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Biman Gati Gupta[1], Jayanta Kumar Biswas[1] and Krishna M Agrawal[2]

[1]Department of Ecological Studies and International Centre for Ecological Engineering, University of Kalyani, Kalyani, India. [2]Department of Environment Management, Indian Institute of Social Welfare & Business Management, Kolkata, India.

ABSTRACT: Hazardous bleaching and dyeing units are rapidly increasing in developing countries due to growing global demand of textile products. The aim of the study is to assess long-term respiratory effect of air pollution generated from textile bleaching and dyeing industries on the residents living in such industrial setting. Such types of long-term (2012-2016) studies have been conducted first time in this area. The control area of Chatta and Kalikapur under Maheshtala textile cluster (10.45°N latitude to 75.90°E longitude) has been identified for the study. Ambient air monitoring with particulate matters (PMs; $PM_{2.5}$ and PM_{10}), NO_2, and SO_2 of 72 air samples has been done with air sampler machine during different seasons. The concentrations of $PM_{2.5}$ and PM_{10} have been found higher than Central Pollution Control Board (India) and World Health Organization norms. Using data on 73 respondents on age, education, occupation, and income, impact on different causes of respiratory ailments has been examined. The survey shows that 67% of total population are having different respiratory complaints. The regression analysis ($R^2 = 0.9998$) and correlation matrix show that cold, cough, bronchitis, asthma, and chronic obstructive pulmonary disease (COPD) have a strongly significant positive correlation with fever ($r = 0.98$, $P < 0.05$); breathing trouble has a significant strong positive correlation with cold, cough, bronchitis, asthma, COPD, and fever ($r = 0.877$, $P < 0.05$); high blood pressure has a negative correlation with cold and fever ($r = -0.655$, $P < 0.05$); cardiovascular problem has a strong positive correlation with high blood pressure ($r = 0.989$, $P < 0.05$) and strong negative correlation with cold, cough, asthma, bronchitis, and cold-related fever ($r = -0.54$, $P < 0.05$) due to $PM_{2.5}$ and PM_{10} concentration. About 56% of villagers who have opted for this occupation have school-level education (class I-IV) with annual income of Rs 60 000 ($870) only. Studies express present scenario of air pollution in the subject area which is still unnoticed and propose to take control of air pollution.

KEYWORDS: bleaching and dyeing, air pollutants, $PM_{2.5}$, PM_{10}, health hazards

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CORRESPONDING AUTHOR: Jayanta Kumar Biswas, Department of Ecological Studies and International Centre for Ecological Engineering, University of Kalyani, Kalyani 741235, West Bengal, India. Email: biswajoy2000@yahoo.com

Introduction

Bleaching and dyeing units (800 units, located in the Maheshtala textile cluster, West Bengal, India) discharge toxic effluents without any treatment to canal, pond, and nearby agricultural land due to absence of common effluent treatment plant. They treat it neither totally nor partially in their own premises to reduce cost of production in Maheshtala cluster. Untreated toxic effluent is characterized by high pH, turbidity, bad odor, total dissolved solids (TDS), total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), chloride, nitrate, sulfuric acid, heavy metals, and low dissolved oxygen (DO), and it contaminates surface water, degrades soil, pollutes air by nitrogen and sulfur dioxides, and contaminates recipient water bodies.[1–3]

Furthermore, textile units produce atmospheric emissions during their various processes. Gaseous emissions have been identified as the second most important pollution problem (after wastewater) from the textile industry. Speculation concerning the amounts and types of air pollutants emitted from bleaching and dyeing operations has been widespread, but generally, air emission data from textile manufacturing operations are not readily available. Air emissions include dust, oil mists, acid vapors, bad odors, and boiler exhausts. Cleaning and production changes result in sludge from tanks and spent process chemicals, which may contain toxic organics and metals. Again, air emission results from combustion of diesel from two major sources: point source boilers, ovens, and storage tanks, and diffusive source solvent based, wastewater treatment, warehouses, and spills.[4]

The contamination of air affects the surrounding area both directly and indirectly.[4,5] Diesel engines and generators contribute to the problem by releasing PMs directly into the air and also emitting SO_2 and NO_2, which transform into secondary particulates in the atmosphere.[6] Particulate matters, $PM_{2.5}$ and PM_{10}, are generated during the incomplete combustion of diesel. Diesel exhaust is a group I carcinogen, which causes respiratory trouble. It contains several substances that are also listed individually as human carcinogens by the International Agency for Research on Cancer.

The aim of the study is (1) to assess health condition of the residents due to air pollution with particular reference to respiratory system such as cold, asthma, chronic obstructive pulmonary disease (COPD), breathing trouble, fever, high blood pressure, and cardiovascular problem and (2) to make a survey

Figure 1. Map showing the Kalikapur area with location for air sampling stations.

of the locality adjoining to the bleaching and dyeing cluster in the control area of Chatta and Kalikapur in terms of age, education, income, occupation, and impact on health. The findings of this study will help future researchers to know the type of diseases prevailing in bleaching and dyeing cluster and to organize further epidemiological studies particularly with respect to air pollution.

Study Area

Maheshtala (44.77 km^2) is an urban area with its administrative headquarters at Alipore of South 24 Parganas district of West Bengal and lies between 10.45°N latitude and 75.90°E longitude. Chatta canal running through Chatta and Kalikapur (1.85 km^2) and most of the new bleaching and dyeing units operating in this area have been selected for the extensive study (2012-2016) on environmental management and eco-planning. Canal receives maximum effluent from bleaching and dyeing units from these areas. Apart from that the canal also receives sewage and household wastewater from different inter-connecting drains of the neighborhood. The water carrying capacity of Chatta canal (cross section and depth) is reducing over the years due to improper cleaning and siltation. Three monitoring points (stations A, B, and C) have been selected along the stretch of Chatta to Kalikapur (500 m apart) for collection of air samples. Samples have been collected in summer, monsoon, and winter seasons. The maps of Chatta canal covering study area, West Bengal, and South 24 Parganas along with the location of Maheshtala are shown in Figure 1, 2 and 3, respectively.

The climate of the area comprises temperature (13.6-40°C), annual rainfall (1760-1800 mm), and relative humidity (47-88%) as per district climate section, Meteorological Department, Government of India (GOI).

Materials and Methods

Collection of samples

Air samples have been collected at three monitoring stations (A, B, and C) along the canal stretch 500 m apart from each other during summer, premonsoon and post-monsoon seasons (2012–2013). The designated station A is at Chatta (latitude:

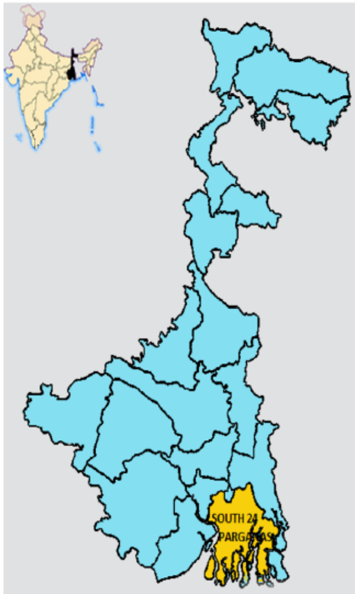

Figure 2. Map of West Bengal.

22.49°N and longitude: 88.24°E) and it indicates the point of direct discharge of raw effluent into the canal from bleaching and dyeing units and characterized by thickly populated area; station B is at Kalikapur and is a point of normal flowing area of canal, concentration of units, and inhabited by population; and station C is the near main road of the study area, Chatta.

Methodology

Air samples have been taken by air sampler machine APM 460 DXNL Dust Monitoring Equipment (Envirotech Instruments, New Delhi, India) installed at specific sites. The samples are taken in 2 different formats: one for 8 hours (8.00 AM to 16.00 PM) and the other for 24 hours (8.00 AM to 8.00 AM).

The sampler machine specifies automatic flow controller with electronic feedback for constant sampling rate throughout the sampling period. Flow control is set for free flow with flow stabilization disabled at >1.1 m^3/min and at 1.0 m^3/min with filter paper installed and flow controller enabled. Samples of 3 filters (in 24 hours) are carried to the laboratory (R. V. Briggs & Co. Pvt. Ltd, National Accreditation Board for Testing and

Figure 3. Map of South 24 Parganas and Mahestala.

Calibration Laboratories [NABL] accredited, India) for analysis using the standard method for quantifying PM. Total suspended PM comprises particles above 10 µm (nonrespirable PM) and particles below 10 µm (respirable PM). Owing to its modular design, APM 460 DXNL can be easily paired with a gaseous sampling attachment (for monitoring SO_2, NO_2, NH_3, ozone, etc) as gaseous sampling requires only a few liquid PM of air flow over a period of 8 hours by sucking a known quantity of air through glass fiber filters. The mass of concentration of SPM is calculated by measuring the weight of collected matter in known volume of air sampled. The method of measurement of $PM_{2.5}$, PM_{10}, SO_2, and NO_2 along with concentration of ambient air in different places against time-weighted average is shown in Table 1.

Sulfur dioxide from air is immersed in a solution of potassium tetrachloromercurate. A dichloro-sulfito mercurate complex is formed which repels oxidation by the oxygen in the air; once formed, this complex is unchanging to strong oxidants such as ozone and oxides of nitrogen, and therefore, the absorber solution may be kept for some time prior to analysis. The complex is made to react with pararosaniline and formaldehyde to form the intensely colored pararosaniline methylsulfonic acid. The absorbance of the solution is measured by means of a suitable spectrophotometer following modified West and Gaeke Method.

Ambient nitrogen dioxide (NO_2) is collected by bubbling air through a solution of sodium hydroxide and sodium arsenite. The concentration of nitrite ion (NO_2^-) produced during sampling is determined colorimetrically by reacting the nitrite ion with phosphoric acid, sulfanilamide, and *N*-(1-naphthyl) ethylenediamine di-hydrochloride and measuring the absorbance of the highly colored azo dye at 540°nm following Jacob & Hochheiser modified method.

The survey format for assessing socioeconomic and health status of local residents has been prepared by Kalyani University (Department of Ecological Studies) and Indian Institute of Social Welfare & Business Management, Kolkata, and the survey has been organized by a 2-member team, one each from the institutions.

Results and Discussion

The characteristics of surface water degrading the atmospheric pollution by emanating acid fumes and bad odor are shown in Table 2. The results of concentrations of each pollutants of ambient air at 3 different locations at Chatta and Kalikapur area under Maheshtala textile cluster have been analyzed in detail. The analytical results for summer, monsoon, and winter seasons taken for each station as well as air quality nature are also depicted as a of part environment management study (2012-2016). The findings are given based on mean values

Table 1. Method of measurement of ambient air samples along with concentration of pollutants in air against time-weighted average at different places. Adapted with permission from CPCB, India.

POLLUTANTS	TIME-WEIGHTED AVERAGE	CONCENTRATION IN AMBIENT AIR		METHODS OF MEASUREMENT
		INDUSTRIAL, RESIDENTIAL, RURAL, AND OTHER AREAS	ECOLOGICALLY SENSITIVE AREA (NOTIFIED BY CENTRAL GOVERNMENT)	
Sulfur dioxide (SO_2), μg/m^3	Annual*	50	20	Improved West and Gaeke Method Ultraviolet fluorescence
	24 h**	80	80	
Nitrogen dioxide (NO_2), μg/m^3	Annual*	40	30	Jacob & Hochheiser modified ($NaOH$-$NaAsO_2$) method Gas-phase chemiluminescence
	24 h**	80	80	
Particulate matter (size less than 10 μm) or PM_{10}, μg/m^3	Annual*	60	60	Gravimetric TEOM Beta attenuation
	24 h**	100	100	
Particulate matter (size less than 2.5 μm) or $PM_{2.5}$, μg/m^3	Annual*	40	40	Gravimetric TEOM Beta attenuation
	24 h**	60	60	

Abbreviation: TEOM, tapered element oscillating microbalance.
*Annual Arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.
**24 hourly or 8 hourly or 1 hourly monitored values, as applicable, shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.

Table 2. Seasonal surface water data taken during 2012-2013 in the study area.[7]

S. NO.	PARAMETERS	S1 SUMMER	S2 SUMMER	S3 SUMMER	S4 RAINY	S5 RAINY	S6 WINTER	S7 SUMMER	SD
1	pH	7.6	7.0	6.9	7.2	7.1	7.9	6.8	±0.68
2	Turbidity (NTU)	—	42	40	8.7	16	60	15.7	±19.98
3	Temperature, °C	34	37	35	31	31	29	30	±2.98
4	TDS, mg/L	3904	—	—	2240	—	2700	3398	±1716.68
5	TSS, mg/L	52	540	110	30	22	51	48	±186
6	$CaCo_3$, mg/L	—	—	666	—	—	867	601	±401.76
7	DO	—	—	0.00	0.90	4.0	0	5.00	±2.35
8	Fe, mg/L	—	—	0.35	0.21	0.11	1.54	—	±0.66
9	Cd, mg/L	0.01	0.013	0.019	0.00	0.00	0.023	0.003	± 0.01
10	Pd, mg/L	0.013	0.22	0.06	0.02	0.027	0.103	0.014	±0.07
11	Cu, mg/L	0.05	—	0.006	0.01	—	—	—	±0.02
12	Zn, mg/L	0.05	0.94	0.284	1.15	0.18	—	—	±0.05
13	Cr, mg/L	0.03	0.05	0.007	0.00	0.061	0.061	0.025	±0.02
14	Ni, mg/L	—	0.012	0.05	0.05	—	—	—	±0.02
15	As, mg/L	0.004	0.013	0.011	0.011	0.00	0.037	0.028	±0.01
16	BOD, mg/L	—	172	365	40	16	91	22	±134.43
17	COD, mg/L	—	552	979	125	70	256	80	±369.71
18	*Escherichia coli*, CFU/100°mL	—	—	380 000	10 000	—	12 000	12 000	±16 621.34

Abbreviations: BOD, biochemical oxygen demand; CFU, colony-forming unit; COD, chemical oxygen demand; DO, dissolved oxygen; NTU, nephelometric turbidity unit; TDS, total dissolved solids; TSS, total suspended solids.

Table 3. Mean values of ambient air quality for 8 hours.

AMBIENT AIR QUALITY PARAMETERS, μG/M³	SUMMER (2012–2013)	MONSOON (2012–2013)	WINTER (2012–2013)	STANDARD DEVIATION	CPCB NORMS (2009)	WHO NORMS (2005)
$PM_{2.5}$	39	49	69	± 15.28	60	25
PM_{10}	90	76	141	± 34.21	100	50
SO_2	20.8	14.1	18.4	± 3.39	80	20
NO_2	50.8	36.4	54.6	± 9.6	80	40

Abbreviations: CPCB, Central Pollution Control Board; WHO, World Health Organization.

Table 4. Mean values of ambient air quality for 24 hours.

AMBIENT AIR PARAMETERS, μG/M³	SUMMER (2012–2013)	MONSOON (2012–2013)	WINTER (2012–2013)	SD	CPCB LIMITS (2009)	WHO LIMITS (2005)
$PM_{2.5}$	31	39	55	±12.22	60	25
PM_{10}	72	61	113	±27.40	100	50
SO_2	17	11	14.4	±3.01	80	20
NO_2	41	30	44	±7.37	80	40

Abbreviations: CPCB, Central Pollution Control Board; WHO, World Health Organization.

considering all 3 stations during 8 and 24 hours of operation and are depicted in Table 3 and 4, respectively.

The surface water quality of the cluster is not suitable for domestic, industrial, and agricultural purposes. The canal water is emanating bad odor, blackish in color, and contaminated with organic chemicals. Metals in surface water contaminate the vegetables and fruits grown in the cluster and ground. The higher level of pH (7.9 ± 0.68), TSS (540 ± 186 mg/L), TDS (3398 ± 1716.68 mg/L), turbidity (60 ± 19.98 mg/L), BOD (365 ± 134.43 mg/L), COD (979 ± 369.71 mg/L) and presence of heavy metals such as Pb (0.22 ± 0.07 mg/L) are major sources of water pollution due to the use of chemicals and dyes. Low DO may result in anaerobic conditions that cause bad odor. The condition further gets endangered by fumes developed by storage of chemicals and dyes used in processing area of the units. Evaporation of surface water in noon due to increased atmospheric temperature (30-40°C) and evapotranspiration from soil and plants add to air pollution. These are evident from the study on soil degradation and contamination of plants and agricultural products at Maheshtala textile cluster due to highly degraded surface water.[8]

Assessment of air pollution in the cluster

Air emission from the drying ovens and diesel generators for producing hot water drives air pollution. The 8-hour sample of ambient air shows that the $PM_{2.5}$ is 39 μg/m³ in summer, 49 μg/m³ in monsoon, and 69 μg/m³ in winter during the study period of 2013–2013. The data resemble the atmospheric condition of the area and contamination level of surface water due to raw effluent discharged from different bleaching and dyeing units. $PM_{2.5}$ levels in summer and monsoon are found safe due to air movement from south to north and rainfall in monsoon because the cluster is near the Bay of Bengal, but higher (69 μg/m³) in winter season due to humidity (47%-71%) which falls beyond the Central Pollution Control Board (CPCB) (India) (2009) limit of >60 μg/m³.[9,10] Air pollutants can have adverse effects on humans and the ecosystem. Carbon monoxide (CO), sulfur dioxide (SO_2) from boiler and motor vehicle exhaust, chlorine gas (from chlorides), sulfuric and nitric acid fumes, oil, and lead particulates from printing area released from factories are considered as primary pollutants. Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact. Ground-level ozone is a prominent example of a secondary pollutant. Some pollutants may be both primary and secondary as they are both emitted directly and formed from other primary pollutants. The bar chart of different air pollutants in summer, monsoon, winter season, and corresponding CPCB permissible limits is presented in Figure 4.

Similarly, the 24-hour sample of ambient air data show that the PM_{10} is 72 μg/m³ in summer, 61 μg/m³ in monsoon, and 113 μg/m³ in winter (2012-2013). Higher concentration of PM_{10} in winter season (113 μg/m³) exceeding the limit of 100 μg/m³ (CPCB, 2009)[10] due to low temperature (10-15°C), smog, direction of air flow (north to south), and humidity (47-71%) as per district meteorological data, GOI.

The $PM_{2.5}$ levels in summer and monsoon are found safe due to air movement from south (ocean side) to north (land) and rainfall (1700-1800 mm annually) (district meteorological data, GOI) in monsoon because the cluster is near the Bay of

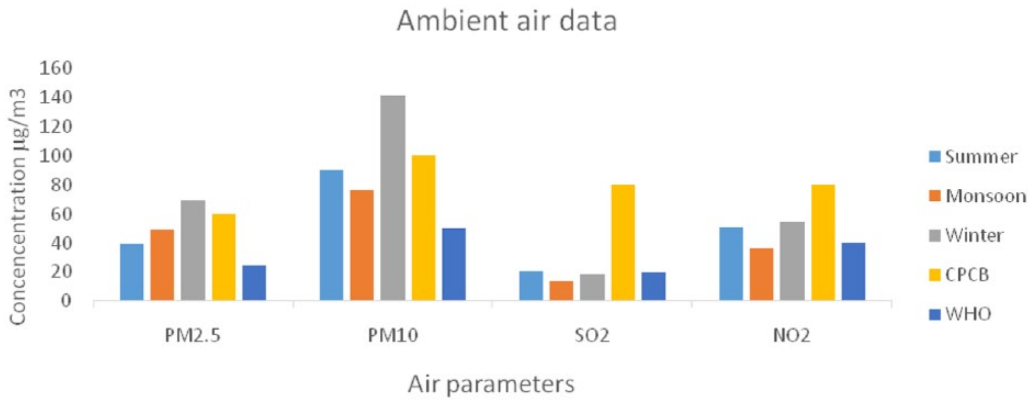

Figure 4. Bar chart showing the air contaminants level on summer, monsoon, and winter seasons. CPCB indicates Central Pollution Control Board; WHO, World Health Organization.

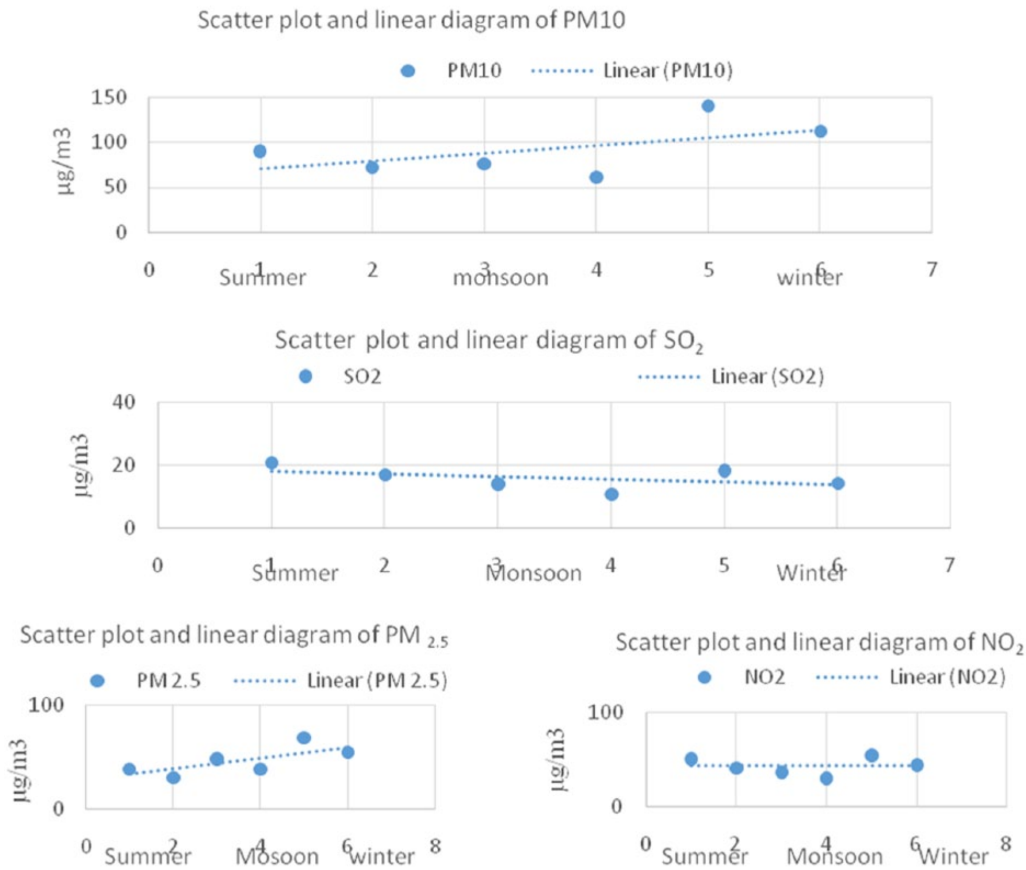

Figure 5. Scatterplots and linear diagrams of PM_{10}, SO_2, $PM_{2.5}$, and NO_2, respectively, during different seasons.

Bengal, but higher in winter season 113 µg/m^3 compared to the limit of 100 µg/m^3 (CPCB, 2009)[10] due to temperature (10-15°C), direction of air flow (north to south), and humidity (47-71%) (district meteorological data, GOI). Residents working in manufacturing factories may also be exposed to toxic chemicals at their workplaces.[11]

The sulfur dioxide (SO_2) level in air samples shows that the concentration in summer (17 µg/m^3), monsoon (11 µg/m^3), and winter (14.4 µg/m^3) is less than the permissible limit of 80 µg/m^3,[10] and is considered to be safe. Similarly, nitrogen dioxide (NO_2) level indicates that during those times, the respective concentrations of 56.4, 36.8, and 58.4 µg/m^3 are within the permissible limit of 80 µg/m^3 (CPCB, 2009).

The scatterplots and linear diagrams of mean $PM_{2.5}$, PM_{10}, SO_2, and NO_2 for 8 and 24 hours of collected air samples are shown in Figure 5.

The combined scatterplot diagram for all air pollutants collected in summer, monsoon, and winter seasons is shown in Figure 6.

As per The Energy and Resources Institute[12] report, diesel exhaust (DE) is a major provider to combustion-derived PM in air pollution. In several human experimental research studies,

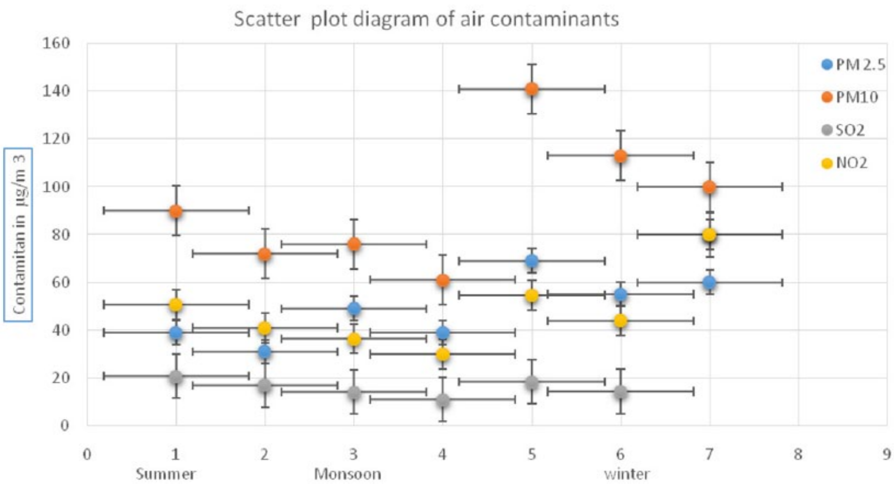

Figure 6. Scatterplot diagram of all air pollutants in summer, monsoon, and winter seasons.

Table 5. Concentrations of SO_2, NO_2, and PM_{10} at different urban locations in West Bengal.

STATE	LOCATION	SO_2, µG/M³	NO_2, µG/M³	PM_{10}, µG/M³
West Bengal	Durgapur	13	48	108
	Haldia	13	41	238
	Howrah	13	40	186
	Kolkata	12	70	135
	Raniganj	14	45	126
	South Suburban	8	59	119

Adapted with permission from CPCB, 2015.[35]

using a well-validated exposure chamber setup, DE has been linked to critical vascular dysfunction and increased thrombus creation.[13] The samples of the air pollutants collected by CPCB, India, from different locations of West Bengal are shown in Table 5.

The study site is located near Kolkata and south suburban. Sample results from industrial townships located in Haldia and Durgapur are shown for comparison. The air samples of bleaching and dyeing cluster show similarity in the air samples collected by CPCB (India) in Kolkata and south suburban.

Health impact due to air pollution

Air pollution is a noteworthy threat factor for a number of pollution-related diseases and health conditions including respiratory infections, heart disease, COPD, heart stroke, and lung cancer. The health effects instigated by air pollution may include difficulty in breathing, wheezing, coughing, asthma, and deterioration of existing respiratory and cardiac conditions.[14]

Increased levels of fine particles in the air as a result of anthropogenic particulate air pollution are consistently and independently related to the most adverse effects, including lung cancer[15] and other cardiopulmonary mortality. The large number of deaths[16] and other health problems associated with particulate pollution were first demonstrated in the early 1970s[17] and has been reproduced many times since long. In 2012 alone, 7 million deaths in the world remained attributable to the combined effects of ambient (3.7 million) and household (4.3 million) air pollution.[18] Ambient air pollution has been acknowledged as the fifth biggest cause of mortality in India.[19]

Size, shape, and solubility matter

The size of the particle is a main element of where in the respiratory tract the particle will come to rest when inhaled. Larger particles are generally filtered in the nose and throat via cilia and mucus, but PM smaller than about 10 µm can settle in the bronchi and lungs and cause health problems.[20] The 10 µm size does not represent a strict boundary between respirable and nonrespirable particles but has been agreed upon for monitoring of airborne PM by most regulatory agencies. Because of their small size, particles on the order of ~10 µm or less (PM_{10}) can penetrate the deepest part of the lungs such as the bronchioles.

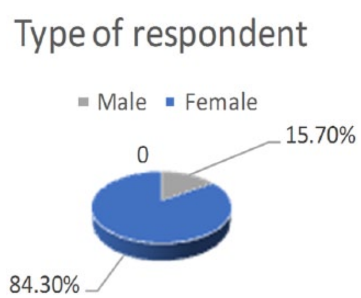

Figure 7. Types of responded villagers.

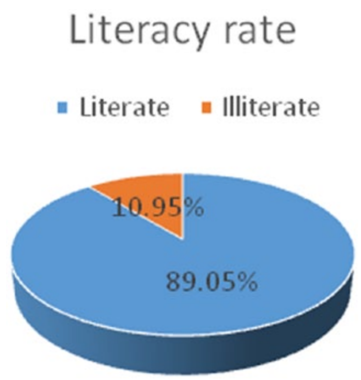

Figure 8. Types of literacy rate of villagers.

Assessment of health status in the cluster area

The survey has been made in the control area of the cluster with 73 persons of 639 villagers, comprising men (84.30%) and women (15.70%) (Figure 7). We found that among total villagers, there are 41.09% local residents and 58.91% are migrated from adjoining areas. Migrated labors filled up the gap of manpower requirement in the cluster as sufficient manpower is not available in the area, and at the same time, some local residents are unwilling to do this kind of hazardous job. Among the respondents, 78.08% and 17.08% are from the age group of 21 to 40 and >50 years, respectively. About 89.04% and 10.95% (Figure 8) are literate and illiterate, respectively, out of 89.04%, 45.20% have completed lower school level from class I-IV and 42.46% have completed middle school–level studies.

It is evident from the study that 56% of the residents (including migrated) are occupied in bleaching and dyeing (B&D), knitting, printing, and other B&D-related activities; 32% are occupied in other businesses such as steel furniture, manufacturing of small steel items, grocery shop, and wooden furniture; and 12% (Figure 9) are engaged as auto, bus, minibus drivers and in automobile jobs. The annual incomes of 1.36%, 86.32%, and 12.32% villagers are ⩾Rs 36 000 ($530), ⩾Rs 60 000 ($870), and ⩾Rs 120 000 ($1740), respectively, against annual per capita income of Rs 74 380 ($1065) of India.[21]

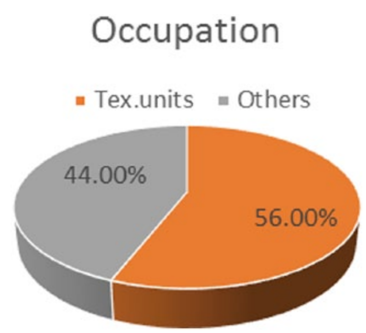

Figure 9. Occupation pattern of villagers.

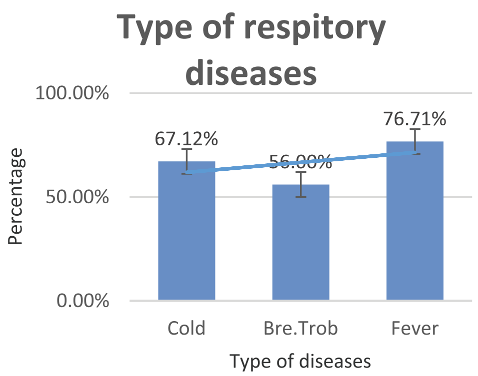

Figure 10. Error line diagram of respiratory diseases.

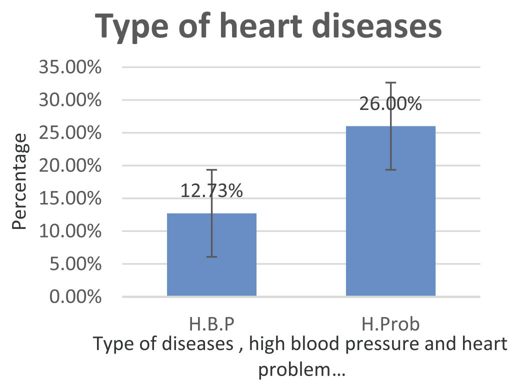

Figure 11. Standard error line diagram of heart diseases.

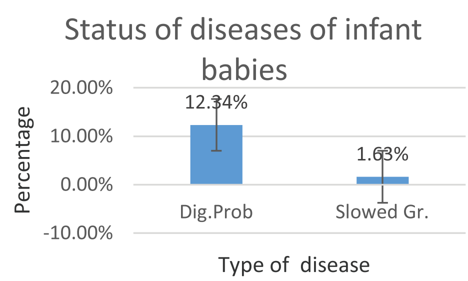

Figure 12. Error line diagram of infant diseases.

Findings of Health Survey

From health survey, it is revealed that the villagers are having cold, cough, bronchitis, asthma and COPD (67.12%), breathing trouble (56 %), and fever (76.71%) (Figure 10) or heart-related diseases such as high blood pressure (12.73%), cardiac problem (26%) (Figure 11), respectively, or both at a time due to air pollution. The findings of infant diseases are shown in Figure 12.

Statistical analyses of PM and respiratory diseases

Statistical and correlation analyses of PM and respiratory diseases are presented in Tables 6 to 8.

Air pollution and respiratory diseases

In this study, it has been seen that cold, cough, bronchitis, asthma, and COPD have a significant positive correlation with fever ($r = 0.98$, $P < 0.05$). Breathing trouble has a strong positive correlation with cold, cough, bronchitis, asthma, COPD, and fever ($r = 0.877$, $P < 0.05$). Similarly, high blood pressure has a negative correlation with cold and fever ($r = -0.655$, $P < 0.05$). Furthermore, heart problem has a strong positive correlation with high blood pressure ($r = 0.989$, $P < 0.05$) and strong negative correlation with cold, cough, asthma, bronchitis, and cold-related fever ($r = -0.54$, $P < 0.05$) (Table 7). It is important that the health survey showed that cold, cough, bronchitis, asthma, and COPD are strongly significant in the cluster area due to the presence of high concentration of PM (PM_{10}) in the atmosphere.

Similarly, effect of $PM_{2.5}$ in atmosphere shows that heart trouble has strongly significant positive correlation with high blood pressure ($r = 0.977$, $P < 0.05$) and breathing trouble ($r = 0.733$, $P \leqslant 0.05$). Fever has positive significant correlation with cold and cough ($r = 0.981$, $P \leqslant 0.05$) and breathing trouble ($r = 0.892$, $P \leqslant 0.05$) (Table 8).

The strength of the observed association between air pollution and mortality is confirmed by previous interpretations of associations between particulate air pollution and other health end points. Elevated levels of particulate air pollution have been associated with declines in lung function or with increases in respiratory symptoms such as cough, cold, breathing, wheezing, and asthma attacks.[22–25] Other studies have found associations between particulate air pollution and rates of hospitalization,[26] COPD,[27] and controlled action due to illness.[28]

Epidemiological investigation is needed to quantify the health impact in an unprotected population. The major pollutants emitted by combustion have all been associated with increased respiratory and cardiovascular morbidity and

Table 6. Regression analysis for PM and effect on respiratory diseases.

REGRESSION ANALYSIS
Multiple $R = 0.999968$
$R^2 = 0.999936$
Adjusted $R = -1.6667$
Standard $R = 0.28463$

Table 7. Correlation matrix between 2 pairs of diseases due to effect of PM_{10} on health.

	COLD	HBP	BREATHING TROUBLE	HEART PROBLEM	FEVER
Cold	1				
HBP	−0.6554	1			
Breathing trouble	0.877364	−0.21263	1		
Heart problem	−0.54152	0.989868	−0.07173	1	
Fever	0.983823	−0.7801	0.777215	−0.68336	1

Abbreviations: HBP, high blood pressure.
Model at significance level ($P < 0.05$).

Table 8. Correlation matrix between 2 pairs of diseases due to effect of $PM_{2.5}$ on health.

	COLD	HBP	BREATHING TROUBLE	HEART PROBLEM	FEVER
Cold	1				
HBP	0.327098	1			
Breathing trouble	0.962013	0.57265	1		
Heart problem	0.520592	0.977121	0.733908	1	
Fever	0.981346	0.139314	0.891584	0.346738	1

Abbreviations: HBP, high blood pressure.
Model at significance level ($P < 0.05$).

mortality.[29] The major urban air pollutants can also give rise to significant respiratory morbidity.[18] For instance, another study was also reported on an exacerbation of asthma among children in Mexico City.[30] An increased risk of respiratory symptoms in middle-aged nonsmokers in Beijing was noted.[31]

In relation to the very young ones, it was found that PM exposure, SO_2 exposure, or both increased the risk of low birth weight in Beijing.[32] Studies found that air pollution increased intrauterine mortality in São Paulo.[33] Previous studies of petrochemical and chemical industrialization have found amplified respiratory symptoms, increased cancer mortality, and shortened life probability in communities near highly polluting petrochemical/chemical areas.[34]

Conclusions

Our findings highlight the long-term adverse impact on population health due to rapidly increasing hazardous bleaching and dyeing units at the Maheshtala cluster mainly on young generation (20-40 years) due to lack of other opportunities.

This study suggests that education and income are not the main predictors for good health; rather, occupation and income for the livelihood are the guiding factors for bad health in this bleaching and dyeing cluster, normally happening in developing countries.

Appropriate authorities should consider monitoring of this situation in terms of (1) effluent treatment, (2) water treatment, (3) reducing air pollution, (4) continuous monitoring of health impacts over long term, and (5) assessment of the impact of industrial cluster as a whole with proper eco-planning and infrastructure.

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Author Contributions

JKB conceived and designed the study; BGG collected samples, analyzed the data, jointly developed the structure with JKB and arrangements of the paper; and BGG, JKB, and KMA made necessary corrections and finalized the article.

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