research. [*Ethiop. J. Health Dev.* 2017;31(4):236-243]

Keywords: Street sweeping, dust, exposure level, Addis Ababa, Ethiopia

Introduction

Street sweeping is a routine practice in many cities to clean up debris and sediments from road surface for aesthetical reasons as well as for prevention of pollution of the street environment. However, street sweeping generally disperses road dust into the air and is believed to expose the surrounding population. Dust is an air borne solid particle whose size generally ranges from 1-100 µm (1). The aerodynamic size of a dust particle is an important factor that determines its behavior in the air.

Larger particles settle on the ground surface because of their weight that is drawn by gravity. The smaller particles (<10 µm), however, remain suspended in the air for long (2) and might thus be inhaled. The health-based threshold limit value (TLV) for total dust (also denoted as nuisance dust or particulates not otherwise specified (PNOS), by the American Conference of Governmental Industrial Hygienists American (ACGIH), is 10 mg/m^{3}for 8-hours exposure. The diverse aerodynamic diameter of a dust allows targeting different parts of the lung for disposition. Larger dust particles (>10µm) deposit in the upper airways and irritate the nose, eye, and throat, while smaller particles (<10µm) are likely to be deposited deeper in the airways. The lung soft tissues could be one suitable harbor. As the research in the association between exposure to dust particles and respiratory illness is advancing, total dust is now often replaced by inhalable (<100 µm), thoracic (<10µm), and respirable fractions(<4 µm) of dust (3).

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Road dust is a mixture of substances that involve vehicular emissions, dust that emanates from tires wears and brake lining; soil and plant fragments and other biological materials (4). It may contain several metals including lead, chromium, nickel and zinc from wear of brake linings of motor vehicles and wear of tires (5, 6). Road pollution may also contain many organic compounds including hydrocarbons, poly-aromatic hydrocarbons, and pesticides (6).

Street sweepers are exposed to a variety of dust sources when they are sweeping (7). A study conducted in Nigeria indicated higher mean respirable dust level in test streets compared to control streets ($0.194 \pm 0.002 mg/m^3$ Vs $0.015 \pm 0.003 mg/m^3$) (7). Exposure to excessive road dust can pose respiratory health risk due to the inhalation of such particulate matter (8). Although only a few studies have investigated dust exposure and its health effects on street sweepers, there are a number of studies of different occupations that have shown exposure to excessive dust to be associated with respiratory illness (9, 10) and decreased lung function (11-13).

Street sweepers have been involved in cleaning selected streets of Addis Ababa since the 1950's (14). The city government is now engaged in scaling up street sweeping to make streets dirt free and satisfy the well being of people who regularly use them. Street sweeping is trying to cope with the fast-growing nature of the city's road infrastructure development. The growing demand of street sweeping in recent years has created an employment opportunity as well. Street sweeping using manual operations in Addis Ababa involves workforce of about 5000 organized small microenterprises under waste management authority (14, 15). The geographical coverage of street sweeping has been increased over the last three years to optimize the cleanliness and standards of the streets. The majority of street sweepers have low socio-economic and educational status. They live in poor housing conditions(16).

Generally, street sweeping in Addis Ababa takes place daily from early morning to midday. The condition they work in, in terms of occupational safety and health, is not well documented. Street sweepers do not often take necessary precautions against inhalation of dust. They cannot get dust masks to wear, for example. Also, they cannot water the streets to minimize the dispersion of dust in air (7). They use traditional brooms to manually clean the litter from the dried street surface. This increases the level of dispersed dust in air and the sweepers' exposure to dust.

The aim of this study was to assess the total dust exposure level among street sweepers in Addis Ababa, Ethiopia. Although this study was a pilot study, the findings from this study would create awareness among street sweepers and policy makers. Above all, this study can serve as baseline data for further studies.

Methods

Study design and area: An exposure study was conducted in one of the widely-served streets which is located close to the Bole International Air Port in Addis Ababa. The specific name of the street is *Bole-Brass Street.* The street stretches from Bole Brass Maternity Hospital to Bole Medhani-Alem Church. This street is part of what is formally known as *Cameroon Street.* The sub city is purposely selected for the study. This is because a fairly large number of street sweepers (n=704) are involved in this activity in this area in Addis Ababa.

Selection of the street site and study participants: The Bole-Brass Street was selected purposely. There are reasons for this purposeful selection. One is accessibility. Also, the street gets swept twice a day. Yet another reason, large amount of street dirt is thought to characterize the street. Proximity of the street to data collectors' team is the other factor for selecting the street for the study. The study participants work from 6 am to noon in the morning shift. The present study involved 1 km long stretch of the street that is served by paired teams that had 5 street sweepers each (Figure 1). The street is swept daily by two teams. Sweeping in the morning shift goes from 6 am – to 12 a. m, (noon). The afternoon shift is from noon to 6 p.m.

The street sweeping teams had one male supervisor who supervised the activities of the cleaners. He also facilitated the logistic support and assisted in all other areas needed during the working hours.

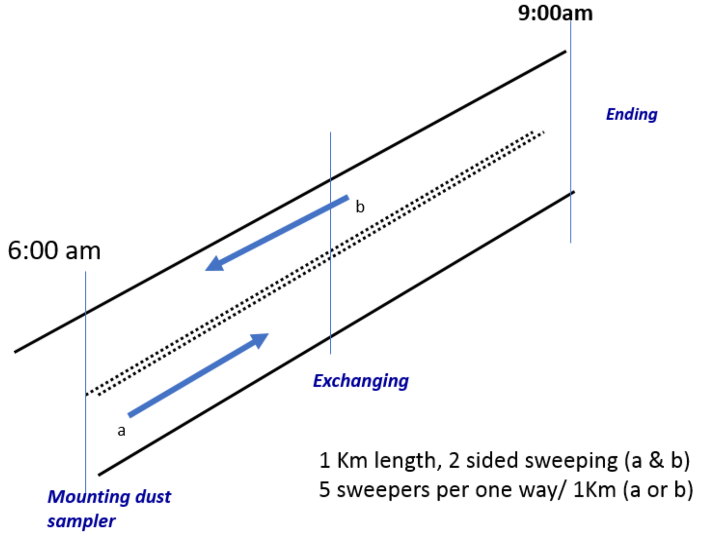
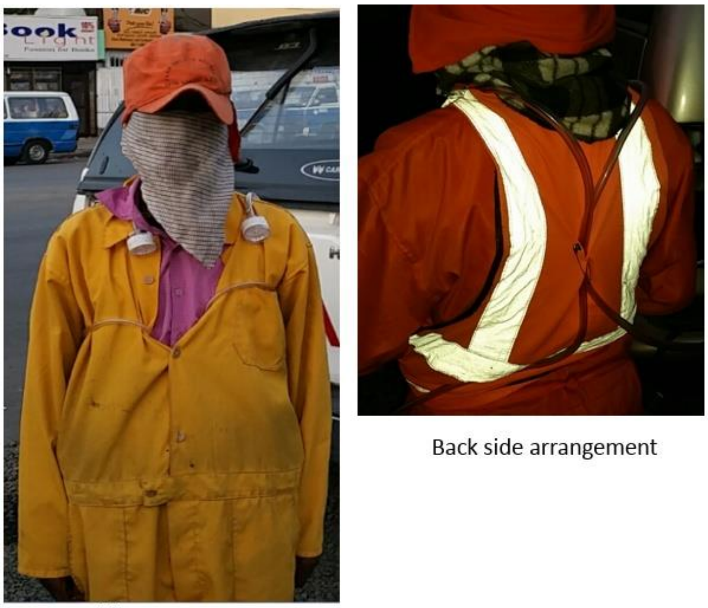


Figure 1: **Context of street sweeping**

Sampling and Sample size determination: The sampling method followed the US National Institute of Occupational Safety and Health (NIOSH) recommended guideline (17). The sample size was determined based on Rappaport et al (2008). According to Rappaport et al 5 to 10 randomly selected individuals with 10-20 measurements of exposure per similar exposure groups (SEG) are adequate to estimate the exposure level for dust sampling(18). We assumed that the street sweepers constituted one SEG. They do the same kind of activities. They use similar equipment in a similar work environment and for the same duration. Given the above provisions, ten street sweepers were randomly selected to undertake a total of 20 dust measurements; five samples on four consecutive days. This amount of sample is believed to be adequate to estimate the exposure level in a similar exposure group(18) . There are other established practices in sample size determination which is similar to the assertion of the recommendation of Rappaport S, Kupper L (19-22).

Data collection and measurement: The study was conducted from 22nd-25thNovember, 2016 in Addis Ababa (i. e, for 4 days, 5 samples per day). Personal total dust was sampled in the breathing zones (about 30cm from the workers nose) using a 37mm diameter of Millipore plastic sampling cassette fitted with polyvinyl carbonated (PVC) filters of 5µmpore size connected to Side Kick Casella (SKC) pumps operating at 2l/min (Figure 2). The position of the sampling head was on both sides (left and right), having each 50% of the sampling duration with the purpose of getting about equal measurements in both sides. The position of the neck (hence breathing position) is expected to adjust the flow of the swept dust in air.



Front side arrangement

Figure 2: **Typical sampling arrangements, Nov 2016 (Source: Photo Abera K)**

Street dust samples from sweepers were taken in the time period of 6 to 9a.m., although the full shift was from 6 to 12 a.m. We believed the greatest exposure occurs in the morning in the streets of Addis Ababa because of the relative cold temperature that tends to hold the dust in a suspended state. In addition, this sampling time (6 to 9 am) was chosen to make sure that the sampling would not result in an overload of the filters. During the preliminary survey, the researchers stayed at the site and observed that the dust levels were high during the time designated for data collection. The selection of this sampling duration is consistent with NIOSH manual on occupational exposure strategy (19, 20). The NIOSH manual makes consideration of using either day long or using a portion of time with the assumption that the exposure levels are similar.

Two trained data collectors were involved in instructing the study participants in a central location, mounting the sampling instruments on the body of the study participants. They also recorded exposure related data of the participants during air sampling. The coded samples were kept in the Environmental and Occupational Health (EOH) laboratory at the College of Health Sciences of Addis Ababa University.

Data analysis: Twenty personal dust samples were analyzed gravimetrically using a standard microbalance scale (*AT261 Mettler Toledo*) at Environmental and Occupational Health (EOSH) laboratory of College of Health Sciences, Addis Ababa University. This laboratory was established with the grant obtained from the Norwegian Agency for Development Cooperation (Norad) through the Norwegian Program for Capacity Building in Higher Education and Research for Development (NORHED) in 2015 to facilitate dust analysis that is required for post-graduate researches. A trained laboratory technician carried out the pre- and post-weighing activities.

Exposure data was recorded in an excel spread sheet that was exported into SPSS Version 20 for descriptive analysis. The distribution of dust concentration in a linear scale was skewed (Shapir of W test: df-19, p=0,011), and because of this, the median was used to describe the exposure level.

The air concentration of dust was calculated using the following formula:

$$\text{Concentration (mg/m}^3\text{)} = \frac{\text{(Post weight of filter-Pre-weight of filter, mg) - Blank weight (mg)}}{\text{Flow rate (lit per min) * Sampling duration (min) * 1000 lit/m}^3}$$

The gravimetric analysis was made at room temperature and relative humidity of 18-20ºC and 50-55%, respectively.

Out of twenty dust measurements, one was omitted from the analysis, as the sampling head was found to be frequently covered with a personal cloth that was dressed around the neck during sampling (code 12AA). The central tendency and variability of the results were described using median and inter quartile range (IQR).

The median concentration was compared to the American Conference of Governmental Industrial Hygienist (ACGIH) TLV for inhalable dust of 10 mg/m^3 (23, 24) assuming the exposure level is the same in the rest of the work shift.

Data quality assurance: Field blanks were used to correct any weight changes caused by atmospheric conditions and the handling of the samples during transportation and sampling in work places. After sampling was completed, the sampling head was capped and transported to the laboratory for post-weighing. PVC filters were not taken out of the cassettes until weighing was made at the laboratory. This requires 24 hours of conditioning in desiccators. The samples and blanks were transported in the same way to the laboratory in a labeled container suitable to prevent damage or disturbance. To do this, the standard operative procedures (SOP) was followed to ensure the quality of weighing using the microbalance. The position of the sampling head was checked every 30 minutes by field supervisors. Field supervisors consistently observed the study participants throughout the study period.

Ethical Considerations: Informed verbal consent was obtained from participants. Information obtained from the participants was coded and stored in a computer without using names of the participants. Participation was fully on a voluntary basis. Verbal consent was also obtained for photos taken to demonstrate the dust sampling condition. The sampling procedure did not inflict any harm and created any disturbance during the data collection period.

Participants were informed that they had the right to withdraw or discontinue participation in the research at any time. The consent information promised to provide the results of the study to the subjects on request.

Results

Socio-demographic characteristics: A total of 10 street sweepers with an average age of 27.5 years, were included in the study. Nine of the participants were females. High school was the highest education level.

Street sweeping description and its operation: A traditional hard broom made of sticks of a plant (a straw broom) is used to clean the floor of the street (Figure3). The fibers of the broom tightly overlap. This helps in collecting, drawing and pulling fine particles to the required collection site. The members of the street sweeping team covered four operations in a sequence: sweeping, collecting the debris and litter at one site, putting it in dust bin, and finally disposing it in a bigger waste container (Figure 3). The allocation of a worker to a given sweeping operation is decided internally, which follows an agreed principle of first come first served.

Observations related to dust exposure: Occasionally, the plume of the dust was very visible, and on many occasions during intense sweeping, it appeared to cover the whole body of the person sweeping. The position of the sampling cassette did not seem to matter much to be on the right or left side of the body, as the sweepers alternately used the right or left hand (personal observation).

The sweepers have adapted the way of positioning their body depending on their needs for the operation of the sweeping, either sweeping to the right or left.

Our observations indicated that the highest exposure during the day occurred when the sweeper is in the front-line of the sweeping, i.e. the first operation when they sweep the surface of the street and collect the dirt in one place. Collecting and disposing the litter/dust seemed to produce fairly low exposure. However, no task-based samples were taken confirm this variability.

The exposure to dust presumably depended on the time covered and the intensity of sweeping. The first km had much sweeping and heavy dust plumes, as the sides are routinely busy with accommodating taxis and road-side businesses such as street food selling and many other nameless petty things. These activities are known to involve massive human movements which leave themselves things like litter, dirt, papers, plastic bags, leaves and straws of *khat*, used mobile phone cards, card boards, and debris (Figure 3).

Figure 3: **Street sweeping: a-Sweeping; b-collecting; c-dumping litters into dust bin; d-Sorting litters, Nov 2016**

Personal exposure to dust: The arithmetic mean (SD) of overall dust concentration was 12.87 mg/m^3 (4.91) ranging between 7.78 - 24.93 mg/m^3. The median (IQR) was 10.71 (7.43) mg/m^3. On the four sampling days, the median exposure concentrations were 9.32 mg/m^3, 10.62 mg/m^3 17.10 mg/m^3 and 10.71 mg/m^3, respectively. There were no significant differences in exposure concentration between the four days (Kruskal-Wallis test; Chi sq, df (3.85, 3), p= 0.278) (Table 1).

Table 1: **Summary of dust exposure levels in Bole Brass Street, Bole Sub City, Nov, 2016, Addis Ababa, Ethiopia**

Day number	n	Sampling duration, minutes	Dust exposure concentration (mg/m^3)	
		Median (IQR)	Median (IQR)	Arithmetic Mean (SD)
1	5	154 (13)	9.32 (3.82)	9.93 (1.96)
2	5	138 (10)	10.62 (6.50)	12.39 (3.51)
3	4	151 (28)	17.10 (9.77)	16.49 (5.28)
4	5	144 (30)	10.71 (10.75)	13.37 (6.83)
All days 1-4	19	147 (17)	10.71 (7.43)	12.87 (4.91)

NB: The dates of Day 1, Day2, Day3, and Day 4 were: 22/7/2016, 23/7/2016, 24/7/2016, 25/7/2016, respectively

Discussion

The median dust exposure level for the street sweepers in Bole-Medhanilam Street was 10.71 mg/m^3. This exceeded the TLV of inhalable dust level of 10 mg/m^3 (23, 24). This high level of dust exposure resulted from the traditional technology of street sweeping which involved manual operation on a dry surface that generated and suspended dust around the breathing zone of the workers.

The dust exposure did not vary between the measurement days. This is probably due to the similarity of the tasks carried out by the sweepers on the sampling days, and the relatively similar weather conditions of the data collection days. However, dust concentration will probably vary between different categories of streets due to different conditions such as difference in road surfaces, traffic volume, human activities and weather conditions. Dust measurements over longer period of time and in different type of streets may reveal the impact of such possible determinants of exposure.

The exposure to dust during active street sweeping is not only targeting the task performers. Streets always become busy every day from 6 am in Addis Ababa (researchers' observation). Human mobility is high. There are pedestrians along the street who also, like street sweepers, can be exposed to dust.

The dust exposure levels are believed to be of multiple natures. For instance, different heavy metals were detected at high levels in the street dust because of industrial and vehicular activities in cities of Kavala (Greece) and Beijing (China) (25-27). As the street dust in Bole-Brass dust is the result of heavy traffic that may result in generating known toxic chemicals in levels exceeding their specific limit values(24). The current measurement of the dust exposure among street sweepers is a major endeavor in the field of occupational health involving exposure measurement using available resources in Ethiopia.

The validity of the measurements is ensured following standard operating procedures of filter weighing and maintaining constant the flow rate of measurements. Also the sampling instruments were properly handled in the laboratory and during sampling in the streets. However, this exposure assessment may not be fully representative since it included only a few of among 5000 street sweepers in the city. It also covered only a small part of one street.

The study had three main methodological limitations. First, the Millipore plastic sampling head has inherent characteristics in underestimating the coarse particles in the inhalable dust fraction. Werner *et al*. (20) reported ratios of inhalable to total dust in different industries to vary from 1.8 to 3.2, and higher ratios were explained by sampling of coarse aerosols. Street dust contains a wide range of particle sizes including coarse particles with aerodynamic diameters > 50 µm. Since the sampling head used in the present study is known to underestimate these coarse particles, the inhalable fraction of the street dust could be up to about three times higher than the total dust fraction sampled in this study (28). Thus, the inhalable fraction for the street sweepers is believed to be considerably higher than the current ACGIH TLV level of 10mg/m^3 for the inhalable fraction (29-31).

Second, the investigators did not have a complete control over the study participants in fixing the sampling head correctly around the breathing area, despite the efforts made by field supervisors to adjust conditions and fix the sampling head properly. This may have led to underestimation of the measured dust concentration.

Thirdly, the best way to measure exposure to dust is to cover the whole working time. However, in this study, it was assumed that the tasks were similar in the morning and therefore considered using half of the work time in the morning shift. This was decided because the dust sampling head used in the study had inherent characteristics of becoming overloaded. This decision did not interrupt the sampling. The sampling strategy used for the given time was based on established practices (19, 20).

Conclusion and Recommendations:

The street sweepers covered in this study were exposed to dust exposure levels higher than the ACGIH recommended level. We recommend expanding the present pilot study to a wider scale. A comparative exposure assessment that involves diverse exposure categories of streets, which will involve characterizing the dust and identifying possible determinants, might help. Undertaking dust speciation study of street dust and determining the prevalence of respiratory illness among the workers, together with exposure assessments, are feasible research areas.

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Competing interest
Authors declare having no competing interests in the publication of this report.

Authors' Contributions
AK carried out protocol development, data collection, data management and analysis, and writing the manuscript. SW was involved in the conception of the research idea; managed the project implementation, and wrote the manuscript. WD, BE, MB, SM were involved in protocol development, project implementation, writing up and editing the manuscript. BT was involved in designing the laboratory SOP and ensuring the laboratory data quality.

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