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COMPARATIVE STUDY OF AIRBORNE MICROBIAL BURDEN IN THE VICINITY OF TWO LANDFILL SITES IN MUMBAI, INDIA.

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ABSTRACT

The municipal landfills are favorable sites for growth of microorganisms because of availability of organic matter. If these landfills are insanitary and situated in densely populated areas they may cause various diseases such as, hypersensitive pneumonitis, bronchitis, chronic airway inflammation etc. Hence, regular monitoring of microorganisms in the vicinity of such places is very important. These studies are also useful to decide the control strategies in order to protect the environment. The present study was aimed to investigate microbial bioaerosol concentrations in the vicinity of two landfill sites of Mumbai. The concentration of total heterotrophic bacteria in the vicinity of landfill sites was maximum in monsoon season (1133 cfu/m^3- 2155 cfu/m^3). While minimum recorded during summer season (153 cfu/m^3 - 221 cfu/m^3). *Staphylococci* and *Actinomycetes* concentrations wereregistered maximum during monsoon (178 cfu/m^3 - 240 cfu/m^3) while minimum during winter season (28 cfu/m^3 - 36 cfu/m^3). No bacteria free month recorded at both the selected dumping sites during the entire period of investigation.

KEYWORDS: ***dumping ground, India, Mumbai, microorganisms, municipal solid waste, staphylococci, actinomycetes***

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INTRODUCTION

Rapid urbanization in developing countries like India is responsible for rise of new problems related to human and environmental health. Municipal Solid Waste (MSW) management is one of the major problems for the local governing authorities of developing nations like India. Mumbai is a megacity and economical capital of India with total population of 12.7 million residing over 603 km^2 of area[1]. Total 7025 metric tons of municipal solid waste is generated daily in Mumbai, of which 4800 metric tons is general municipal solid waste and the rest is the inert matter like plastic, metal, etc.[16] Municipal solid waste of Mumbai is disposed on two landfill sites namely Deonar and Mulund. Poor handling of Municipal Solid Waste may result in harmful consequences. The activities related with solid waste management such as sweeping, sorting, compressing, transporting, and dumping of solid waste responsible for elevated level of bioaerosols in air[2- 4]. Bioaerosols are fine biological particles which include fungal propagules, spores, mycotoxins, bacteria, endotoxins, enterotoxins, viruses, pollens and dust particles[2, 5]. Many studies related with health effects on solid waste management workers reveals that consistent exposure to bioaerosols is harmful for human health. Bioaerosols show acute toxic effects on human body. They are responsible for respiratory diseases such as asthma, lung mycosis, hypersensitive pneumonitis etc.[2, 6 - 10]. Apart from the human health hazards, the dispersal of microorganisms from the various source could give technical problems like biodegradation and biodeterioration[17]. Endotoxins secreted from Gram negative bacteria reported as toxic for human beings causing fever, shivers, headache, respiratory problems etc. Commonly occurring bacteria at contaminated places are *Micrococcus*, *Enterobacteria*, *Staphylococcus*, *Bacillus*, *Mycobacterium*, *Pseudomonas*, *Escherichia*, *Enterobacter*etc.[4, 11.] Apart from Gram negative and Gram positive bacteria, Actinomycetes can be share a small part in bioaerosols. Actinomycetes are filamentous, branching bacteria with a fungal type of morphology. Thermophilic actinomycetes were reported from composting facilities in several studies. *Saccharopolyspora rectivirgula, Saccharomonospora spp* etc are commonly reported thermophilic actinomycetes in previous studies[12, 13]. The present study is based on assessment of microbial bioaerosol contamination of air in the vicinity of two landfill sites in Mumbai.

MATERIAL AND METHODS

Area of study and sampling strategy

The study sites selected for this study were two landfill sites situated in Mumbaithey are,Deonar and Mulund.Four sampling stations were selected in the vicinity of Deonar landfill site out of which three were on the downwind direction approximately 200-500 m away from point source and one toward upwind direction approximately 900 m away from the point source (Figure #1). Six sampling stations were selected for the study around in the vicinity of Mulund landfill site out of which five were towards the downwind approximately 200 to 500 metre far from point source and one was upwind approximately 1000 metre far from point source(Figure # 2). Air samples were collected fortnightly for the duration of one year (2015-16) using different culture media with an Impaction air sampler named *Biomerieux Sampl'air* Sampler which has flow rate of 100 litre of air per minute.

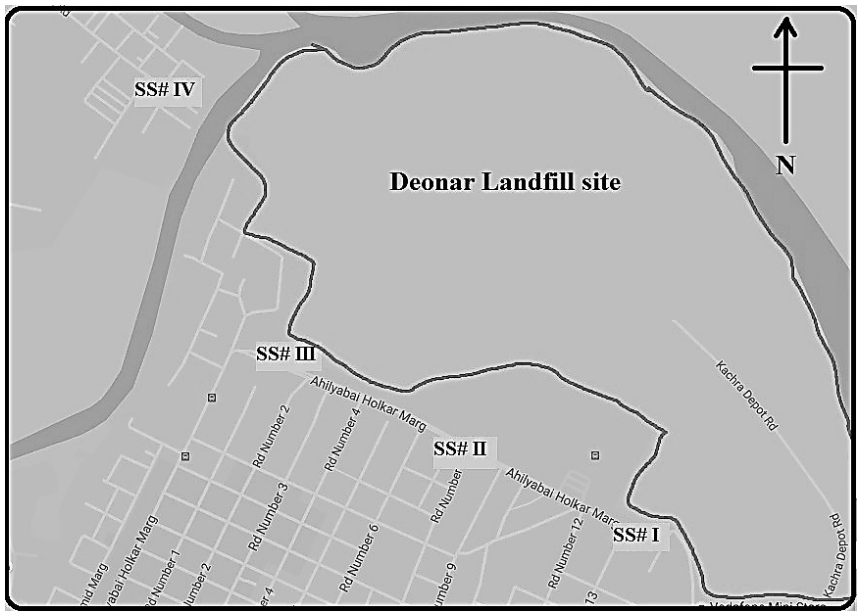


Figure 1
Map of Deonar landfill showing sampling stations

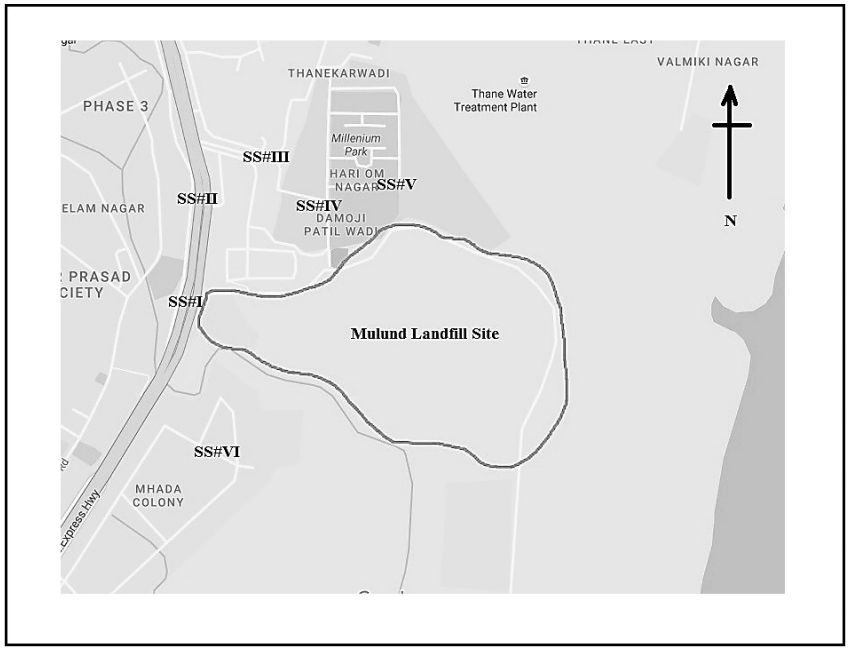


Figure 2
Map of Mulund landfill showing sampling stations

Meteorological data
The meteorological data of temperature and relative humidity was collected while sampling by using portable digital equipment. The data of wind speed was collected from web site of Indian Meteorological Department (Table # 3& 4).

Culture media statistical analysis
The culturable airborne microorganisms investigated in this study were heterotrophic bacteria, Actinomycetes and Staphylococci. Culture media used for entrapment were Nutrient agar, Kenknight's and Munaier's Medium, Mannitol Salt Agar respectively. 90 mm diameter sterile Petri dishes were poured with respective culture media, packed in polythene bags and carried to the field for air sampling. The duration of air sample (3 minutes in summer and winter season & 1 minute in monsoon season) was adjusted according to season to avoid over clumping of colonies on petri dishes. After exposing with impaction sampler the Petri dishes were carried to laboratory and incubated at 30± 2^{o}C for 2-7 days. Colonies on Petri dishes were counted and positive hole correction method was applied to determine concentration of airborne microorganisms per litre of air. Colonies of staphylococci and actinomycetes were distinguished with the help of colony characteristics. A non parametric statistical test, Correlation coefficient was applied to the data to check relation between meteorological factors and concentration of bioaerosols.

RESULT AND DISCUSSIONS

Concentration of total heterotrophic bacteria at Deonar landfill was registered maximum at sampling station (SS) # I (2155 cfu/m^3) which is at downwind direction located at 200-250 m away from point source. Staphylococci concentration was highest at SS # II (235 cfu/m^3) and highest concentration of actinomycetes registered 178 cfu/m^3 at SS # IV (Table # 1).

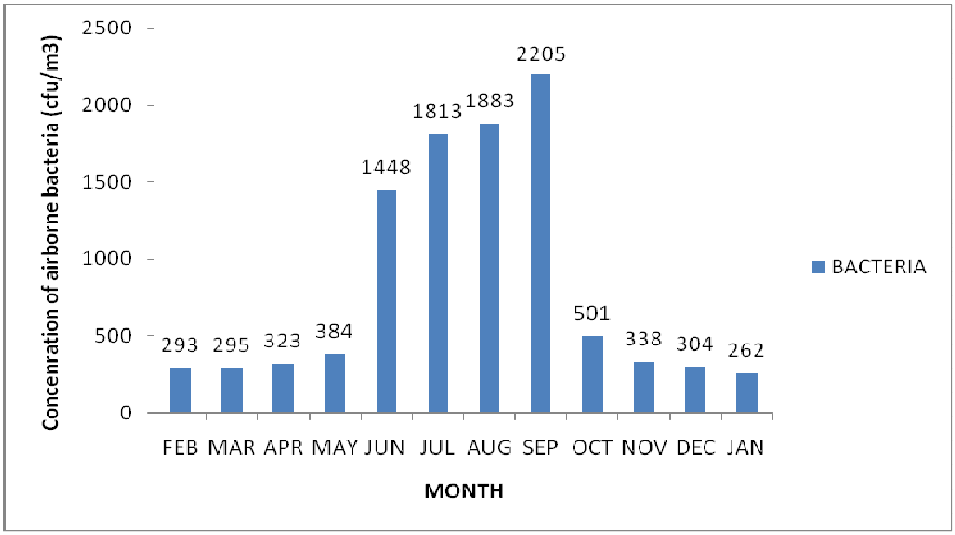
Table 1
Concentration of airborne microorganisms in the vicinity of Deonar landfill site (in cfu/m^3)

SEASON	MONTH	SAMPLING STATION	TOTAL HETEROTROPHIC BACTERIA	STAPHYLOCOCCI	ACTINOMYCETES
SUMMER SEASON	FEB'15	I	330	60	20
		II	303	53	23
		III	340	47	23
		IV	197	33	20
	MAR'15	I	350	50	33
		II	323	37	17
		III	313	63	33
		IV	193	40	17
	APR'15	I	323	80	47
		II	323	70	60
		III	370	73	37
		IV	273	50	37
	MAY'15	I	400	83	63
		II	400	87	60
		III	393	83	47
		IV	343	67	47
MONSOON SEASON	JUN'15	I	1380	260	130

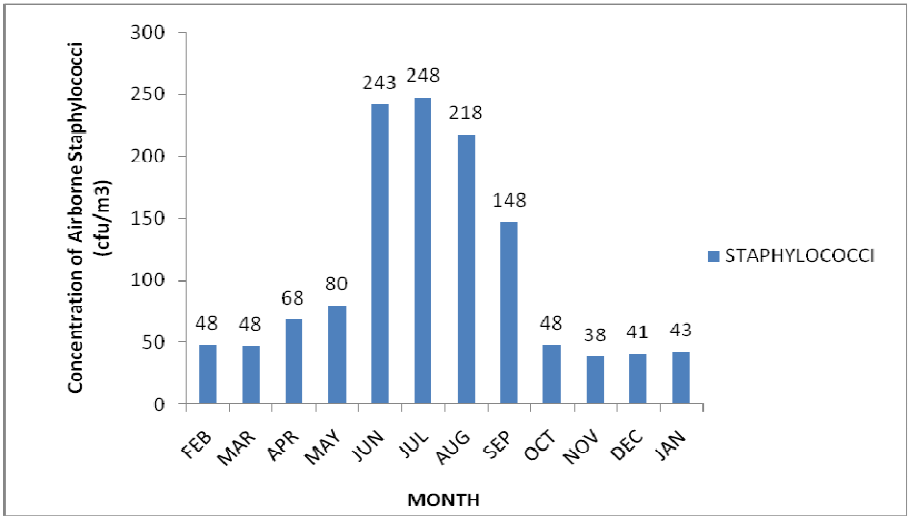
		II	1610	270	180
		III	1630	250	160
		IV	1170	190	100
	JUL'15	I	2520	290	160
		II	1680	270	210
		III	1650	250	130
		IV	1400	180	140
	AUG'15	I	2200	200	190
		II	1910	240	110
		III	2040	250	140
		IV	1380	180	100
	SEP'15	I	2520	150	140
		II	2580	160	210
		III	2370	120	130
		IV	1350	160	140
WINTER SEASON	OCT'15	I	457	60	33
		II	557	47	43
		III	617	47	40
		IV	373	40	33
	NOV'15	I	380	40	33
		II	333	50	40
		III	350	37	37
		IV	290	27	20
	DEC'15	I	260	37	27
		II	343	43	43
		III	350	50	50
		IV	263	33	37
	JAN'16	I	273	47	27
		II	287	43	27
		III	240	37	30
		IV	247	43	23

Average higher concentration of total heterotrophic bacteria in air at all sampling stations was reported in monsoon season in September (2205 cfu/m^3). Maximum of emission of Staphylococci (in July 248 cfu/m^3) and Actinomycetes (in September 155 cfu/m^3) was also reported in monsoon season. Lowest concentration of heterotrophic bacteria was observed in winter season in January (262 cfu/m^3). Minimum concentration of Staphylococci and Actinomycetes registered in December (41 cfu/m^3) and January (27 cfu/m^3) respectively (Graph # 1-3). Our results are similar to the results reported by Malecka Adamcowicz et *al.* (2006)[14]. In their study they reported that sampling stations located on periphery of waste disposal site in Poland are less contaminated with microbial load. But, in case of seasonal distribution, our results differ with the above study. The higher concentration of airborne microbes we reported in monsoon season, in above study, higher concentration of airborne microbes was higher in summer season.

Graph 1
Monthly average concentration of total heterotrophic bacteria in the vicinity of Deonar landfill site (in cfu/m^3)



Graph 2
Monthly average concentration of staphylococci in the vicinity of Deonar landfill site (in cfu/m^3)



Graph 3
Monthly average concentration of actinomycetes in the vicinity of Deonar landfill site (in cfu/m^3)

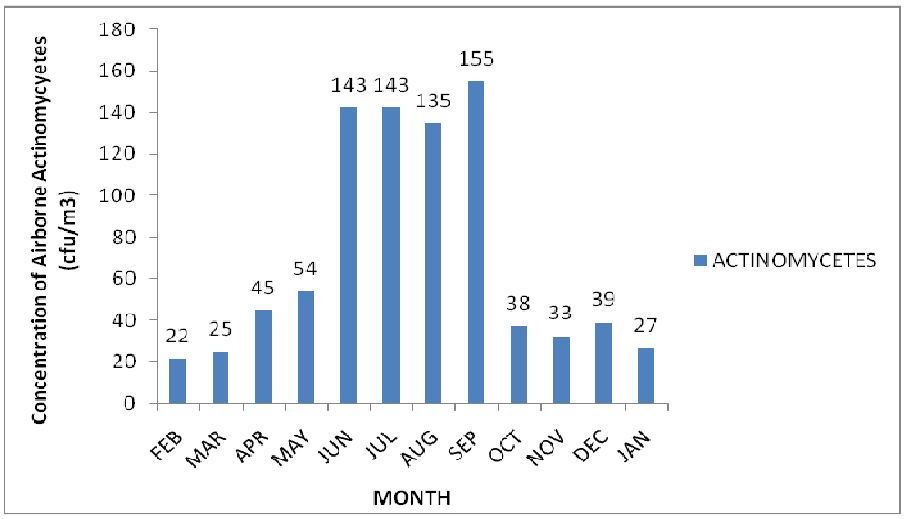


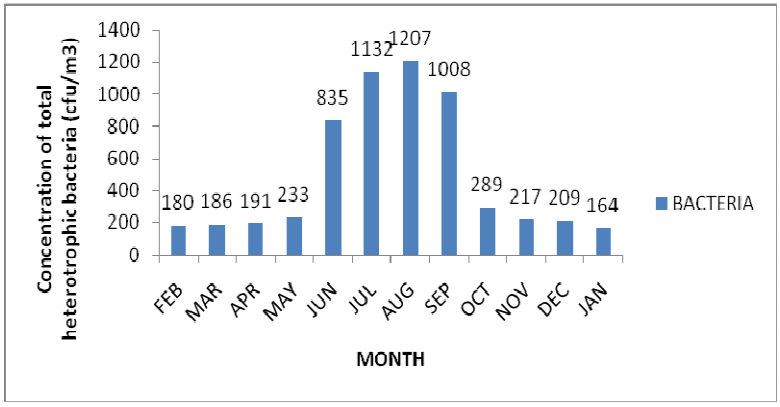
Table 2
Concentration of airobrone microorganisms in the vicinity of Mulund landfill (in cfu/m^3)

SEASON	MONTH	SAMPLING STATION	TOTAL HETEROTROPHIC BACTERIA	STAPHYLOCOCCI	ACTINOMYCETES
SUMMER SEASON	FEB'15	I	193	33	40
		II	203	40	33
		III	173	30	33
		IV	170	47	43
		V	190	50	47
		VI	150	37	20
	MAR'15	I	197	33	43
		II	203	37	47
		III	187	17	30
		IV	187	43	50
		V	190	37	33
		VI	153	20	33
	APR'15	I	210	47	47
		II	213	40	47
		III	190	30	30
		IV	220	47	50
		V	180	40	40
		VI	130	33	30

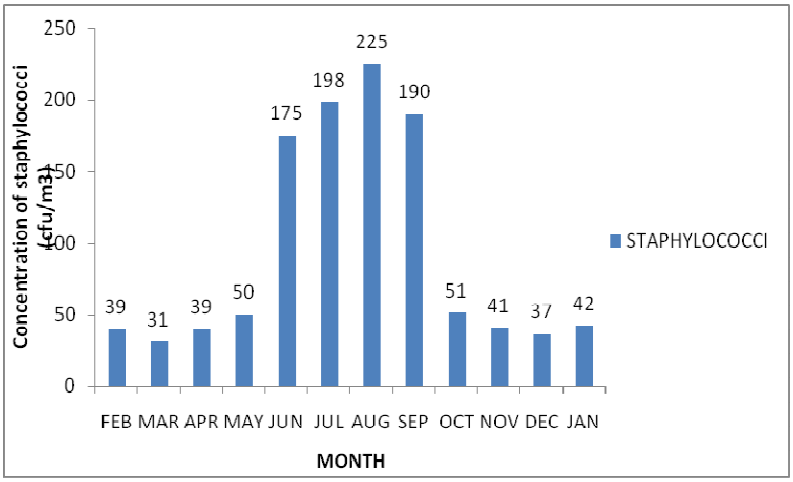
	MAY'15	I	260	70	43
		II	250	57	40
		III	233	40	37
		IV	250	57	43
		V	227	40	33
		VI	180	37	27
MONSOON SEASON	JUN'15	I	940	200	180
		II	940	180	160
		III	870	130	130
		IV	930	220	160
		V	750	200	130
		VI	580	120	90
	JUL'15	I	1200	270	120
		II	1230	230	120
		III	1140	150	140
		IV	1200	230	120
		V	1060	200	160
		VI	960	110	70
	AUG'15	I	1180	260	260
		II	1200	260	190
		III	1090	190	150
		IV	1380	240	210
		V	1330	220	180
		VI	1060	180	120
	SEP'15	I	1110	230	210
		II	1090	240	220
		III	940	150	160
		IV	1020	210	150
		V	1090	180	160
		VI	800	130	100
WINTER SEASON	OCT'15	I	303	63	43
		II	313	53	37
		III	273	37	30
		IV	280	53	43
		V	310	60	43
		VI	253	40	27
	NOV'15	I	227	40	47
		II	233	50	43
		III	237	33	37
		IV	253	43	40
		V	197	50	43
		VI	157	27	30
	DEC'15	I	207	40	37
		II	223	33	50
		III	210	27	37
		IV	237	43	33
		V	207	40	37
		VI	170	37	33
	JAN'16	I	173	47	37
		II	170	43	40
		III	150	40	27
		IV	173	50	40
		V	177	40	33
		VI	143	33	30

Downwind sampling stations in the vicinity of Mulund landfill ***site*** were more contaminated with airborne microorganisms. Maxima of total heterotrophic bacteria in air registered at Sampling station (SS) # IV (1133 cfu/m^3) and minima registered at SS # III (196 cfu/m^3). Concentration of staphylococci was registered maximum at SS # I (240 cfu/m^3) and in case of actinomycetes it was maximum at SS # I (240 cfu/m^3). Minimum concentration of Staphylococci and Actinomycetes was registered at SS # III which was 29 cfu/m^3 and 33 cfu/m^3 respectively (Table # 2). Month of August registered maximum concentration of airborne bacteria, Staphylococci and Actinomycetes. Concentration of total heterotrophic bacteria in air was 1207 cfu/m^3, Staphylococci (225 cfu/m^3) and Actinomycetes (185 cfu/m^3). Minimum concentration of total heterotrophic bacteria and Actinomycetes was reported in January 2016 which was 164 cfu/m^3 and 34 cfu/m^3 respectively. Minimum concentration of Staphylococci was reported in the month of March (31 cfu/m^3) (Graph #4-6).

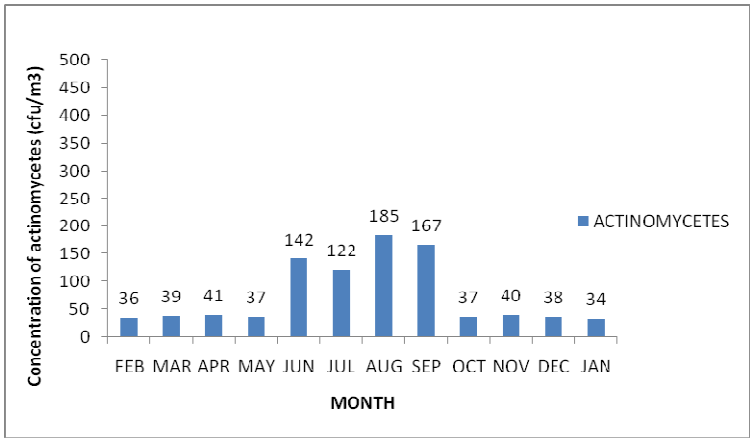
Graph 4
Monthly fluctuation in concentration of total heterotrophic bacteria in the vicinity of Mulund landfill site (in cfu/m^3)



Graph 5
Monthly fluctuation in concentration of staphylococci in the vicinity of Mulund landfill site (in cfu/m^3)



Graph 6
Monthly fluctuation in concentration of actinomycetes in the vicinity of Mulund landfill site (in cfu/m^3)



Similar findings were registered by some research workers[4] where they highlighted that concentration of total bacteria was 138 cfu/m^3 and the concentration of Actinomycetes in air ranged from 4 cfu/m^3 to 85 cfu/m^3 to 1095 cfu/m^3 at the sampling stations located 200 m away from waste disposal facility[4]. In our study, sampling stations are located outside the dumping area approximately 200-250 m away from the point source.

Sampling stations located on downwind direction of landfill are more contaminated with microbial bioaerosols than sampling station located on upwind direction. Similar findings were reported by many aerobiologists [4,10,14] where they recorded lower concentration of bioaerosols at sampling stations located beyond the boundary of landfills 200-300 m away from point source[4, 10, 14].

Table 3
Meteorological conditions in the vicinity of Deonar landfill site in the year 2015-16

Month	Average Temperature (°C)	Average Relative Humidity (%)	Wind Speed (m/s)
February	30.1	62	1.9
March	33.4	50	2.2
April	35.0	72	1.9
May	38.6	73	2.2
June	31.5	92	2.8
July	33	79	3.1
August	32	80	1.9
September	34.1	80	1.9
October	35.2	72	1.7
November	33.1	70	1.7
December	34.4	68	1.9
January	31.2	59	1.9

Table 4
Meteorological conditions in the vicinity of Mulund landfill site in the year 2015-16

Month	Average Temperature (°C)	Average Relative Humidity (%)	Wind Speed (m/s)
February	31.2	62	1.9
March	32.4	51	2.2
April	36.1	71	1.9
May	37.5	73	2.2
June	32.4	92	2.8
July	33.0	79	3.1
August	32.0	80	3.1
September	33.2	82	1.9
October	35.0	72	1.7
November	34.0	70	1.7
December	32.4	65	1.9
January	32.0	59	1.9

Table 5
Pearson correlation between concentration of bioaerosols and meteorological factors in the vicinity of Deonar landfill

	conc. of bioaerosols	*temperature*	*relative humidity*	*wind speed*
conc. of bioaerosols	1			
temperature	-0.171	1		
relative humidity	0.735	0.064	1	
wind speed	0.694	-0.222	0.512	1

Table 6
Pearson correlation between concentration of bioaerosols and meteorological factors in the vicinity of Mulund landfill

	conc. of bioaerosols	*temperature*	*relative humidity*	*wind speed*
conc. of bioaerosols	1			
temperature	-0.273	1		
relative humidity	0.722	0.147	1	
wind speed	0.778	-0.251	0.512	1

Pearson correlation test was applied to the data to check relation between environmental factors and fluctuation in concentration of bioaerosols. The results of test show that there is positive correlation between concentration of bioaerosols and relative humidity, wind speed. There was negative correlation between temperature and concentration of bioaerosols which may be because consistent burning of solid waste and increase in temperature affects emission of bioaerosols in the air (Table # 5 & 6). The same conclusion drawn by Malecka-Adamcowicz et al., (2006) where they stated that weather conditions strongly affect concentration of microorganisms in air[14]. In their study, they reported that winter season is unfavorable for emission of bioaerosols because of low relative humidity which agrees with our findings. Tang, (2009) reported in their review paper that temperature above 24°C appear to decrease airborne bacteria. Relative humidity in the range of 50-70% was found favorable for microbial survival in air[15].In our study, besides high temperature,

concentration of airborne bacteria was registered higher which may be because of wind current flowing in one direction from point source. As per our findings, monsoon season is favorable for bioaerosol emission which may be because; in monsoon season the water droplets in the air are in higher amount because of high rate of humidity. This condition favors the carrying capacity of living organisms in the air. Consequently, airborne microbes survive in air for more time, because of which concentration of bioaerosol rises in monsoon period.

CONCLUSION

The concentration of bioaerosols is positively correlated with humidity and wind speed. As expected the downwind sampling stations were more contaminated than upwind sampling station. Bioaerosol emission trend showed seasonal fluctuation, monsoon season was more favorable for increase in concentration of airborne bacteria. The air in the vicinity of Deonar landfill site is more contaminated rather than the air in the vicinity of Mulund landfill. This may be because of higher amount of waste is dumped at Deonar landfill. Bacterial load in the air around landfills can be immediately decreased by masking the daily deposits of refuse with soil of debris material of by using alternative methods such as biogas, composting, bioreactor landfilling. The above study would be helpful to build strategies regarding to safe disposal of solid waste in Indian cities and it will also tend to the government to try for alternative ways for solid waste management.

CONFLICT OF INTEREST

Conflict of interest declared none.

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