Effect of Pollution on Health of People Living Near Landfill Sites in Delhi-NCR

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ABSTRACT

Introduction: Pollution has become a major public health problem because of its impact on human health. Landfills are the most commonly used methods for disposing municipal solid waste. But, solid waste as a source of environmental pollution has been relatively under-discussed. To the best of our knowledge, there is no study available in India, which has analyzed the implications of pollution on a large number of health parameters. **Aims:** The study was conducted to compare the health of people living in close proximity to landfill sites (within 2 km) to those living in non-landfill areas (beyond 7 km) and also to find out any association between the living conditions on various health parameters in the study population. **Materials and methods:** An observational study was conducted jointly by Heart Care Foundation of India (HCFI) and Dainik Bhaskar Group in association with Urja, a non-governmental organization (NGO). Three landfill sites in Delhi-National Capital Region (NCR) were selected for the study. People residing within 2 km of the three selected landfill sites formed the study group (n = 276). The control group (n = 252) included people residing beyond 7 km of the three landfill sites. An 8-member team visited all the six sites on different days and carried out the study. Height, weight, peak expiratory flow rate (PEFR), abdominal circumference, pulse rate, blood pressure (BP), heart rate, blood (peripheral capillary) oxygen saturation (SpO_2), the 6-minute walk test (6MWT), particular matter (PM)2.5 and PM10 were measured. Water samples were collected for analysis. **Results:** The levels of PM2.5 and PM10 were quite high in the landfill areas compared to the control group; 264 μg/m^3 vs. 155 μg/m^3; 320 μg/m^3 vs. 172 μg/m^3, respectively. Height was lower in the study group (159 cm vs. 164 cm) as also weight (63 kg vs. 71 kg). Participants in the study group had lower PEFR (315 L/min) in comparison to the control group (398 L/min). The study group also had reduced effort tolerance on 6MWT and lower SpO_2. Water samples tested from the landfill sites also showed increased total dissolved solids (TDS), hardness and bicarbonate levels indicating ground water contamination. **Conclusion:** Compared to the control group, systolic and diastolic BP were found to be significantly higher, while height, weight, body mass index (BMI), PEFR, SpO_2 (before and after 6MWT) were lower in the study group. Our study has only focused on observing the changes in health parameters due to exposure to pollution and does not attempt to identify a cause and effect association. Our observations are significant enough to consider a trial in a larger sample size. An extended study is being undertaken.

Keywords: Solid waste, PM2.5, PM10, PEFR, effort tolerance, total hardness, total dissolved solids

Pollution is a burning issue today and has become a major public health problem because of its impact on human health. The adverse health effects of air pollution can be due to either short- or long-term exposure.

The latest World Health Organization (WHO) data show that many countries in the world have dangerously high levels of air pollution. Nine out of 10 people breathe air containing high levels of pollutants and around 7 million people die every year from exposure to fine particles in polluted air.[1]

Air pollution has been linked to many diseases such as stroke, heart disease, lung cancer, chronic obstructive pulmonary disease (COPD) and respiratory infections. As per WHO estimates, 24% of all adult deaths from heart disease, 25% from stroke, 43% from COPD and 29% from lung cancer are attributed to air pollution. More than 90% of air pollution-related deaths occur in low- and middle-income countries. Ambient (outdoor) air pollution alone accounted for around 4.2 million deaths in 2016.[1]

Amongst the various pollutants, particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) have the strongest body of evidence for their effects on human health.[2]

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Pollution-related diseases increase healthcare costs, particularly in middle-income countries that have high levels of pollution.[3] Pollution also affects worker productivity by reducing how much is produced "on the job."[4]

Ozone and PM2.5 have also been shown to be associated with worker productivity. Ozone reduces lung function, increases lung sensitivity to allergens and irritants and causes chronic damage to the lung structure.[5] PM2.5 can penetrate deep into the lung, where they irritate and it damages the alveolar wall resulting in impaired lung function.[6] PM2.5 is also known to affect blood pressure (BP), cognitive function and immune function.[4,7] Ozone breaks down rapidly and disappears indoors; hence, its effects are more evident outdoors. PM2.5, on the other hand can affect workers both outdoors and indoors as indoor levels can be 70-100% of outdoor levels.[4]

Vehicular exhaust emissions, industrial emissions, crop stubble burning, construction activities, garbage burning, dust on roads are major sources of air pollution.

While, traffic emissions, crop stubble burning, construction activities, industrial waste have been established as major contributors to air pollution, particularly in Delhi-National Capital Region (NCR), solid waste as a source of environmental pollution has been relatively under-discussed.[8]

Solid waste includes municipal waste, industrial waste and hazardous wastes.[9]

Municipal solid waste, also called urban solid waste, includes mainly household waste (domestic waste) with sometimes the addition of commercial wastes, construction and demolition debris, sanitation residue and waste from streets collected by a municipality within a given area.[10] There are generally five categories of municipal solid waste in India:[11]

- *Biodegradable waste:* Food and kitchen waste, green waste (vegetables, flowers, leaves, fruits) and paper.
- *Recyclable material:* Paper, glass, bottles, cans, metals, certain plastics, etc.
- *Inert waste:* Construction and demolition, dirt, debris, rocks.
- *Composite waste:* Waste clothing, Tetra packs, waste plastics such as toys.
- *Domestic hazardous waste (also called "household hazardous waste") and toxic waste:* Waste medicine, e-waste, paints, chemicals, light bulbs, fluorescent tubes, spray cans, fertilizer and pesticide containers, batteries and shoe polish.

Untreated solid waste can pollute air, water and soil, due to improper handling and transportation and cause health hazard. Hence, solid waste management is very essential.[9]

Landfills are the most commonly used method for disposing municipal solid waste.[12] Living near landfills is a known health hazard.[13]

Delhi-NCR has three main landfill sites, all of which have exhausted their capacity. Also, their present height has crossed the permitted height of 5-20 m as recommended by Central Pollution Control Board (CPCB), Ministry of Environment and Forests,[14] posing a threat to the health of the people living in their vicinity and also endangering their safety. Last year in September, a part of the Ghazipur landfill collapsed due to heavy rains killing two people and injuring few others.

While a Graded Response Action Plan has been notified by the Govt. When air quality index (AQI) has ranged between severe and hazardous levels in Delhi-NCR, not much is being done about the landfills and not quickly enough.

With this background, we decided to conduct a study with the aim to compare the health of people living in close proximity to landfill sites (within 2 km) to those living in non-landfill areas (beyond 7 km). The study also attempted to find out any association between the living conditions on various health parameters in the study population.

To the best of our knowledge, there is no study available in India, which has analyzed the implications of pollution on a large number of health parameters.

MATERIALS AND METHODS

This is an observational study conducted jointly by Heart Care Foundation of India (HCFI) and Dainik Bhaskar Group in association with Urja, a non-governmental organization (NGO).

Ethical clearance for the study was taken by the HCFI Internal Ethics Committee.

Study Sites

Three landfill sites in Delhi were selected for the study namely:

- Bhalswa landfill site in Northwest Delhi
- Ghazipur landfill site in East Delhi
- Okhla landfill site in South Delhi.

Bhalswa landfill site in Northwest Delhi is spread over 40 acres. It started overflowing in 2003 and was declared exhausted in 2006. It is 50 meters high.

Ghazipur landfill site in East Delhi is the oldest landfill site. Spread over 70 acres, it is around 60 meters in height. The landfill site exceeded its capacity in 2002.

Okhla landfill site located in South Delhi is spread over 56 acres and is 50 m high. It was declared as exhausted way back in 2010.

Study Population

The study group included people residing within 2 km of the three selected landfill sites in Delhi.

The control group included people residing beyond 7 km of the three landfill sites. The three non-landfill locations selected for the study were:

- Ashok Vihar in Northwest Delhi, located at a distance of around 8 km from Bhalswa landfill site
- GTB Enclave in East Delhi, located at a distance of 8 km from Ghazipur landfill site
- Kotla Mubarakpur in South Delhi, located at a distance of around 10-11 km from Okhla landfill site.

Data Collection

The study was conducted in the month of December 2017. An 8-member team comprising of 1 doctor, 2 technicians, 1 representative of Dainik Bhaskar Group and 4 members of HCFI visited all the six sites on different days and carried out the study.

- The team visited Bhalswa landfill site on 13.12.2017, Ghazipur landfill site on 16.12.2017 and Okhla (Lal Kuan village) landfill site on 21.12.2017 between 10 am to 5 pm.
- The team also visited the three non-landfill areas on the following dates: Ashok Vihar on 17.12.2017 and GTB Enclave on 23.12.2017 between 10 am to 5 pm. The visit at Kotla Mubarakpur was on 22.12.2017 between 9:30 am to 5:00 pm.

The variables included in the study were: Height, weight, peak expiratory flow rate (PEFR), abdominal circumference, pulse rate, BP, heart rate, blood (peripheral capillary) oxygen saturation (SpO_2), the 6-minute walk test (6MWT), PM2.5 and PM10.

Data was collected by means of physical examination and check-up. Height (in cm), weight (in kg), BP, both systolic and diastolic (in mmHg), abdominal circumference (in cm) were measured.

Body mass index (BMI) was calculated using the formula weight (in kg) divided by height in meters squared.

PEFR (in L/min) was measured using peak flow meter. PM2.5 and PM10 levels were measured using Particulate Pollution meter. Effort tolerance of all the participants was measured using the 6MWT with rounds of 50 feet each. SpO_2 was measured before and after the 6MWT with a finger pulse oximeter. Ground water samples were collected for analysis.

RESULTS

Sample Size

We had planned to enroll 100 subjects in each of the three landfill sites (study group; n = 300) and three non-landfill areas (control group; n = 300). But, we could enroll 276 participants in the study group and 252 participants in the control group. There were 134 males and 142 females in the study group, while the control groups had 186 males and 66 females.

The mean age (in years) was 49.20 years (standard deviation [SD] 17.05) in the study group. In the control group, the mean age was 46.33 years (SD 17.16).

Table 1 shows the overall comparison of the health parameters between the landfill and non-landfill areas. Compared to the control group, the systolic BP, diastolic BP, PM2.5 and PM10 levels were higher while height, weight, BMI, PEFR, SpO_2 (before and after 6MWT) were lower in the study group. These findings were statistically significant. There was no change in heart rate after 6MWT.

The observations in males were same as in males and females combined in both the study group and the control group (Table 2). Changes in diastolic BP, abdominal circumference and SpO_2 after 6MWT were not statistically significant in females, though the trends were similar to those observed in males (Table 3).

Table 4 shows overall comparison between the three landfill areas. Table 5 shows overall comparison between the three non-landfill areas.

The various health parameters were also compared between each landfill site and non-landfill areas as shown in Tables 6-8.

Bhalswa landfill site, when compared to non-landfill area, showed similar findings except for no significant difference in weight and BMI (Table 6).

Ghazipur area when compared to non-landfill areas showed similar findings except for diastolic BP, which

Table 1. Overall Comparison between Landfill and Non-landfill Areas

Parameters	Non-landfill areas (Control group) (n = 252)			Landfill areas (Study group) (n = 276)			P value
	Mean	SD	SEM	Mean	SD	SEM	
Age (years)	49.20	17.05	1.07	46.33	17.16	1.03	0.055
Systolic BP (mmHg)	122.10	7.57	0.48	128.95	17.66	1.10	0.000
Diastolic BP (mmHg)	76.31	6.40	0.40	80.57	12.60	0.78	0.000
Height (cm)	164.45	10.40	0.66	159.18	11.86	0.72	0.000
Weight (kg)	71.98	15.70	0.99	63.02	15.14	0.99	0.000
BMI (kg/m^2)	26.35	4.77	0.30	24.56	5.00	0.33	0.000
PEFR (L/min)	398.80	105.98	6.69	315.35	105.72	6.47	0.000
PM10 (µg/m^3)	172.55	76.76	4.88	320.12	161.86	10.10	0.000
PM2.5 (µg/m^3)	155.60	64.18	4.08	264.74	125.22	7.83	0.000
6MWT (rounds of 50 feet each)	23.10	6.38	0.40	20.40	6.43	0.40	0.000
SpO_2 before 6MWT (%)	98.24	0.67	0.00	97.57	2.00	0.00	0.000
SpO_2 after 6MWT (%)	96.88	1.00	0.00	96.23	2.23	0.00	0.000
Pulse rate after 6MWT (beats per minute)	112.57	9.41	0.60	112.37	9.86	0.62	0.814

SD = Standard deviation; SEM = Standard error of the mean.

Table 2. Overall Male-wise Comparison between Landfill and Non-landfill Areas

Parameters	Non-landfill areas (Control group) (n = 186)			Landfill areas (Study group) (n = 134)			P value
	Mean	SD	SEM	Mean	SD	SEM	
Age (years)	49.18	17.56	1.29	45.58	19.33	1.67	0.084
Systolic BP (mmHg)	121.88	7.66	0.56	129.89	18.07	1.64	0.000
Diastolic BP (mmHg)	75.81	6.12	0.45	81.25	10.97	0.99	0.000
Height (cm)	167.27	9.72	0.72	163.73	12.50	1.09	0.005
Weight (kg)	73.00	16.70	1.23	64.37	16.54	1.54	0.000
BMI (kg/m^2)	25.65	4.46	0.33	23.48	4.32	0.40	0.000
PEFR (L/min)	417.54	108.61	7.98	364.18	109.36	9.55	0.000
PM10 (µg/m^3)	177.69	75.60	5.62	308.98	164.32	14.88	0.000
PM2.5 (µg/m^3)	161.75	63.68	4.73	253.67	127.02	11.50	0.000
6MWT (rounds of 50 feet each)	22.88	6.34	0.47	20.89	6.70	0.61	0.009
SpO_2 before 6MWT (%)	98.21	0.73	0.05	97.44	2.64	0.24	0.000
SpO_2 after 6MWT (%)	96.96	1.01	0.07	95.87	2.66	0.23	0.000
Pulse rate after 6MWT (beats per minute)	112.44	9.32	0.69	111.80	10.28	0.94	0.578

Table 3. Overall Female-wise Comparison between Landfill and Non-landfill Areas

Parameters	Non-landfill areas (Control group) (n = 66)			Landfill areas (Study group) (n = 142)			P value
	Mean	SD	SEM	Mean	SD	SEM	
Age (years)	49.24	15.65	1.93	47.04	14.87	1.25	0.328
Systolic BP (mmHg)	122.73	7.35	0.90	128.13	17.31	1.47	0.016
Diastolic BP (mmHg)	77.73	6.97	0.86	79.97	13.90	1.18	0.217
Height (cm)	156.62	7.98	0.98	154.88	9.43	0.80	0.200
Weight (kg)	69.15	12.17	1.50	61.73	13.61	1.24	0.000
BMI (kg/m^2)	28.26	5.09	0.63	25.59	5.40	0.49	0.001
PEFR (L/min)	346.29	77.52	9.54	268.31	77.22	6.62	0.000
PM10 (µg/m^3)	158.47	78.73	9.69	330.18	159.55	13.73	0.000
PM2.5 (µg/m^3)	138.74	62.98	7.75	274.82	123.16	10.64	0.000
6MWT (rounds of 50 feet each)	23.70	6.50	0.80	19.95	6.16	0.53	0.000
SpO_2 before 6MWT (%)	98.32	0.47	0.00	97.71	1.04	0.00	0.000
SpO_2 after 6MWT (%)	96.65	0.95	0.00	96.56	1.68	0.00	0.694
Pulse rate after 6MWT (beats per minute)	112.94	9.74	1.20	112.87	9.47	0.82	0.964

Table 4. Overall Comparison between Different Locations of Landfill Areas

Parameters	Bhalswa (n = 92)			Ghazipur (n = 96)			Okhla (Lal Kuan village) (n = 88)		
	Mean	SD	SEM	Mean	SD	SEM	Mean	SD	SEM
Age (years)	46.41	15.91	1.66	54.36	14.30	1.46	37.48	17.11	1.82
Systolic BP (mmHg)	137.48	22.75	2.54	131.04	13.80	1.41	118.45	8.71	0.95
Diastolic BP (mmHg)	90.30	16.67	1.86	77.65	6.93	0.71	74.64	6.30	0.69
Height (cm)	159.16	9.86	1.06	159.30	9.16	0.94	159.06	15.76	1.68
Weight (kg)	68.67	15.83	2.22	64.22	12.73	1.30	58.45	15.95	1.70
BMI (kg/m^2)	26.67	5.78	0.81	25.07	4.97	0.51	22.79	3.88	0.41
PEFR (L/min)	344.37	108.07	11.39	296.40	105.26	10.92	305.24	97.95	10.69
PM10 (µg/m^3)	336.55	35.39	4.14	139.39	34.71	3.54	503.65	66.34	7.07
PM2.5 (µg/m^3)	278.90	29.88	3.50	123.29	27.48	2.82	405.69	47.87	5.10
6MWT (rounds of 50 feet each)	17.58	2.66	0.31	19.24	5.63	0.59	24.02	7.76	0.83
SpO_2 before 6MWT (%)	96.65	3.35	0.40	98	0.97	0.10	98.30	0.51	0.05
SpO_2 after 6MWT (%)	96.30	3.00	0.32	95	1.78	0.19	97.24	0.84	0.09
Pulse rate after 6MWT (beats per minute)	108.80	12.14	1.28	116.53	6.94	0.79	112.38	7.89	0.84

Between Bhalswa and Ghazipur	
Parameters	**P value**
Age (years)	0.000
Systolic BP (mmHg)	0.022
Diastolic BP (mmHg)	0.000
Height (cm)	0.921
Weight (kg)	0.066
BMI (kg/m^2)	0.083
PEFR (L/min)	0.003
PM10 (µg/m^3)	0.000
PM2.5 (µg/m^3)	0.000
6MWT (rounds of 50 feet each)	0.019
SpO_2 before 6MWT (%)	0.011
SpO_2 after 6MWT (%)	0.003
Pulse rate after 6MWT (beats per minute)	0.000

Between Bhalswa and Okhla (Lal Kuan Village)	
Parameters	**P value**
Age (years)	0.000
Systolic BP (mmHg)	0.000
Diastolic BP (mmHg)	0.000
Height (cm)	0.958
Weight (kg)	0.000
BMI (kg/m^2)	0.000
PEFR (L/min)	0.013
PM10 (µg/m^3)	0.000
PM2.5 (µg/m^3)	0.000
6MWT (rounds of 50 feet each)	0.000
SpO_2 before 6MWT (%)	0.000
SpO_2 after 6MWT (%)	0.005
Pulse rate after 6MWT (beats per minute)	0.021

Between Ghazipur and Okhla (Lal Kuan Village)	
Parameters	**P value**
Age (years)	0.000
Systolic BP (mmHg)	0.000
Diastolic BP (mmHg)	0.003
Height (cm)	0.896
Weight (kg)	0.007
BMI (kg/m^2)	0.001
PEFR (L/min)	0.565
PM10 (µg/m^3)	0.000
PM2.5 (µg/m^3)	0.000
6MWT (rounds of 50 feet each)	0.000
SpO_2 before 6MWT (%)	0.000
SpO_2 after 6MWT (%)	0.000
Pulse rate after 6MWT (beats per minute)	0.000

Table 5. Overall Comparison between Different Locations of Non-landfill Areas

Parameters	Ashok Vihar (n = 75)			GTB Enclave (n = 91)			Kotla Mubarakpur (n = 86)		
	Mean	**SD**	**SEM**	**Mean**	**SD**	**SEM**	**Mean**	**SD**	**SEM**
Age (years)	56.23	15.82	1.83	52.67	16.70	1.75	39.40	13.85	1.49
Systolic BP (mmHg)	123.33	8.90	1.03	122.75	6.16	0.65	120.35	7.43	0.80
Diastolic BP (mmHg)	76.53	6.88	0.79	77.36	5.93	0.62	75.00	6.28	0.68
Height (cm)	168.43	12.87	1.52	161.86	9.86	1.03	163.85	7.33	0.79
Weight (kg)	79.41	19.10	2.25	71.01	12.37	1.30	66.79	13.30	1.43
BMI (kg/m^2)	27.14	4.72	0.56	27.21	4.92	0.52	24.79	4.29	0.46
PEFR (L/min)	390.20	98.00	11.39	426.92	106.21	11.13	376.45	106.89	11.53
PM10 (µg/m^3)	137.61	26.97	3.22	130.30	28.26	2.96	245.70	85.37	9.21
PM2.5 (µg/m^3)	138.93	50.57	6.04	118.20	24.90	2.61	208.76	67.85	7.32
6MWT (rounds of 50 feet each)	23.25	6.12	0.72	23.78	6.60	0.69	22.24	6.32	0.68
SpO_2 before 6MWT (%)	98.07	0.84	0.10	98.42	0.54	0.06	98.19	0.59	0.00
SpO_2 after 6MWT (%)	96.19	1.05	0.12	97.14	0.81	0.08	97.19	0.86	0.00
Pulse rate after 6MWT (beats per minute)	114.52	7.77	0.92	109.51	8.93	0.94	114.16	10.37	1.12

Between Ashok Vihar and GTB Enclave	
Parameter	**P value**
Age (years)	0.164
Systolic BP (mmHg)	0.618
Diastolic BP (mmHg)	0.405
Height (cm)	0.000
Weight (kg)	0.001
BMI (kg/m^2)	0.919
PEFR (L/min)	0.024
PM10 (µg/m^3)	0.099
PM2.5 (µg/m^3)	0.001
6MWT (rounds of 50 feet each)	0.596
SpO_2 before 6MWT (%)	0.002
SpO_2 after 6MWT (%)	0.000
Pulse rate after 6MWT (beats per minute)	0.000

Between Ashok Vihar and Kotla Mubarakpur	
Parameter	**P value**
Age (years)	0.000
Systolic BP (mmHg)	0.022
Diastolic BP (mmHg)	0.141
Height (cm)	0.006
Weight (kg)	0.000
BMI (kg/m^2)	0.001
PEFR (L/min)	0.401
PM10 (µg/m^3)	0.000
PM2.5 (µg/m^3)	0.000
6MWT (rounds of 50 feet each)	0.314
SpO^2 before 6MWT (%)	0.295
SpO^2 after 6MWT (%)	0.000
Pulse rate after 6MWT (beats per minute)	0.810

Between GTB Enclave and Kotla Mubarakpur	
Parameter	**P value**
Age (years)	0.000
Systolic BP (mmHg)	0.020
Diastolic BP (mmHg)	0.011
Height (cm)	0.130
Weight (kg)	0.030
BMI (kg/m^2)	0.001
PEFR (L/min)	0.002
PM10 (µg/m^3)	0.000
PM2.5 (µg/m^3)	0.000
6MWT (rounds of 50 feet each)	0.116
SpO^2 before 6MWT (%)	0.008
SpO^2 after 6MWT (%)	0.731
Pulse rate after 6MWT (beats per minute)	0.002

Table 6. Comparison between Non-landfill Areas and Bhalswa

Parameters	**Non-landfill areas (n = 252)**			**Bhalswa (n = 92)**			**P value**
	Mean	**SD**	**SEM**	**Mean**	**SD**	**SEM**	
Age (years)	49.20	17.05	1.07	46.41	15.91	1.66	0.173
Systolic BP (mmHg)	122.10	7.57	0.48	137.48	22.75	2.54	0.000
Diastolic BP (mmHg)	76.31	6.40	0.40	90.30	16.67	1.86	0.000
Height (cm)	164.45	10.40	0.66	159.16	9.86	1.06	0.000
Weight (kg)	71.98	15.70	0.99	68.67	15.83	2.22	0.171
BMI (kg/m^2)	26.35	4.77	0.30	26.67	5.78	0.81	0.671
PEFR (L/min)	398.80	105.98	6.69	344.37	108.07	11.39	0.000
PM10 (µg/m^3)	172.55	76.76	4.88	336.55	35.39	4.14	0.000
PM2.5 (µg/m^3)	155.60	64.18	4.08	278.90	29.88	3.50	0.000
6MWT (rounds of 50 feet each)	23.10	6.38	0.40	17.58	2.66	0.31	0.000
SpO_2 before 6MWT (%)	98.24	0.67	0.04	96.65	3.35	0.40	0.000
SpO_2 after 6MWT (%)	96.88	1.00	0.06	96.30	3.00	0.32	0.008
Pulse rate after 6MWT (beats per minute)	112.57	9.41	0.60	108.80	12.14	1.28	0.003

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Table 7. Comparison between Non-landfill Areas and Ghazipur

Parameters	Non-landfill areas (n = 252)			Ghazipur (n = 96)			P value
	Mean	SD	SEM	Mean	SD	SEM	
Age (years)	49.20	17.05	1.07	54.36	14.30	1.46	0.009
Systolic BP (mmHg)	122.10	7.57	0.48	131.04	13.80	1.41	0.000
Diastolic BP (mmHg)	76.31	6.40	0.40	77.65	6.93	0.71	0.090
Height (cm)	164.45	10.40	0.66	159.30	9.16	0.94	0.000
Weight (kg)	71.98	15.70	0.99	64.22	12.73	1.30	0.000
BMI (kg/m^2)	26.35	4.77	0.30	25.07	4.97	0.51	0.030
PEFR (L/min)	398.80	105.98	6.69	296.40	105.26	10.92	0.000
PM10 (µg/m^3)	172.55	76.76	4.88	139.39	34.71	3.54	0.000
PM2.5 (µg/m^3)	155.60	64.18	4.08	123.29	27.48	2.82	0.000
6MWT (rounds of 50 feet each)	23.10	6.38	0.40	19.24	5.63	0.59	0.000
SpO_2 before 6MWT (%)	98.24	0.67	0.04	97.59	1.00	0.10	0.000
SpO_2 after 6MWT (%)	96.88	1.00	0.06	95.20	1.78	0.19	0.000
Pulse rate after 6MWT (beats per minute)	112.57	9.41	0.60	116.53	6.94	0.79	0.001

Table 8. Comparison between Non-landfill Areas and Okhla (Lal Kuan Village)

Parameters	Non-landfill areas (n = 252)			Okhla (Lal Kuan village) (n = 88)			P value
	Mean	SD	SEM	Mean	SD	SEM	
Age (years)	49.20	17.05	1.07	37.48	17.11	1.82	0.000
Systolic BP (mmHg)	122.10	7.57	0.48	118.45	8.71	0.95	0.000
Diastolic BP (mmHg)	76.31	6.40	0.40	74.64	6.30	0.69	0.039
Height (cm)	164.45	10.40	0.66	159.06	15.76	1.68	0.00
Weight (kg)	71.98	15.70	0.99	58.45	15.95	1.70	0.00
BMI (kg/m^2)	26.35	4.77	0.30	22.79	3.88	0.41	0.00
PEFR (L/min)	398.80	105.98	6.69	305.24	97.95	10.69	0.00
PM10 (µg/m^3)	172.55	76.76	4.88	503.65	66.34	7.07	0.00
PM2.5 (µg/m^3)	155.60	64.18	4.08	405.69	47.87	5.10	0.00
6MWT (rounds of 50 feet each)	23.10	6.38	0.40	24.02	7.76	0.83	0.270
SpO^2 before 6MWT (%)	98.24	0.67	0.04	98.30	0.51	0.05	0.455
SpO^2 after 6MWT (%)	96.88	1.00	0.06	97.24	0.84	0.09	0.003
Pulse rate after 6MWT (beats per minute)	112.57	9.41	0.60	112.38	7.89	0.84	0.862

Table 9. Comparison of Water Quality between Non-landfill Areas and Bhalswa

Parameters	Non-land fill areas			Bhalswa	
	Mean	SD	SEM	Value	P value
Alkalinity (as $CaCO_3$) (mg/L)	302.07	60.18	34.75	1211.60	0.006
Acidity (as $CaCO_3$) (mg/L)	36.40	29.53	17.05	222.30	0.032
Chloride (as Cl) (mg/L)	66.20	30.34	17.52	1191.00	0.001
Conductivity (µS/cm)	1016.67	251.66	145.30	6000.00	0.003
Total hardness (as $CaCO_3$) (mg/L)	278.40	82.02	47.36	960.00	0.019
Bicarbonate alkalinity (as $CaCO_3$) (mg/L)	302.07	60.18	34.75	1211.60	0.006
pH	7.85	0.32	0.19	7.47	0.417
Total solids (mg/L)	664.00	180.13	104.00	3980.00	0.004
Total suspended solids (mg/L)	15.67	3.21	1.86	80.00	0.003
Total dissolved solids (mg/L)	648.33	179.78	103.80	3900.00	0.004
Total volatile solids (mg/L)	67.67	14.57	8.41	488.00	0.002
Total Kjeldahl nitrogen (as N) (mg/L)	2.49	1.57	1.11	10.80	0.145
Nitrate (as N) (mg/L)	1.40	0.28	0.20	3.70	0.095
Calcium (as Ca) (mg/L)	52.53	17.33	10.01	184.50	0.022
Magnesium (as Mg) (mg/L)	35.77	9.39	5.42	121.30	0.016
Potassium (as K) (mg/L)	1.40	0.78	0.45	14.20	0.005
Sodium (as Na) (mg/L)	87.73	19.14	11.05	614.00	0.002
Iron (as Fe) (mg/L)	0.01	0.01	0.00	0.03	0.104
Manganese (as Mn) (mg/L)	0.03	0.04	0.03	0.06	0.667

showed comparable findings between the two groups (Table 7).

Okhla (Lal Kuan village) landfill site when compared to non-landfill areas showed similar findings except for no difference in 6MWT and baseline SpO_2 (Table 8).

Quality of water was compared between the non-landfill areas and each landfill site individually (Tables 9-11).

The water in Bhalswa area was more alkaline and had more hardness and total dissolved solids (Table 9).

The water in Ghazipur area had only high potassium levels (Table 10). The water in Okhla (Lal Kuan village) was more alkaline and had more hardness and total dissolved solids (Table 11).

DISCUSSION

Landfilling is a common method for disposal of solid waste in India. But, because of the scarcity of land for waste disposal, landfill sites in metro cities have exhausted their capacity[11] as is also the case with the three landfill sites (Bhalswa, Ghazipur and Okhla [Lal Kuan village]) selected for our study.

With rising population and urbanization, the garbage quantity generated increases, which, in turn, exhausts the landfill sites.[15]

These three landfill sites are also nearing or have crossed their life span, which has been defined as at least 20-25 years as per the latest Solid Waste Management Rules, 2016 notified in April 2016. Ghazipur is the oldest landfill site in Delhi having been commissioned in the year 1984; Bhalswa landfill site became functional in 1994 and Okhla in 1996.[16]

Hence, these landfills are potential sources of exposure to hazardous chemicals.

Studies have shown that living near municipal solid waste landfill is harmful to health as people are exposed

Table 10. Comparison of Water Quality between Non-landfill Areas and Ghazipur

Parameters	Non-landfill areas			Ghazipur	
	Mean	SD	SEM	Value	P value
Alkalinity (as $CaCO_3$) (mg/L)	302.07	60.18	34.75	453.00	0.162
Acidity (as $CaCO_3$) (mg/L)	36.40	29.53	17.05	74.10	0.384
Chloride (as Cl) (mg/L)	66.20	30.34	17.52	35.70	0.476
Conductivity (µS/cm)	1016.67	251.66	145.30	1200.00	0.593
Total hardness (as $CaCO_3$) (mg/L)	278.40	82.02	47.36	240.00	0.724
Bicarbonate alkalinity (as $CaCO_3$) (mg/L)	302.07	60.18	34.75	453.00	0.162
pH	7.85	0.32	0.19	7.60	0.575
Total solids (mg/L)	664.00	180.13	104.00	779.00	0.636
Total suspended solids (mg/L)	15.67	3.21	1.86	22.00	0.230
Total dissolved solids (mg/L)	648.33	179.78	103.80	757.00	0.653
Total volatile solids (mg/L)	67.67	14.57	8.41	60.00	0.693
Total Kjeldahl nitrogen (as N) (mg/L)	2.49	1.57	1.11	1.10	0.601
Nitrate (as N) (mg/L)	1.40	0.28	0.20	0.80	0.333
Calcium (as Ca) (mg/L)	52.53	17.33	10.01	46.10	0.778
Magnesium (as Mg) (mg/L)	35.77	9.39	5.42	30.30	0.664
Potassium (as K) (mg/L)	1.40	0.78	0.45	7.00	0.025
Sodium (as Na) (mg/L)	87.73	19.14	11.05	66.60	0.440
Iron (as Fe) (mg/L)	0.01	0.01	0.00	0.01	0.732
Manganese (as Mn) (mg/L)	0.03	0.04	0.03	0.02	0.808

to the emitted air pollutants (landfill gas containing methane, carbon dioxide, hydrogen sulfide and other contaminants including volatile organic compounds [VOCs], PM and bioaerosols) or to contaminated soil and water.[17] Exposure may occur through dispersion in the ground and in contaminated air, and through percolation and seepage of leachates. Leaching occurs not only in landfill sites that are functional, but also after they have been deactivated, as the organic substances continue to decompose.[18]

The Solid Waste Management Rules, 2016 now stipulate that the landfill site shall be 100 m away from river, 200 m from a pond, 200 m from Highways, Habitations, Public Parks and water supply wells and 20 km away from Airports or Airbase.

A study from Italy, which examined the potential health effects of living near (within 5 km) nine landfills, found respiratory symptoms among residents, both in adults and in children, living close to waste sites. Exposure to hydrogen sulfide, a tracer of air-borne contamination from landfills, was positively associated with lung cancer mortality as well as with mortality and morbidity from respiratory diseases including hospitalizations, especially acute respiratory infections among children (0-14 years).[17] Our study too found reduced PEFR in residents living within 2 km of landfill sites compared to those residing beyond 7 km of landfill sites; 315 L/min vs. 398 L/min, respectively.

Occurrence of respiratory symptoms in workers engaged in waste collection and sorting has been linked to inhalation exposure to endotoxin and microorganisms during work, which increases the risk of respiratory problems including other health-related complaints.[19]

CONCLUSION

A large number of data is required to perform an observational study. With this in mind, we conducted

Table 11. Comparison of Water Quality Between Non-landfill Areas and Okhla (Lal Kuan Village)

Parameters	Non-landfill areas			Okhla (Lal Kuan village)	
	Mean	SD	SEM	Mean	P value
Alkalinity (as $CaCO_3$) (mg/L)	302.07	60.18	34.75	591.00	0.053
Acidity (as $CaCO_3$) (mg/L)	36.40	29.53	17.05	136.50	0.099
Chloride (as Cl) (mg/L)	66.20	30.34	17.52	6452.00	0.000
Conductivity (µS/cm)	1016.67	251.66	145.30	4200.00	0.008
Total hardness (as $CaCO_3$) (mg/L)	278.40	82.02	47.36	768.00	0.035
Bicarbonate alkalinity (as $CaCO_3$) (mg/L)	302.07	60.18	34.75	591.00	0.053
pH	7.85	0.32	0.19	7.33	0.299
Total solids (mg/L)	664.00	180.13	104.00	2730.00	0.010
Total suspended solids (mg/L)	15.67	3.21	1.86	12.00	0.427
Total dissolved solids (mg/L)	648.33	179.78	103.80	2718.00	0.010
Total volatile solids (mg/L)	67.67	14.57	8.41	191.00	0.018
Total Kjeldahl nitrogen (as N) (mg/L)	2.49	1.57	1.11	4.14	0.548
Nitrate (as N) (mg/L)	1.40	0.28	0.20	2.27	0.241
Calcium (as Ca) (mg/L)	52.53	17.33	10.01	153.80	0.037
Magnesium (as Mg) (mg/L)	35.77	9.39	5.42	95.30	0.032
Potassium (as K) (mg/L)	1.40	0.78	0.45	2.83	0.254
Sodium (as Na) (mg/L)	87.73	19.14	11.05	383.00	0.006
Iron (as Fe) (mg/L)	0.01	0.01	0.00	0.01	0.448
Manganese (as Mn) (mg/L)	0.03	0.04	0.03	0.01	0.677

an observational study at six locations in Delhi-NCR; three in the vicinity of the landfill sites and three away from the landfills. Our study is more focused on observing the changes in health parameters in different population and does not attempt to identify a cause and effect association.

Systolic and diastolic BP were found to be significantly higher in the study group, while height, weight, BMI, PEFR, SpO_2 before and after 6MWT were lower in the study group compared to the control group.

Water samples tested from the landfill sites also showed increased total dissolved solids, hardness and bicarbonate levels indicating ground water contamination.

These findings re-emphasize the urgent need to manage solid waste in Delhi-NCR. All stakeholders including concerned authorities and environmental agencies should join hands to formulate and implement policies that uphold modern and sustainable practices for solid waste management.

There are some methodological limitations of our study. We did not check for VOCs, benzene, SO_2 and NO_2. Also, we have not identified the possible route of exposure among the study population. We cannot rule out the effect of bias and confounding factors on these observations. This is preliminary data indicative of the risks, which people residing in the vicinity of landfill sites are exposed to. Nevertheless, our observations are significant enough to consider a trial in a larger sample size as the culprit environmental factor needs to be investigated further. An extended study is being undertaken.

Conflict of Interest: None.

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■■■■

Snoring

Formula of 5/10/15

- Men with more than 5 attacks of apnea or hypopnea per hour during sleep are 5 times more prone to automobile accident.
- Patients with more than 10 attacks of apnea or hypopnea per hour during sleep need continuous positive airway pressure (CPAP) treatment.
- Man and woman with more than 15 attacks of apnea or hypopnea per hour during sleep are 7 times are more likely to have an accident.