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RESEARCH PAPER

Particulate Matter and Adverse Respiratory Health Outcome: Exposure of Street Vendors in Kolkata city in India

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ABSTRACT

Exposure to airborne particulates is a major occupational hazard especially for outdoor workers who spending time outdoors at ground level getting exposed to traffic fumes and roadside dust. Aim of this study was to assess respiratory health symptoms and determine the change of lung functions of the roadside vendors and its association with traffic-related exposures and their working experience. A cross-sectional study was conducted in key market places of Kolkata – Gariahat (GH), Esplanade-Park Street (EP), Shyambazar-Hatibagan (SH) and Behala (BE). Particulate (PM_{10} and $PM_{2.5}$) levels and meteorological parameters (wind speed, temperature and relative humidity) were monitored in the morning, afternoon and night over the period of October 2019 to February 2020. Lung function status (FEV1, FVC, FEV1/FVC ratio and PEF) was measured for 111 purposively selected participants. PM concentration was observed higher in the morning and night peak hours for all sites. At SH area the average occupational exposure level for PM_{10} and $PM_{2.5}$ were observed as 1502.22 μg/m^{3}h and 684.01 μg/m^{3}h. Percentage predicted FEV_1 (%FEV_1) of street vendors was found decreasing with their work experience and the worst-case scenario was observed in the EP area, with the corresponding value being 70.75%, 49.15% and 47.3% for less than 10 years, 10 to 20 years and more than 20 years participation respectively. The higher particulate burden was observed to have declining lung function status of the street vendors. A strong policy framework should be adopted to improve outdoor working environment for outdoor workers.

Keyword: Urban environment, Air pollution, Occupational exposure, Outdoor workers, Respiratory symptoms

INTRODUCTION

Research from around the world indicates that human exposure to air pollution along the roadside is higher compared to indoor, ambient and outdoor away from roadside (Amegah & Jaakkola, 2014; Jones et al., 2008).There are three possible health hazard of inhaling large amounts of air pollutants during outdoor exercisers or long time exposure. Firstly, minute

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ventilation during exercise increasing quantity of pollutants inhaled (Greenwald et al., 2019). Secondly, with effectively bypassing nasal mechanisms large particles and soluble vapors inhaled through the mouth during exercise. Thirdly, the increased airflow carries pollutants deeper into the respiratory tract (Carlisle & Sharp, 2001). Additionally, pulmonary diffusion capacity has been shown to increase with exercise (Turcotte et al., 1992; Gupta & Elumalai, 2017). Exposure to airborne particulates is a major occupational hazard especially in roadside pavements where levels of exposure may be unacceptably high. The risk of exposure is higher for the street vendors compared to those traders with businesses having permanent built up structure, because of the poor working environment, lack of awareness of potential health hazards associated with long exposure to airborne particulates, and lack of use of personal protective measures such as using of masks etc. The working conditions of street vendors expose them to a range of occupational hazards putting their livelihoods and well-being at risk (Amegah & Jaakkola, 2016). Street vendors, who mostly work and spend time outdoors at ground-level, are one important susceptible and vulnerable population subgroup who are at risk to exposures and adverse risks associated with traffic fumes from passing vehicles (Kongtip et al., 2006; Noomnual & Shendell, 2017), roadside dust (Loomis et al., 2013) and further, environmental and occupational noise exposure (Barbaresco et al., 2019). Airborne particulates exposure poses a serious threat to human health. Epidemiological studies show that urban air pollution exposure is associated with adverse respiratory outcomes including upper respiratory symptoms (runny or stuffy nose, sinusitis, sore throat, wet cough, cold, and eye irritation), lower respiratory symptoms (wheezing, dry cough, phlegm, shortness of breath, and chest discomfort or pain), asthma, chronic bronchitis, chronic obstructive pulmonary disease and lung cancer (Dockery & Pope, 1994; Haque & Singh, 2017; Kongtip et al., 2006; Manojkumar & Srimuruganandam, 2019). Regarding associated adverse health effects, the studies (Domingues et al., 2018; Ruchirawat et al., 2005) reported that biomarkers of early biologic effects i.e. observed levels of DNA adducts and highly DNA-damaged cells among street vendors to be significantly high. The review indicated that the studies are suggestive of possible development of diseases such as cancer later in life among the workers. According to the studies, street vending was also associated with increased risk of sore throat, cold, cough, eye irritation, dizziness, hearing impairment, and musculoskeletal problems (Gupta & Elumalai, 2017; Jones et al., 2008). Adverse reproductive outcomes including infertility, miscarriage, low birth weight, and preterm birth have also been reported among street vendors (Amegah & Jaakkola, 2014; Melody et al., 2019). Mainly Young adult street vendors, who are typically aged 18-34 years are affected, but 35-44-year-olds are considered as an even more vulnerable subgroup of workers as it affects their remaining years of life expectancy, child- bearing age, etc. (Noomnual & Shendell, 2017).

In India, the Street Vendors Act (protection of livelihood and regulation of street vendors) was enacted in 2014 and this act defined the rights and obligations of street vendors. According to this act the total number of street vendors in the country is projected at about 10 million and urban vending is not only a source of employment but provides 'affordable' services to the majority of the urban population. However, the act does not cover any subject related to their health perspectives. Also, worldwide there is limited research on the health effects more specifically respiratory health of street vending activities. In Hong Kong, China, one study determined the lung function parameters and respiratory symptoms between roadside vendors directly 'exposed' to traffic fumes and vendors working in 'protected' air-conditioned shops along the same road (Jones et al., 2008). In Bangkok, Thailand, a study estimated self-report adverse respiratory health outcomes including fatigue, cough, dizziness, eye irritation, headache, and nasal congestion among young adult street vendors (Noomnual

& Shendell, 2017). In Dehradun City, India, a study estimated the corresponding respiratory deposition dose in alveolar, trachea-bronchial and head airway regions on street vendors working at the Residential and Commercial marketplace (Prabhu et al., 2019).

With reducing opportunities in organized industrial sector and agriculture has pushed large percentage of West Bengal population to informal economy and in terms of number of unorganized sector employment as well as enterprises and this state now ranks second in India (Planning Commission, 2010). It is estimated that about 1.6 million population in West Bengal works as street vendors, where in Kolkata city their numbers are 270,000 to 300,000, excluding mobile vendors in local trains and buses or those who move about push-carts. As their job requires hard physical labour, an overwhelming 97% of Kolkata's hawkers are male and near about 80% of them are in the 25-45 age bracket (Roy, 2014). In India and similar developing countries, widespread urban poverty and the dependence of poor families on single income sources means street vendors have to work throughout the day even if they become ill with severe consequences. It is against this background the study objective is to investigate whether working as a street vendor in Kolkata, impairs respiratory status and evaluates to what extent exposure to air pollution due to street vending is responsible for these adverse effects. The relationship between street vendors occupational exposure to particulate pollutants and adverse respiratory outcomes with working experience years remains unexplored. As such, a study of exposure to air pollution among roadside vendors will close the existing gap of knowledge in the scientific field and help in generating recommendations to protect this specific group of workers.

MATERIALS AND METHODS

A cross sectional study was conducted among street vendors at Kolkata megacity 22°30´ North latitude and 88°30´ East longitude, altitude of 9.0 m above mean sea level, with a total area of 206.08 km^2. This city is the main port of entry in North-Eastern India and 120 km from the Bay of Bengal and stands on the eastern bank of river Hooghly. As per the 2011 Indian census report, this metropolitan city had a population density of 24252 persons per km^2, and a total of 4.5 million people and 14.1 million in Kolkata district. In this present study four busy marketplace areas of Kolkata where potentially large number of participating street vendors are present have been selected. The selected four sampling sites are Gariahat, south of Kolkata (GH), Esplanade-Park street, central part of Kolkata (EP), Shyambazar-Hatibagan, East of Kolkata (SH) and Behala, west of Kolkata (BE). Those four areas are selected in terms of high traffic flow as these areas are the key areas of Kolkata and most importantly the number of street vendors presence in these areas are significantly very high rather than the other marketplace in Kolkata. Facilities like security for field investigators, housing space for instruments and electrical connection for monitoring work are provided by local market committee members. Figure.1 shows the sampling locations where air quality was monitored. GH is a mixed type of marketplace (both residential and commercial market area) characterized by 2 leaned 2 roadways with high traffic intersections and several shopping complexes. EP is a commercial area characterized by a busy office area, shopping complex, government buildings and numerous food stalls and numerous traffic intersections. SH and BE areas also have a mixed type of market place area with narrow residential streets and busy market place and additionally numerous food stalls and many educational institutions, offices are present. Air quality at the GH and EP areas are mainly influenced by vehicular exhaust, roadside dust resuspension, commercial activities, and open burning of papers and solid waste, whereas the SH area is also influenced by roadside coal combustion and most importantly narrow roadways which creates obstacles in dispersion of the particulate matter. In the BH area one of the important sources of Particulate matter are roadside dust resuspension and ongoing metro construction activities.

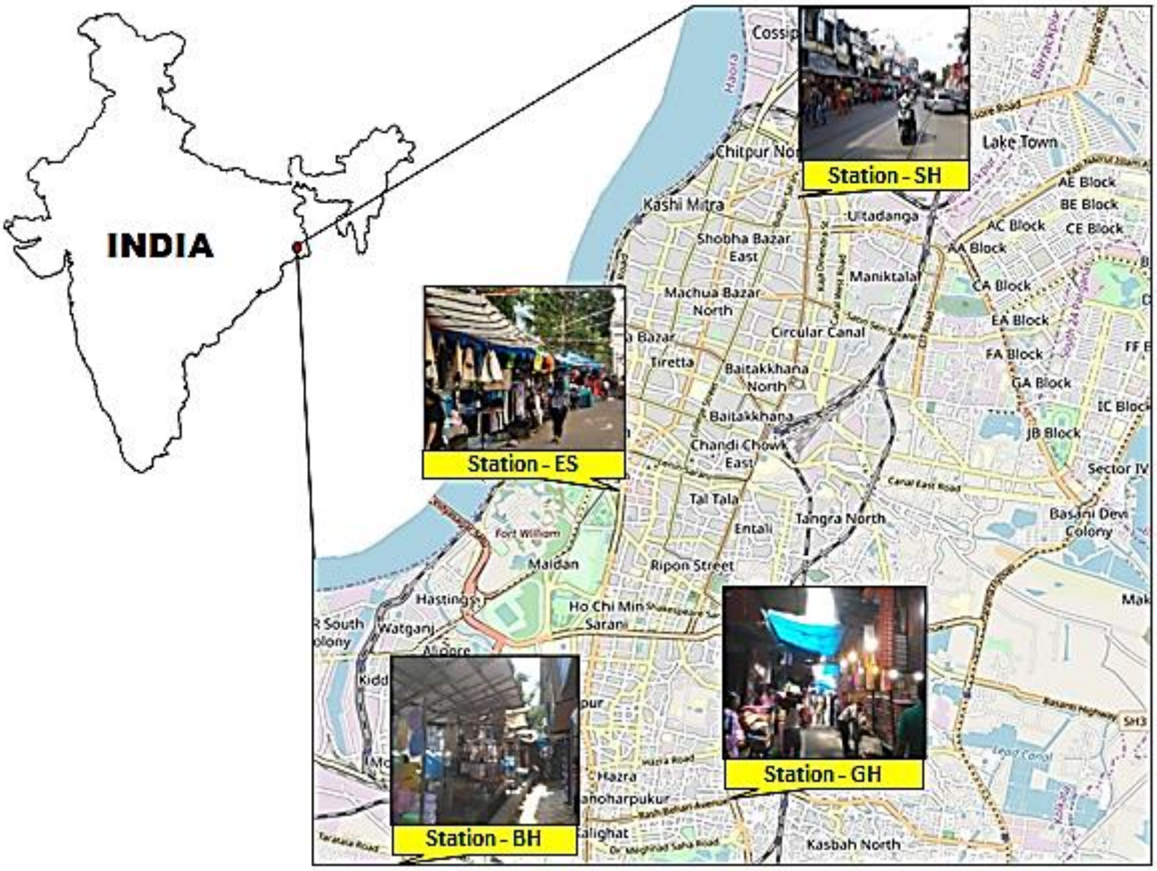


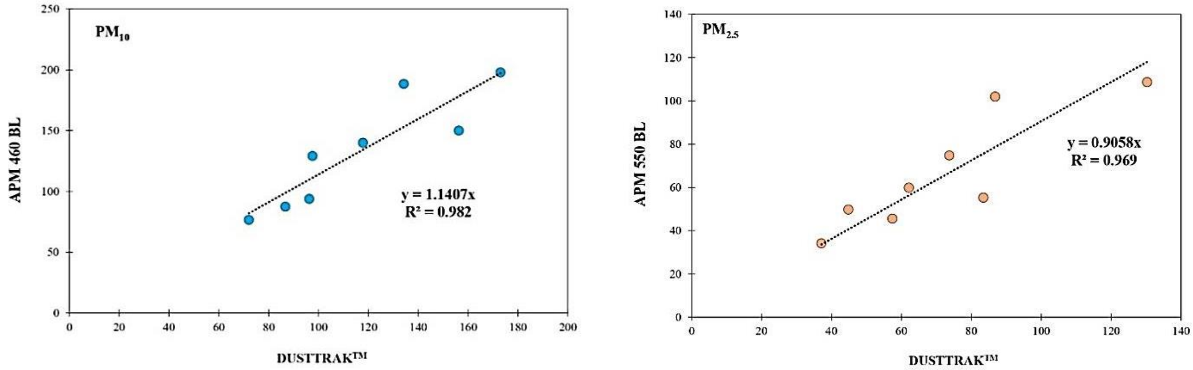
Figure.1: Map of the selected study area

The air pollutant and meteorological parameters data has been collected in varying time schedules on weekdays (Monday to Saturday) during the dry season, from the month of 19^{th} October 2019 to the month of 28^{th} February 2020. The air pollutants sampled are respirable coarse PM_{10} (Particle size ≤10 μm) and fine fractions $PM_{2.5}$ (Particle size ≤2.5 μm) whereas the meteorological parameters include wind speed (m/s), temperature (°C) and relative humidity (%). To cover different peak and non-peak hours, the 2 hours of 3 sampling time spans have been chosen for different sampling days as 9:00 am to 11:00 am (morning slot), 1:00 pm to 3:00 pm (afternoon slot) and 6:00 pm to 8:00 pm (evening slot). Total 15 days data was collected at GH site, where 13 days data was collected from EP, SH, and BE site. The real-time PM concentrations were monitored as per NAAQS 2009 guidelines using high quality laser photometer-based aerosol monitor DUSTTRAK™ (model 8530, TSI Inc. Mn), which worked under Beta Attenuation Monitor (BAM) technology (Figure.2a). The air quality monitoring device was placed at a height of 1.5 m from the ground level by a tripod stand to ensure that the pollutant concentration was measured at the human breathing zone, as the street vendors in the city stand during their working hours. In order to study the impact of local meteorology on particulate matter concentration level, meteorological parameters at the study region were noted in every 15 minutes interval for 2 hours monitoring period by using a sensor-based anemometer device AVM 06 (Figure.2b). In Addition, wind Direction data was recorded from the nearest automated air quality monitoring station for respected areas. Monitoring based data on PM are used to calibrate the aerosol monitor device with the standard gravimetric measurement device data.

(a) (b)

Figure.2: (a) Aerosol monitor DUSTTRAK™ (model 8530, TSI Inc. Mn)
(b) Digital Anemometer Device AVM 06

Quality Control (QC) is the technique needed to fulfil the requirements for data quality. The QC procedures for the air sampling and monitoring sections of this protocol include preventative maintenance of equipment and calibration of equipment. In order to improve the accuracy and reliability for practical use, a direct comparison of High-quality laser sensors, DUSTTRAK™ device with gravimetric measurement device (APM 460 BL and APM 550 BL) parallel ambient air concentration measurements were conducted. After data collection a linear regression relationship (Figure.3a, 3b) was prepared using both DUSTTRAK™ device data and APM 460 BL and APM 550 BL data.



(a) (b)

Figure.3: Linear regression relationship of (a) PM_{10} concentration between DUSTTRAK™ device and APM 460 BL (b) $PM_{2.5}$ concentration between DUSTTRAK™ device and APM 550 BL

From the purposively selected locations, a total of 292 participants were randomly selected more precisely through fourth person rule technique, which means every fourth street hawker was interviewed for the preliminary questionnaire survey. The number of hawkers surveyed in each area varied depending on the size of the area and total number of hawker presence in the area. Out of the total participant 111 (38%) respondents participated in the lung function test. A breakdown shows that 34 respondents were from GH, 53 and 24 from EP and SH respectively, making a total of 111 complete dataset. In case of our fourth monitoring station

BE we are unable to carry out the questionnaire survey and Pulmonary Function test as the COVID19 phase 1 lockdown in 2020 was enforced in India from 24th March, after the start of the Coronavirus (SARS-CoV-2) pandemic, to reduce infection transmission rate, where in West Bengal partial lockdown started from 16th March (Singh, 2020).

A socio-economic survey was conducted using detailed questionnaire[1]. Street vendors are interviewed on some standard questions: socio-demographic characteristics (e.g., age, sex, monthly income, family size and work experience/duration (months and/or years), shift duration per day (hours)); history of diagnosed air pollution-caused diseases recommended by WHO (i.e. asthma, chronic obstructive pulmonary disease (COPD), bronchitis, allergies, dizziness, cancer, ischemic heart disease (IHD), other cardiovascular disease) for the past 5 years; smoking and alcohol consumption status; frequency and duration of physical activity. After this questionnaire survey participants are screened through a subject screening questionnaire to identify street vendors with the following criteria: (1) they did not smoke or use any protective mask, (2) they did not currently have respiratory infection, asthma, chronic bronchitis, congestive heart failure or lung cancer and (3) they were willing to participate in the study. These are finally selected 111 numbers of street vendors participate in the Pulmonary Function test (PFT).

All anthropometric measurements including weight (kg) and height (m) and the PFT were performed by trained volunteer students. Body mass index (BMI) was calculated by dividing weight in kilograms by height in square meters. BMI was categorized according to the international classification of adult underweight, overweight and obesity prescribed by the World Health Organization (WHO). Pulmonary function assessment was performed according to European Respiratory Society and American Thoracic Society guidelines using Genesis Medical System Pvt. Ltd. a windows-based spirometer named SpiroWin. In this study a disposable mouthpiece was inserted to the inlet of the spirometer for each participant, to avoid contamination. The PFT measurements included Forced Expiratory Flow in 1sec (FEV_1), Forced Vital Capacity (FVC), FEV_1/FVC ratio and Peak Expiratory Flow Rate (PEF). The tests were performed for all participants at the same time of day, between 12:00 and 16:00, once a month from January 2020 to March 2020 (Figure. 4a, 4b). Before this spirometry test each participant was told to take at least 15 mins of rest and during the test they were instructed to sit in siting position. They were instructed to take a deep breath can be taken in then the mouth placed tightly around the mouthpiece before a full expiration is performed. Next participant asked to completely empty their lungs then take in a quick full inspiration, followed by a full expiration. The readings were recorded after one or more practice attempts and the highest value among those technically satisfactory efforts were used in each case. The best values were selected and incomplete or unacceptable spirometry tests are omitted for further analysis. All used disposable mouthpieces were disposed safely and sustainably according to 2016 Biomedical waste management rules in India.

1. Questionnaire can be availed upon written request from the corresponding author.

(a) **(b)**

Figure.4: (a) Author team conducting pulmonary function test (b) collecting demographic data

In order to estimate the air pollution exposure due to PM_{10} and $PM_{2.5}$, an occupational exposure (Exp_i) has to be calculated which gives the actual exposure due to particulate pollution. Exposure index is calculated for each of the participants based on their average time spent in different time zones (micro-environments) of their working hours (Kornartit et al., 2010). Daily work time activity of each of the participants was recorded during the questionnaire survey. Next the measured concentration of PM_{10} and $PM_{2.5}$ estimated is used to develop the exposure index which is adapted from some existing literatures (Borrego et al., 2008; Sidhu et al., 2017; Kornartit et al., 2010). The occupational exposure is discussed below:

$$Exp_i = \sum_{j=1}^{n} C_j t_{i,j} \tag{1}$$

Where, Exp_i is the total exposure for person i over the specified period of time; C_j is the pollutant concentration in each microenvironment j and $t_{i,j}$ is the time spent by the person i in microenvironment j.

Microsoft Access databases were used to collate and store the air quality, questionnaire and PFT test data. As a quality control check, written questionnaire data were double entered by separate data entry staff. Data entries that did not match were compared against the original hard copies and corrected. Raw data were checked for missing values, anomalies (e.g., non-physical data such as negative concentrations, impossibly high concentrations) and any other errors (e.g., missing data due to instrument malfunction, survey and PFT test missing data and error during survey data entry). Data was removed in a manner consistent with our laboratory standard operating procedures, and thus, excluded from the analysis. Descriptive statistics were used to summarize the data. Mean ± standard deviation and range were calculated for $PM_{2.5}$ and PM_{10} levels of the grinding environment.

RESULT AND DISCUSSION

Of 292 street vendors initially approached for a questionnaire survey, 111 street vendors were purposively selected in the final study. For livelihood the products/services they sold range from accessories and cosmetics, flowers, cloth, footwear repairing services, stationery and magazines, food, snacks, beverages, etc. The street vendors who sold cook food and snacks using liquefied petroleum gas (LPG) and few of them use charcoal as fuel for cooking on site. The participation rate was 95.57% for male and 4.43% for females. Participants were mostly male (95.57%), aged above 32 years old (62.63%) and only 3.12% were below 18 years. Most of participants were with work experience of more than 10 years (70%) and work shifts durations more than eight hours per day (91.9%). These are summarized in Table.1.

Table.1: Physical Characteristics of Participating Street Vendors

Characteristic	GH (n=107)	ES (n=100)	SH (n=85)
Age Group (n %)			
<18	1.86	4	3.52
18-32	31.77	45	25.88
32-45	23.36	27	27.05
45-55	26.16	11	16.47
>55	16.82	13	27.05
BMI (M ± SD)	23.83±11.57	25.24±3.77	23.85 ± 3.83
Gender (n %)			
Male	93.45	98	96.47
Female	6.54	2	3.53
Monthly Income (n %)			
0-5000	11.21	5	11.76
5001-10000	61.68	70	77.64
10001-15000	21.49	17	10.58
15001-20000	5.6	5	0
>20000	0	3	0
Smokers (n %)			
Yes	43.92	32	63.52
No	56.07	68	36.47
Alcohol Use (n %)			
Yes	34.57	23	49.41
No	65.42	77	50.59
Years of work (M ± SD)	19.42 ± 13.6	15 ± 10.73	18.89± 16.98
Duration of work hours (M ±SD)	9.96 ± 2.94	11.18 ± 1.69	10.76 ± 2.86

***note:** *M = Arithmetic mean, SD = Standard Deviation, n = Total number of Street Vendor population, BMI = Body Mass Index*

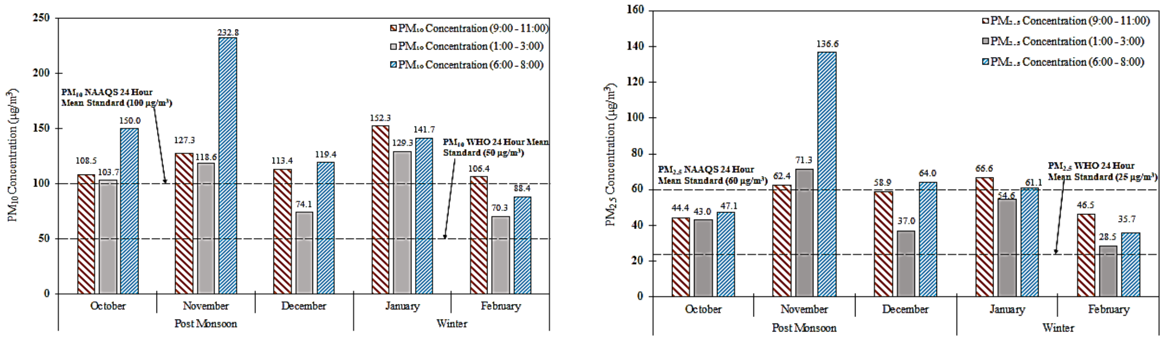
The results from self-reported disease and field observations of street vendor are summarized in Table.2. The symptom results suggested other symptoms (13.15%), i.e., headache, wheezing, fatigue, chest pain, dry throat, and eye irritation. The specific symptoms street vendors reported were asthma (17.64%), dry cough (10.62%), allergy (8.64), dizziness (5.25%), ischemic heart disease (0.7%) and other cardiac diseases (2.61%).

This study ensured more accurate PM concentration-to-exposure estimates, which possibly affected street vendor respiratory health symptoms measured. Nevertheless, the air and environmental quality monitoring in the present study is not claimed to represent the total personal exposure. As these do not include every potential exposure, particularly variation among individuals due to physiological parameters and time-activity patterns apart from working as street vendors near roadways. In addition, these health symptoms might not be highly specific to PM. These symptoms can also be caused by workload, ergonomic issues, and hypersensitivity.

Table.2: Self-reported disease among participating Street Vendors

Self-Reported Measurement (n%)	GH (n=107)	ES (n=100)	SH (n=85)
No Disease	46.72	47	51.76
Asthma	10.28	25	17.64
Bronchitis	0	0	0
Dry Cough	16.82	8	7.05
Allergy	13.08	2	9.41
Dizziness	8.41	5	2.35
Cancer	0	0	0
IHD	0.93	0	1.17
Other Cardiac Disease	4.67	2	1.17
Other Symptoms	15.88	13	10.58

Data of PM_{10} and $PM_{2.5}$ among the roadside monitored showed a wide spread in particulate concentrations, reflecting the variances in PM concentrations in the study cites (Table.3). Several factors must have influenced the variation in PM_{10} and $PM_{2.5}$ concentrations in the different roadside areas monitored such as the degree of traffic and local demography. The local micro-climatic factor of the area (Table.4) is one factor among others influencing the PM concentration as wind speed, turbulence, virtual temperature and relative humidity significantly inversely correlated with outdoor PM concentration (Elminir, 2005; Owoade et al., 2012).The built environment surrounding arterials affects the dispersion of vehicular emissions in urban areas, lack of dispersion rate causes the accumulation of PM and decreases mixing and dilution of the PM (Pan et al., 2013).The results of the studies mentioned and this study indicate excessive exposure to roadside dust among the vendors. There is no technological standard followed as regards particulate control in the vending spaces and as the vending spaces are all informally set up and are mostly covered by plastic sheets are poorly ventilated and must have resulted in high level of pollution in all the work places monitored. The high particulate concentration in the morning and night time might be explained by increased traffic rush and activity rate compared to afternoon (Figure. 5). Aside from human activity levels, temperature and humidity might have affected the concentrations of PM in the morning and night because the temperature is normally low in that time. This makes the environment moist and may further trap dust particles in the air thereby reducing the particulate concentrations in air circulation. However, as noon approaches there is a steady



(a) **(b)**

Figure.5: Monthly seasonal variation (a) PM_{10} concentration (b) $PM_{2.5}$ concentration increase in temperature, which may dry up the moist particles, thus increasing their kinetic properties thereby making them highly dispersed and more available in the atmosphere with a corresponding increase in particulate burden at noon (Iyogun et al., 2019).

Table.3: Summary statistics of peak hours (morning and evening) and non-peak hours (afternoon) PM concentrations.

Season	Monitoring period	Respirable and Fine Particulate Matter Concentration (μg/m^3) M ± SD (min–max)							
		GH - area		ES – area		SH- area		BE- area	
		PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Post Monsoon (19 Oct 2019 to 31 Dec 2019)	**Morning peak hours** (9:00 a.m. to 11:00 a.m.)	115.42 ± 34.35 (76.06-178.24)	54.54 ± 15.51 (36.53-78.65)	146.98 ± 37.5 (87.87-199.14)	71.74 ± 21.79 (45.4-116.25)	131.31 ± 50 (95.85-253.63)	62.07 ± 14.41 (37.27-85.27)	117.12 ± 63.12 (50.02-196.65)	50.15 ± 26.01 (21.77-84.35)
	Afternoon non-peak hours (1:00 p.m. to 3:00 p.m.)	99.26 ± 42.03 (50.53-197.29)	49.68 ± 27.21 (25.23-118.05)	96.44 ± 50.61 (35.59-165.16)	49.76 ± 25.11 (17.34-81.74)	92.38 ± 36.29 (33.27-152.81)	44.04 ± 18.53 (16.98-70.5)	90.5 ± 50.4 (38.32-166.48)	41.06 ± 23.15 (18.27-67.85)
	Evening peak hours (6:00 p.m. to 8:00 p.m.)	154.32 ± 77.56 (89.46-228.14)	71.73 ± 48.33 (33.17-202.9)	125.49 ± 32.71 (80.95-184.08)	62.54 ± 16.70 (38.75-89.24)	133.42 ± 61.63 (66.37-259.9)	69.24 ± 52.59 (26.35-194.02)	159.84 ± 50.8 (93.99-269.86)	70.85 ± 14.9 (33.55-83.32)
Winter (1 Jan 2020 to 28 Feb 2020)	**Morning peak hours** (9:00 a.m. to 11:00 a.m.)	117.84 ± 46.03 (51.63-152.32)	51.49 ± 22.91 (20.67-71.08)	176.02 ± 59.46 (111.61-228.82)	72.44 ± 30.22 (45.25-105.81)	176.08 ± 86.63 (90.9-305.06)	77.42 ± 41.77 (37.88-140.79)	127.71 ± 31.85 (100.26-173.39)	55.49 ± 19.21 (41.64-83.62)
	Afternoon non-peak hours (1:00 p.m. to 3:00 p.m.)	85.03 ± 34.05 (55.04-129.28)	35.05 ± 14.68 (20.95-54.07)	113.95 ± 44.83 (63.36-168.57)	44.35 ± 19.54 (25.36-70.8)	118.75 ± 62.35 (60.37-201.21)	55.34 ±33.79 (26.4-102.66)	91.66 ± 16.8 (95.7-107.28)	37.78 ± 7.86 (26.1-42.48)
	Evening peak hours (6:00 p.m. to 8:00 p.m.)	101.73 ± 46.28 (42.14-141.69)	42.07 ± 21.26 (16.25-61.12)	115.03 ± 84.91 (42.68-208.51)	54.41 ± 48.49 (15.03-108.58)	244.47 ± 196.58 (71.55-318.59)	99.82 ±73.13 (30.62-205.77)	123.99 ± 66.71 (80.89-222.32)	53.95 ± 36.34 (28.21-107.67)

***note:** *M = Arithmetic mean, SD = Standard Deviation, Max = Maximum value, Min = Minimum value*

Table.4: Summary statistics of peak hours (morning and evening) and non-peak hours (afternoon) meteorological parameters.

Monitoring station	Season	Wind Speed (m/s)	Temperature (℃)	Relative humidity (%)
GH - area	Post Monsoon	0.595	27.4	61.8
	Winter	0.507	24.7	52.025
ES - area	Post Monsoon	0.557	27.9	59.69
	Winter	0.717	24.2	56.17
SH- area	Post Monsoon	0.357	27.9	60.43
	Winter	0.423	22.9	61.07
BE- area	Post Monsoon	0.537	26.6	63.85
	Winter	0.744	24.2	53.83

From the questionnaire survey, it became clear that the average exposure time frame for street vendors is 6:00 AM-11:00 PM. So, we break this total time frame into 3 slots and each slot acts as a microenvironment of the respondents. A 17-hr occupational exposure profile is prepared using 6-hr PM concentrations measured in different microenvironments (i.e., morning peak hours, evening non peak hours and night peak hours) using the above-mentioned equation (1). It was found that (Table.5) in our monitoring station, SH area the average occupational exposure level for PM_{10} and $PM_{2.5}$ were 1502.22 μg/m^3.h and 684.01 μg/m^3.h respectively which is highest among the other two stations. In SH area the vendors are present from 9 AM to 11 PM but the maximum population present from 12 PM to 11 PM, so they are mostly exposed in afternoon non-peak hours and evening peak hours. In SH area PM concentration is more than other study areas especially in evening time where the average concentration of PM_{10} was 188.94 μg/m^3 and $PM_{2.5}$ was 84.53μg/m^3. The full stretch of SH market area is situated along the road side which is relatively narrower than Gariahat or esplanade market and surrounded by so many tall buildings. Thus, the emission from the source (mainly from automobiles) cannot be dispersed and increase the PM concentration.

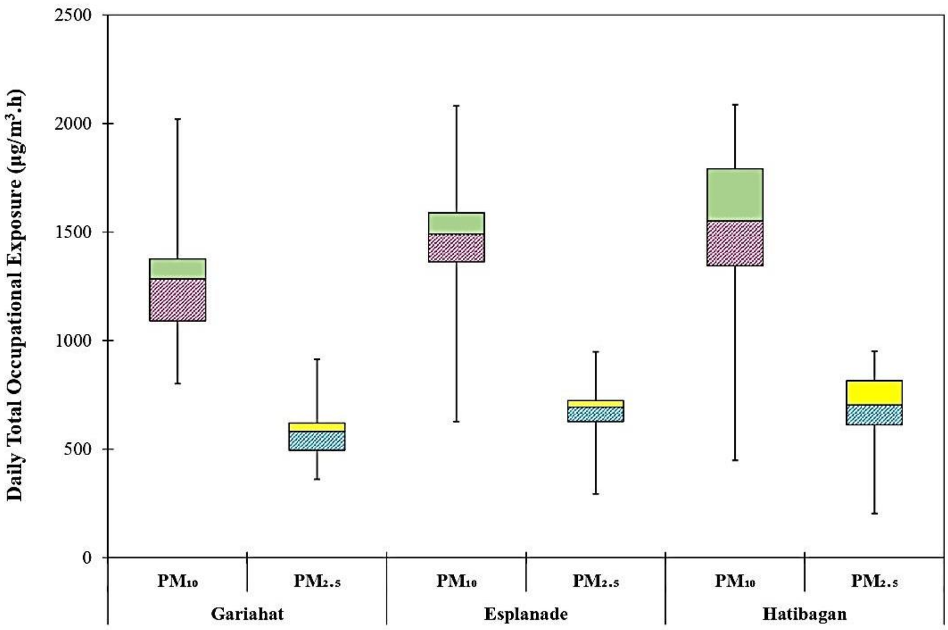


Figure.6: Occupational exposure for participants in three locations

Table.5: Summary statistics of occupational exposure level

	GH		ES		SH	
	PM_{10}	**$PM_{2.5}$**	**PM_{10}**	**$PM_{2.5}$**	**PM_{10}**	**$PM_{2.5}$**
M ± SD	1259.59 ± 279.79	569.57 ± 126.33	1445.73 ± 248.53	666.80 ± 112.85	1502.22 ± 386.18	684.01 ± 175.61
Range	2020.8 - 801.62	913.62 - 361.44	2081.24 - 627.48	948.72 - 294.55	2087.26 - 448.19	950.06 - 203.96

***note:** *M = Arithmetic mean, SD = Standard Deviation*

A total of 292 street vendors were included in the study and out of them 111 were selected for lung function tests as they did not smoke or did not currently have any respiratory disease. The average FEV_1(exp)(liters) for the three-study location was as follows: 2.46 (GH), 2.78 (ES) and 2.48 (SH); The expected(exp) value is standard value for the particular person as per his or her age, gender, weight, and height. The respective FEV_1(obs)(liters) values were 1.65 ± 0.93, 1.24 ± 0.8 and 1.8 ± 0.625 the observed (obs) values which are obtained by actual performance of that person. The highest FEV_1(avg) was recorded at SH area. The detailed summary statistics of lung function data are shown in Table.6.

Table.6: Summary statistics of lung function data of the participants during the study

Study location	**FVC** M ± SD (litre)		**FVE1** M ± SD (litre)		**FVE1/FVC (%)** M ± SD (litre)		**PEF** M ± SD (litre)		**Lung Age** M ± SD (Yrs)
	Exp	**Obs**	**Exp**	**Obs**	**Exp**	**Obs**	**Exp**	**Obs**	
GH	2.89± 0.73	2.17± 0.74	2.46± 0.66	1.65± 0.93	80.26± 2.32	72.6± 27.04	6.193± 1.17	3.502± 1.86	71.44± 37.35
ES	3.30± 0.504	2.25± 0.69	2.78± 0.47	1.24± 0.8	80.6± 2.66	56.13± 29.57	6.88± 0.73	2.8± 1.52	103.69± 35.35
SH	2.97± 0.401	2.33± 0.72	2.48± 0.38	1.8± 0.625	79.42± 2.802	78.94± 16.59	6.38± 0.68	4.0± 1.62	73.75± 28.16

***note:** *M = Arithmetic mean, SD = Standard Deviation*

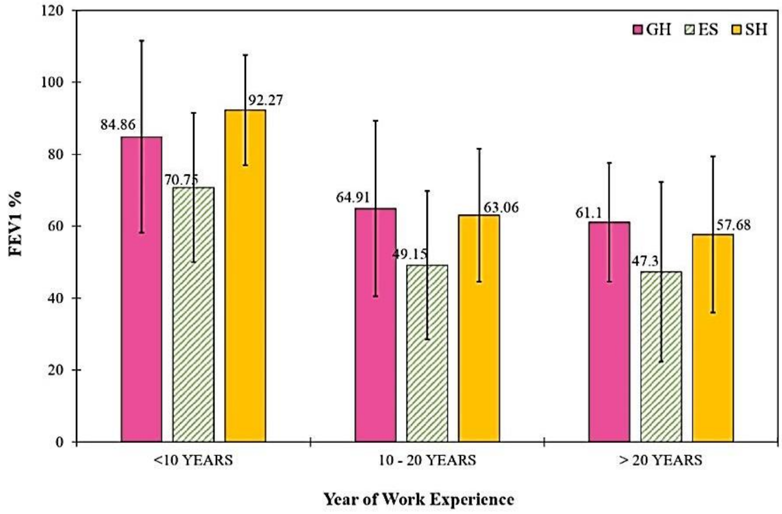


Figure.7: Variation of participant's FEV_1% with their working duration (years) at the present working place

In figure.7, A graphical representation of lung function status in terms Percentage predicted FEV_1 (%FEV_1) of street vendor was decreasing with their increasing years of outdoor work activities in the three study areas. The worst case was observed in the Esplanade area, the value was 70.75% for less than 10 years experienced participants, for 10 to 20 years experienced participants it was 49.15% and for those who worked more than 20 years was 47.3%. In the Gariahat area the values were 84.86%, 64.91% and 61.1% respectively. This reduction is not due to increasing age of subjects since each parameter was analysed as a %FEV_1 value, thus controlling for the age-related decline in spirometric values. It is likely that this decline in lung function is due to the factors such as exposure to air pollutants, fuel vapour inhalation etc. The results of air quality analysis showed that the levels of PM_{10} and $PM_{2.5}$ were higher than the maximum permissible levels, supporting the above assumption. Animal studies have demonstrated that exposure to particulate matter of the size of 2.5µm and 10µm (PM_{10}, $PM_{2.5}$) have been found to be significantly associated with reduced FVC. Similar effects of automobile exhausts and outdoor sources on the FVC and FEV_1 have been reported in petrol station workers, traffic polices, roadside vendors and shopkeepers (Chawla & Lavania, 2008; Jones et al., 2008; Sasikumar et al., 2020).

Air Pollutants put a burden on the lungs and the resulting oxidative stress is thought to contribute to the genesis of fibrotic lung diseases, chronic bronchitis, emphysema, and lung cancer. Street Vendors are particularly prone to these occupational hazards. Vehicular exhaust, particularly, organic extracts of diesel exhaust induce reactive oxygen species in macrophages and bronchial epithelial cells which are the key cell types targeted by the particulate matter in the lungs (Sasikumar et al., 2020).These diesel exhaust particles thought to be made up of carbon core are surrounded by trace metals, such as nickel and salts which adsorb organic hydrocarbons and a number of these components do have inflammatory lung effects seen in laboratory animals (Inoue et al., 2008).These observations indicate that diesel particles themselves can induce airway inflammation (Nightingale et al., 2000). We observed that the actual value of FEV_1, FVC, FEV_1/FVC ratio and PEF were reduced in street vendors as compared to predicted values (Table. 6). This shows some degree of obstruction being present in the respiratory tract of street vendors. The changes might be in the tissue of the lungs due to the chronic irritation by vehicular pollutants.

One limitation was the difficulty to recruit the street vendors as participants because of the following reasons: (1) they were too busy to participate; (2) they were scared, e.g., this study might distract them from their business activities and products and selling of the goods. Some participants, however, had a different mindset, but in that case street vendor union leaders played an important role in negotiating and convincing the local vendors to cooperate with use survey team and the process. Another limitation was that towards the end of this study period due to COVID-19 outbreak the research team could not conduct the demographic study in our pre-selected fourth study location BE. The main strength of this study was that the air pollution concentrations were collected at the roadsides, while vendors are at work and whose health indicator measurements were also taken at the same time. Moreover, there were four study locations visited; we included only locations in which street vending existed. Thus, this study ensured more accurate PM concentration-to-exposure estimates, which possibly affected street vendor respiratory health symptoms measured. However, more studies are needed, e.g., a longer duration for collecting samples; more sites on different days—weekday and weekend and times of the day; measurements in different seasons—winter and summer; measure other traffic related air pollutants like PM_1, CO, NO_x, SO_x etc. and metallic criteria air pollutants e.g. Pb, Ni, As, Hg etc., inclusion of cardiovascular and possibly psychosocial/mental health and, need to considered others vulnerable groups of people like auto-rickshaw drivers, construction workers, traffic police whose work places are all outdoor. Other than this demographic study some more socio-economic parameters and health expenditure study can help in getting more policy-oriented results.

CONCLUSION

Exposure to urban air pollution is very high and poses multiple health risks among the street vendors usually categorised as informal sector workers. Association between informal workplace exposure and health outcomes is often poorly characterized because of lack of detailed data on simultaneous environmental monitoring and health impacts. This study is a unique contribution in that respect as first-hand monitoring data on outdoor environment and roadside street vendors' individual exposure level data were collected in four market areas in Kolkata city following appropriate monitoring protocol. Randomly selected 292 vendors were interviewed and 111 were selected after applying screening criteria for pulmonary function tests based on self-reported disease history. The findings of this study show at individual level exposure to particulate matters PM_{10} and $PM_{2.5}$ impacts vendors' respiratory health symptoms as their workplace is road side and with no appropriately ventilated spaces individual work place exposures were very high ranging upto 1502.22 $\mu g/m^3$.h and 684.01 $\mu g/m^3$.h for PM_{10} and $PM_{2.5}$ respectively. As their work hours are very long from sometimes extending form 6 a.m. to 11 p.m. they are exposed to peak concentration levels during morning and peak hours due to high traffic movements and dust particles. During traffic off-peak hours i.e., during noon through afternoon as temperature rises particulate concentration also rises. The FEV_1 (Forced Expiratory Flow in 1sec), FVC (Forced Vital Capacity), FEV_1/FVC ratio and PEF (Peak Expiratory Flow Rate) of the street vendors are found to decrease depending on length of years in the occupation with high exposure, thus confirming the significant adverse health impacts of exposure of individuals to outdoor air pollution and automobile exhausts. These vendors were selected after screening for their self-reported health history and with no smoking and drinking habits, with no respiratory disease history and measurements also controlled for age and compared against predicted values. Urban vending in India provides livelihood to almost 10 million people and provides affordable products and services to consumers. So, these measurements reveal the vulnerability of urban vendors due to adverse health impact arising out of outdoor air pollution and positively varying with higher concentration levels. The study confirms prolonged exposure to outdoor air pollution due to dust, automobile exhausts and temperature cause airway obstruction by inducing chronic airway irritation and increased mucus production leading to obstructive kind of lung diseases. There is need for more larger study compared to this pilot scale study for outdoor workers like traffic police, rickshaw and autorickshaw drivers and non airconditioned bus drivers who are living with occupational hazard due to long work time related exposure to urban outdoor pollution levels to help in making policies and decisions at various levels.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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