Seasonal Variations in Human Health Impacts of PM_{10}, $PM_{2.5}$, SO_2, and NO_2 Emissions from a Solid Waste Disposal Facility at Turbhe, Navi Mumbai

Hasan Rameez, Vikas Varekar, Navneet Rai and Harshit Mishra

Abstract A supercity Navi Mumbai has a Solid Waste Disposal Facility (SWDF) that processes and disposes 740 tons/day of waste. The emissions from the SWDF cause direct health impacts to the population residing in the vicinity of the facility. Since the severity and extent of health impacts may vary seasonally, the analysis is performed separately for monsoon and non-monsoon seasons for 3 consecutive years: 2011, 2012, and 2013. The hourly concentrations for the pollutants PM_{10}, $PM_{2.5}$, SO_2, and NO_2 have been procured from Navi Mumbai Municipal Corporation, having an ambient air quality monitoring station installed within the SWDF. The population residing within 1 km radius of the monitoring station is considered for the analysis. The human health impact assessment has been performed using AirQ+ model to quantify health risks in terms of mortality and morbidity caused by various short-term health effects, which include total mortality, cardiovascular mortality, respiratory mortality, hospital admissions—cardiovascular diseases, respiratory diseases, and chronic obstructive pulmonary disease. Results demonstrate the seasonal variations in terms of total Excess Number of Cases (ENCs) of all the health effects under consideration for 3 consecutive years during monsoon and non-monsoon seasons, which ranges from 21 to 23 and 152 to 156, respectively. The analysis indicates that PM_{10} contributed most toward ENCs, while NO_2 had no health impacts. This study can be used by policy-makers to evaluate the present scenario for health impacts, which may serve as a tool to assess the existing solid waste management infrastructure and to adopt necessary augmentations for future.

H. Rameez · V. Varekar (✉) · N. Rai
Veermata Jijabai Technological Institute, Mumbai 400019, India
e-mail: vbvarekar@ci.vjti.ac.in

H. Rameez
e-mail: rameez.ced@gmail.com

N. Rai
e-mail: rai.navneet177@gmail.com

H. Mishra
Indian Institute of Technology Bombay, Mumbai 400076, India
e-mail: harshit.cese@gmail.com

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1 Introduction

Rapid growth of urbanization and industrialization across the globe has led to a drastic increase in the levels of air pollution over the last few decades. Air pollutants such as PM_{10}, $PM_{2.5}$, CO, NO_2, SO_2, and O_3 are known to have various short term and long-term health impacts on the exposed human population [1–5]. The presence of these pollutants above threshold limits in the ambient air may have several human health impacts including many respiratory and cardiovascular diseases that result in large-scale loss of life. Many studies have been conducted across the globe to carry out Human Health Impact (HHI) assessment to quantify the health risks posed by air pollutants in terms of mortalities and morbidities due to several health impacts [6–11].

The mammoth amount of solid waste generation and its disposal is one of the critical issues being faced by Indian metropolitan regions. To mitigate this problem, many solid waste disposal facilities (SWDF) have been deployed in India where the solid waste is processed in various ways before it is finally disposed in the sanitary landfills. These solid waste disposal facilities may contribute significantly to the ambient air pollution through emission of particulate and gaseous pollutants. The resulting elevated levels of pollutants in the ambient air can cause harmful effects to the exposed population. Under the Indian scenario, no past study has been reported for evaluation of health impacts due to the emissions from a SWDF. Hence, a need is felt to carry out the human health impact assessment for a SWDF. Also, India being a tropical country, it receives heavy rainfall in the months of June, July, August, and September (monsoon season), while the other 8 months (non-monsoon season) receive scanty to no rainfall. Since the concentration of pollutants in the air is significantly lower in monsoon as compared to non-monsoon season, therefore, the human health impacts associated with these pollutants may also vary seasonally. Hence, the present study is carried out with the objective of evaluation of the short-term human health impacts of PM_{10}, $PM_{2.5}$, SO_2, and NO_2 emissions from a SWDF by considering the variations between monsoon and non-monsoon seasons. The area selected for this study is the Turbhe SWDF, located in Navi Mumbai.

2 Material and Method

2.1 Study Area

Turbhe solid waste disposal facility comes under the jurisdiction of Navi Mumbai Municipal Corporation (NMMC), Navi Mumbai, situated on the west coast of Maharashtra. It lies between 19°5′N and 19°15′N latitude and 72°55′E and 73°5′E longitude. The climate of the region is predominantly tropical wet type, experiencing average daily temperature variations from 12 °C to 43 °C over the course of year [12]. In 2012, the region received a total rainfall of 2623.4 mm, of which 90% was concentrated in the monsoon season, i.e., June to September [13]. Turbhe SWDF has been in operation since 2008. Navi Mumbai's booming economy and growing population have contributed to about 1.5-fold increase in the amount of solid waste processed and disposed from 491 tons per day in 2008 to a peak of 740 tons per day in 2017. Solid waste coming to this facility undergoes various pre-processes before it is finally disposed into the engineered landfill. These pre-processes include sorting of waste, recycling, composting, refuse-derived fuel generation and landfilling of waste. These pre-processes involve various operations such as local transportation of waste within the facility, loading and unloading of waste from vehicles, drying, crushing, and compaction of waste, and turning of waste piles during windrow composting. Carrying out these operations require consumption of large quantity of fuel on daily basis, which contributes to the concentration of particulate matter and noxious gases such as methane, carbon monoxide, carbon dioxide, sulfur dioxide, nitrogen dioxide, and hydrocarbons.

2.2 Health Risk Assessment Tool

In the present study AirQ+ software, developed by World Health Organization, is used to quantify the health risks in terms of excess number of cases (ENCs) of mortality and morbidity caused due to various health impacts, namely, total mortality, cardiovascular mortality, respiratory mortality, hospital admissions—cardiovascular diseases, respiratory diseases, and chronic obstructive pulmonary disease. The framework of AirQ+ software is based upon the values of relative risk and baseline incidence developed through time-series epidemiological studies.

The HHI assessment is based on the attributable proportion (AP), defined as "the fraction of the health outcome in a certain population attributable to exposure to a given atmospheric pollutant, assuming a proven causal relation between exposure and health outcome and no major confounding effects in that association" [14]. The AP can be calculated using the formula [15].

$$AP = \frac{\sum \{[\mathrm{RR(c)} - 1] * \mathrm{p(c)}\}}{\sum [\mathrm{RR(c)} * \mathrm{p(c)}]} \tag{1}$$

where RR(c) = Relative risk for health outcome in category 'c' of exposure

p(c) = Proportion of population in category 'c' of exposure.

Relative Risk (RR) is the estimate of the magnitude of an association between exposure and disease. "RR gives the increase in the probability of the adverse effect associated with a given change in the exposure levels and comes from time-series studies, where day-to-day changes in air pollutants over long periods were related to daily mortality, hospital admissions, and other public health indicators" [14]. Mathematically, RR can be defined as [16]

$$\mathrm{RR} = \frac{\text{Probability of event when exposed to air pollution}}{\text{Probability of event when non\_exposedtoairpollution}} \tag{2}$$

The RR value can be calculated as [17]

$$\mathrm{RR} = \mathrm{e}^{\beta * \Delta \mathrm{C}} \tag{3}$$

where β = Concentration response function (CRF)

ΔC = Change in ambient air concentration.

Concentration Response Function (CRF) is defined as increase in incidence of a health effect per unit change in pollutant concentration. ΔC is the difference between the value of ambient air concentration of a pollutant and its cut off limit, i.e., its permissible limit as established by WHO or other concerned authorities.

The RR values given as input to AirQ+ are corresponding to increase in pollutant concentration by 10 $\mu g/m^3$ above the cutoff limit. From this relative risk value (corresponding to increase of 10 $\mu g/m^3$), the actual relative risk value corresponding to an existing ambient air concentration of the pollutant is calculated as [11].

$$\mathrm{RR}' = 1 + [\Delta \mathrm{C} \; * \; (\mathrm{RR} - 1)/10] \tag{4}$$

where RR′ = Relative risk corresponding to existing pollutant concentration

RR = Relative risk corresponding to increase of pollutant concentration by 10 $\mu g/m^3$.

If the baseline frequency (I), i.e., the population incidence (number of cases per 100,000) of the given health effect is known, then the excess number of cases per unit population attributed to exposure E can be calculated as [18].

$$\mathrm{I_E} = \mathrm{I} * \mathrm{AP} \tag{5}$$

where I = Frequency/incidence of a health effect per unit population

I_E = ENCs attributable to exposure E per unit population

The ENCs for the population under consideration can be obtained as [18].

$$N_E = I_E * N \quad (6)$$

where N_E = ENCs for population under consideration

N = Size of population under consideration.

The inputs required by AirQ+ includes mean concentration of the pollutants, population under consideration, relative risk values (per 10 μg/m^3 increase of concentration for hazardous substances) for pollutants and baseline frequency of health effects. The hourly concentrations of the pollutants under consideration, i.e., PM_{10}, $PM_{2.5}$, SO_2, and NO_2, have been procured from Navi Mumbai Municipal Corporation's ambient air quality monitoring station installed within the solid waste disposal facility. This data was used to calculate mean concentrations for monsoon and non-monsoon seasons for the years 2011–2013. Four months of June, July, August, and September were considered for monsoon season, while remaining 8 months comprised non-monsoon season. The population within 1 km radius of the facility is considered as the population exposed to the pollution levels measured at the monitoring station. The human health data for the relative risk and baseline incidence values, as adopted from [11, 19], are shown in Table 1.

Table 1 WHO specified values of Relative Risk (per 10 μg/m^3 increase of PM_{10}, $PM_{2.5}$, SO_2, and NO_2) with 95% confidence interval and Baseline Incidence values per 100,000 population

Pollutants	Mortality/morbidity	Relative risk (RR)[c] (95% CI) per 10 μg/m^3	Baseline incidence per 100,000[d]
PM_{10}	Total mortality[x]	1.0074 (1.0062–1.0086)	1013
	Cardiovascular mortality[y]	1.008 (1.005–1.018)	497
	Respiratory mortality[z]	1.012 (1.008–1.037)	66
	HA respiratory disease	1.008 (1.0048–1.0112)	1260
	HA cardiovascular disease	1.009 (1.006–1.013)	436
$PM_{2.5}$	Total mortality	1.015 (1.011–1.019)	1013
	HA COPD[a]	1.0058 (1.0022–1.0094)	101.4
SO_2	Total mortality	1.004 (1.003–1.0048)	1013
	Cardiovascular mortality	1.008 (1.002–1.012)	497
	Respiratory mortality	1.01 (1.006–1.014)	66
	HA[b] COPD	1.0044 (1–1.011)	101.4
NO_2	Total mortality	1.003 (1.002–1.004)	1013
	HA COPD	1.0026 (1.0006–1.0044)	101.4

Source [11, 19]

[a]COPD: Chronic Obstructive Pulmonary Disease

[b]HA: Hospital Admissions

[c]Lower and upper limits (range) of RR values

[d]Baseline Incidence per 100,000 is based on threshold limit given in WHO guideline

[x]International Classification of Diseases (ICD) code number: ICD-9-CM < 800

[y]ICD-9-CM 390–459

[z]ICD-9-CM 460–519

3 Results

The human health impact assessment was carried out for Turbhe SWDF. The concentrations of PM_{10}, $PM_{2.5}$, SO_2, and NO_2 for non-monsoon and monsoon seasons for the duration 2011–2013 are shown in Table 2. Concentration of PM_{10} averaged over the 3-year duration was found to be 13.6 times and 3.5 times the WHO recommended guidelines for non-monsoon and monsoon season, respectively. Similarly, $PM_{2.5}$ concentrations for non-monsoon and monsoon seasons were 9.4 times and 2.4 times the WHO guidelines, respectively. SO_2 concentrations for non-monsoon and monsoon seasons were 2.8 times and 1.6 times the WHO guidelines, respectively. However, the NO_2 concentrations for non-monsoon and monsoon seasons were found to be 0.5 times and 0.3 times the WHO guidelines, respectively. Since the NO_2 concentrations were well within the limits, therefore, no health impacts were found to be associated with NO_2.

The health impacts of various pollutants under consideration were categorized into total mortality, cardiovascular mortality, respiratory mortality, cardiovascular hospitality, respiratory hospitality, and COPD hospitality. The ENCs of these impact categories due to PM_{10}, $PM_{2.5,}$ and SO_2 in non-monsoon and monsoon season for the duration 2011–2013 are shown in Fig. 1.

Total Mortality

The ENCs of total mortality (95% CI) were 76 (61–88), 77 (62–91), and 79 (62–92) in the non-monsoon season, and 12 (9–13), 11 (8–12), and 12 (9–13) in the monsoon season, for the years 2011, 2012, and 2013, respectively. The ENCs for total mortality were almost 7 times in non-monsoon as compared to monsoon season. The contributions of PM_{10}, $PM_{2.5,}$ and SO_2 were 59, 39, and 8%, respectively, in non-monsoon season; 50, 33, and 17%, respectively, in monsoon season for the year 2011, the trend being almost same for the years 2012 and 2013 (Fig. 2). The value of attributable proportion (95% CI) for PM_{10} was found to be 18.13% (15.44–20.73) for non-monsoon and 4.6% (3.87–5.33) for monsoon season for the year 2011 (Table 3). AP values for SO_2 were 2.36% (1.78–2.82) and 1.17% (0.88–1.4), respectively, for non-monsoon and monsoon. AP values for $PM_{2.5}$ were 13.74% (10.29–17.04) and 3.65% (2.69–4.59), respectively, for non-monsoon and monsoon. AP values followed the similar trend for the years 2012 and 2013. AP

Table 2 Average concentrations of PM_{10}, $PM_{2.5}$, SO_2, and NO_2 for non-monsoon and monsoon seasons, along with their WHO limits

Year	Non-Monsoon (μg/m^3)				Monsoon (μg/m^3)			
	PM_{10}	$PM_{2.5}$	SO_2	NO_2	PM_{10}	$PM_{2.5}$	SO_2	NO_2
2011	281.3	99.3	59.8	13.9	73.9	25.0	29.5	9.8
2012	274.4	97.9	55.3	26.8	69.4	21.1	31.1	13.2
2013	259.9	85.4	53.9	27.1	68.4	25.7	37.7	17.0
Average	271.9	94.2	56.3	22.6	70.6	23.9	32.8	13.3
WHO limits	20.0	10.0	20.0	40.0	20.0	10.0	20.0	40.0

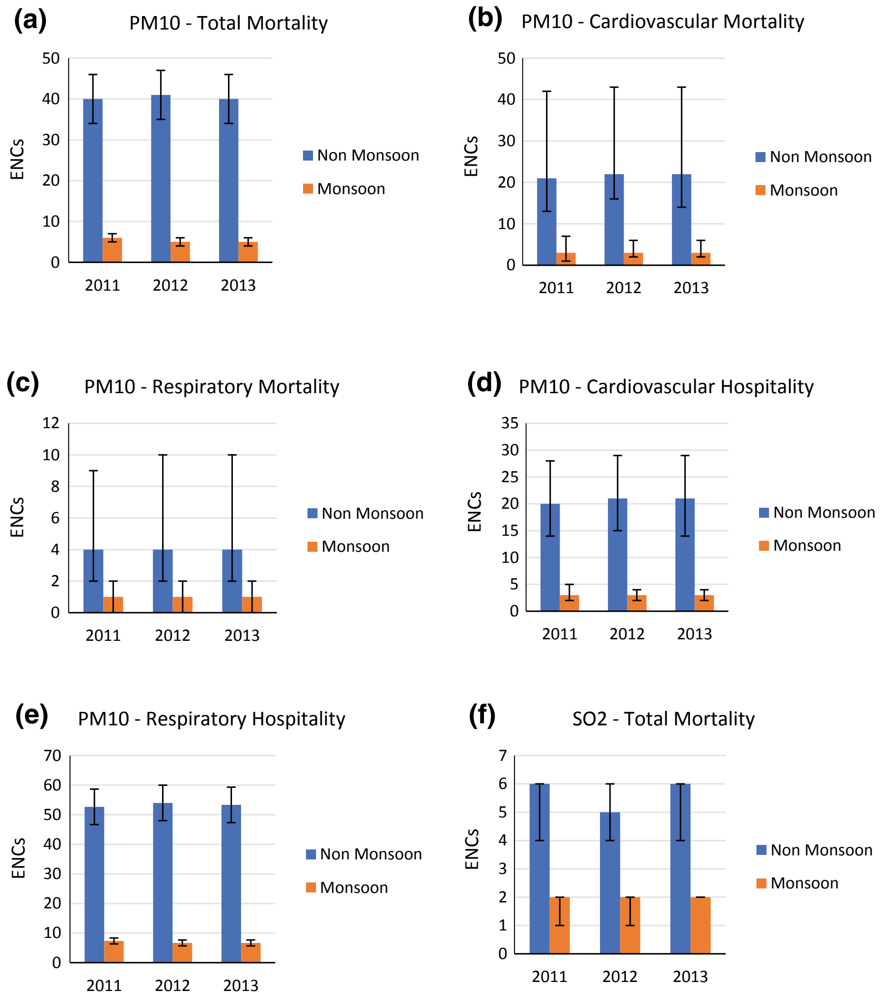

Fig. 1 (a–k) Seasonal variations in ENCs of various health effects due to PM_{10}, SO_2, and $PM_{2.5}$

values suggest that PM_{10} attributes to most total mortalities (among pollutants under consideration) followed by $PM_{2.5}$ and SO_2. NO_2 was also analyzed for total mortality; however, it yielded zero ENCs since its concentration was below WHO guidelines.

Cardiovascular Mortality

The ENCs of cardiovascular mortality (95% CI) were 26 (15–49), 26 (17–49), and 26 (15–49) in the non-monsoon season; 5 (2–8), 5 (2–8), and 5 (2–8) in the monsoon season, for the years 2011, 2012, and 2013, respectively. The ENCs of cardiovascular mortality were found to be 6.5 times in non-monsoon as compared to monsoon season. The contributions of PM_{10} and SO_2 were 81 and 19%,

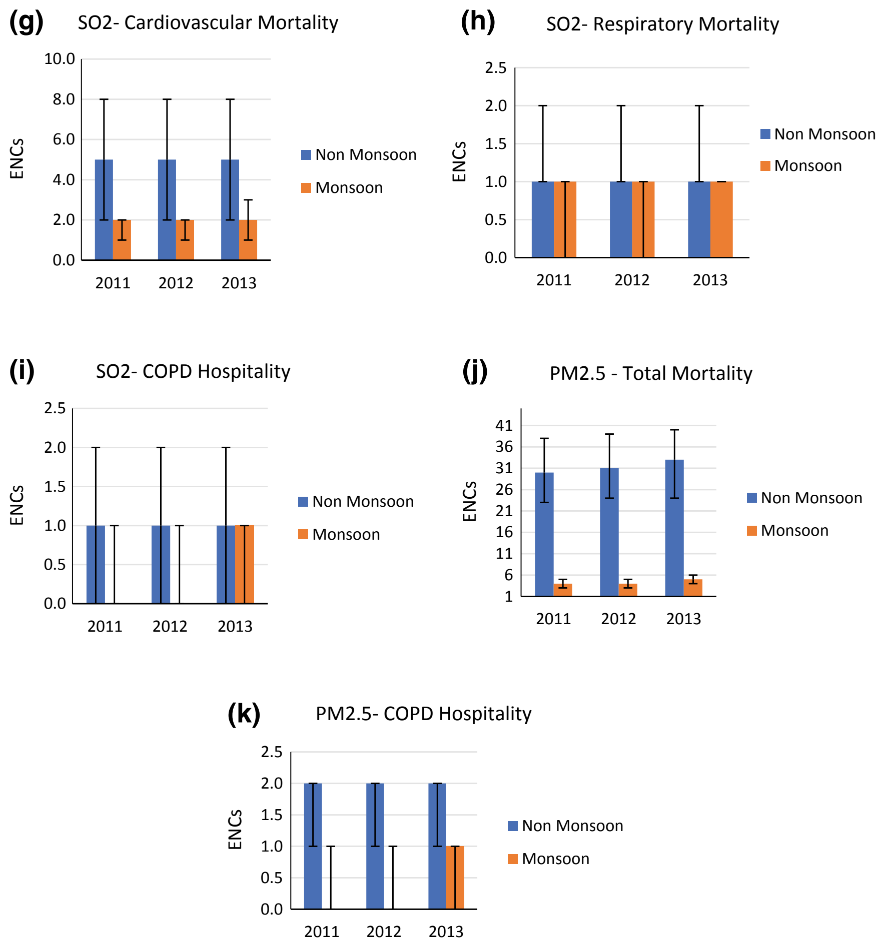

Fig. 1 (a–k) (continued)

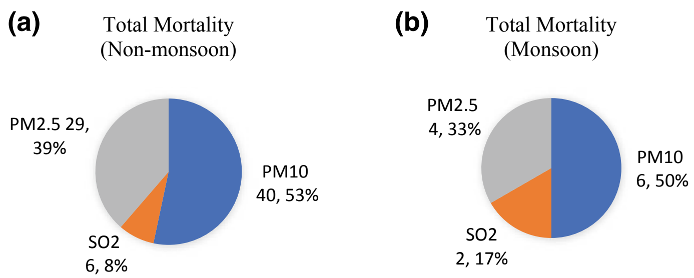

Fig. 2 (a–b) Contribution of individual pollutants in total mortality for non-monsoon and monsoon seasons

Table 3 Estimated Attributable Proportion (AP%) values for PM_{10}, $PM_{2.5}$, and SO_2 for non-monsoon and monsoon seasons

Health point	Air pollutant	2011		2012		2013	
		Non-Monsoon	Monsoon	Non-Monsoon	Monsoon	Non-Monsoon	Monsoon
Total mortality	PM_{10}	18.13 (15.44–20.73)	4.6 (3.87–5.33)	18.13 (15.44–20.73)	4.6 (3.87–5.33)	16.83 (14.31–19.27)	4.22 (3.55–4.88)
	SO_2	2.36 (1.78–2.82)	1.17 (0.88–1.4)	2.18 (1.64–2.61)	1.23 (0.93–1.48)	2.13 (1.6–2.55)	1.49 (1.12–1.79)
	$PM_{2.5}$	13.74 (10.29–17.04)	3.65 (2.69–4.59)	13.74 (10.29–17.04)	3.65 (2.69–4.59)	11.93 (8.91–14.84)	3.74 (2.76–4.71)
Cardiovascular mortality	PM_{10}	19.44 (12.66–38.37)	4.96 (3.14–10.78)	19.44 (12.66–38.37)	4.96 (3.14–10.78)	18.06 (11.72–35.97)	4.55 (2.87–9.9)
	SO_2	4.65 (1.19–6.88)	2.32 (0.59–3.46)	4.3 (1.1–6.37)	2.44 (0.62–3.64)	4.2 (1.07–6.22)	2.95 (0.75–4.39)
Respiratory mortality	PM_{10}	27.67 (19.44–62.68)	7.34 (4.96–20.72)	27.67 (19.44–62.68)	7.34 (4.96–20.72)	25.78 (18.06–59.67)	6.73 (4.55–19.13)
	SO_2	5.78 (3.51–7.98)	2.89 (1.75–4.02)	5.35 (3.25–7.39)	3.04 (1.84–4.23)	5.22 (3.17–7.21)	3.68 (2.23–5.1)
Cardiovascular hospitality	PM_{10}	21.58 (14.98–29.56)	5.57 (3.75–7.92)	21.58 (14.98–29.56)	5.57 (3.75–7.92)	20.06 (13.89–27.59)	5.1 (3.43–7.27)
Respiratory hospitality	PM_{10}	19.44 (12.18–26.08)	4.2 (2.55–5.83)	19.44 (12.18–26.08)	4.2 (2.55–5.83)	17.4 (10.85–23.45)	3.79 (2.29–5.25)
COPD hospitality	SO_2	2.59 (0–6.33)	1.29 (0–3.17)	2.4 (0–5.86)	1.35 (0–3.34)	2.34 (0–5.72)	1.64 (0–4.03)
	$PM_{2.5}$	5.58 (2.16–8.87)	1.43 (0.55–2.31)	5.5 (2.13–8.75)	1.21 (0.46–1.95)	4.82 (1.86–7.67))	1.47 (0.56–2.37)

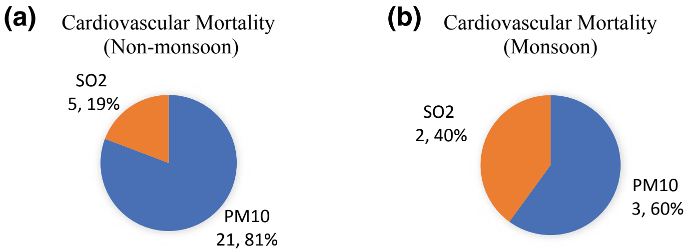

Fig. 3 (a–b) Contribution of individual pollutants in cardiovascular mortality for non-monsoon and monsoon seasons

respectively, in non-monsoon; 60 and 40%, respectively, in monsoon season for 2011 (Fig. 3). AP values of PM_{10} for non-monsoon and monsoon seasons were found to be 19.44% (12.66–38.37) and 4.96% (3.14–10.78), respectively, for the year 2011. AP values for SO_2 were 4.65% (1.19–6.88) and 2.32% (0.59–3.4), respectively, for non-monsoon and monsoon. AP values suggest that PM_{10} attributes more to cardiovascular mortality as compared to SO_2.

Respiratory Mortality

The ENCs of respiratory mortality (95% CI) were 5 (3–10), 5 (3–11), and 5 (3–11) in the non-monsoon season; 2 (1–2), 2 (1–2), and 2 (1–2) in the monsoon season, for the years 2011, 2012, and 2013, respectively. The ENCs of respiratory mortality in non-monsoon season were found to be 2.5 times as compared to monsoon season. The contributions of PM_{10} and SO_2 were 80 and 20%, respectively, in non-monsoon; 50 and 50%, respectively, in monsoon season for 2011 (Fig. 4). AP values of PM_{10} for non-monsoon and monsoon seasons were found to be 27.67% (19.44–62.68) and 7.34% (4.96–20.72), respectively, for 2011. AP values for SO_2 were 5.785% (3.51–7.98) and 2.89% (1.75–4.02), respectively, for non-monsoon and monsoon. AP values suggest that PM_{10} attributes more to respiratory mortality as compared to SO_2.

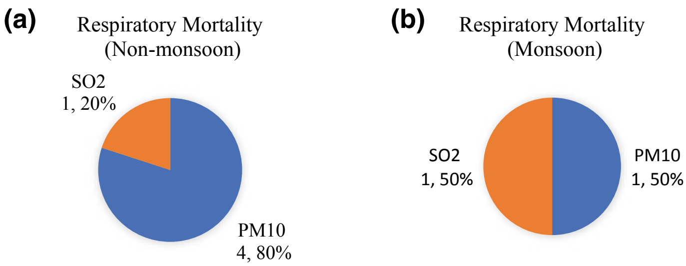

Fig. 4 (a–b) Contribution of individual pollutants in respiratory mortality for non-monsoon and monsoon seasons

Cardiovascular Hospitality

The ENCs of cardiovascular hospitality (95% CI) were 20 (14–28), 21 (15–29), and 21 (14–28) in the non-monsoon season; 3 (2–4), 3 (2–4), and 3 (2–4) in the monsoon season, for the years 2011, 2012, and 2013, respectively. The ENCs of cardiovascular hospitality were found to be 7 times in non-monsoon as compared to monsoon season. PM_{10} solely contributed to all cardiovascular hospitality cases. AP values of PM_{10} for non-monsoon and monsoon seasons were found to be 21.58% (14.98–29.56) and 5.57% (3.75–7.92), respectively, for 2011.

Respiratory Hospitality

The ENCs of respiratory hospitality (95% CI) were 53 (33–71), 53 (33–72), and 53 (33–72) in the non-monsoon season; 7 (4–10), 7 (4–9), and 7 (4–9) in the monsoon season, for the years 2011, 2012, and 2013, respectively. The ENCs of respiratory hospitality were found to be 7.5 times in non-monsoon as compared to monsoon season. PM_{10} solely contributed to all respiratory hospitality cases. AP values of PM_{10} for non-monsoon and monsoon seasons were found to be 19.44% (12.18–26.08) and 4.2% (2.55–5.83), respectively, for 2011.

COPD Hospitality

The ENCs of COPD hospitality (95% CI) were 3 (1–4), 3 (1–4), and 3 (1–4) in the non-monsoon season; 0 (0–2), 0 (0–2), and 2 (0–2) in the monsoon season, for the years 2011, 2012, and 2013, respectively. The ENC values are found to be very low as compared to other hospitalities. This is due to the fact that the pollutants contributing to COPD hospitality are relatively lower in concentrations as compared to PM_{10}, which does not contribute toward COPD hospitality. AP values of $PM_{2.5}$ for non-monsoon and monsoon seasons were found to be 5.58% (2.16–8.87) and 1.43% (0.55–2.31), respectively, for 2011. AP values for SO_2 were 2.59% (0–6.33) and 1.29% (0–3.17), respectively, for non-monsoon and monsoon. AP values suggest that $PM_{2.5}$ attributes more to COPD hospitality as compared to SO_2.

The comparison of ENCs for total mortality and total morbidity (sum all hospital admissions under consideration) between non-monsoon and monsoon seasons for 3-year duration is depicted in Fig. 5. It was found that the ENCs of total mortality

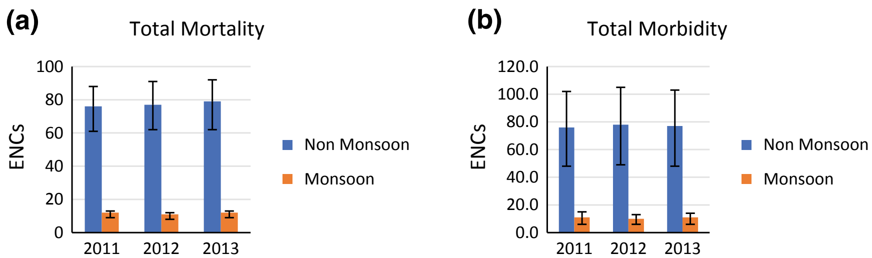

Fig. 5 (a–b) Seasonal variations in total mortality and total morbidity were 76 (61–88), 77 (62–91), and 79 (62–92) in the non-monsoon season, and 12 (9–13), 11 (8–12), and 12 (9–13) in the monsoon season, for the years 2011, 2012, and 2013, respectively. The ENCs of total morbidity were 76 (48–102), 78 (49–105), and 77 (48–103) in the non-monsoon season, and 11 (6–15), 10 (6–13), and 11 (6–14) in the monsoon season, for the years 2011, 2012, and 2013, respectively.

4 Discussion

Navi Mumbai is a coastal city with tropical wet climate that receives 90% of its annual precipitation in the monsoon season, i.e., June, July, August, and September. During these 4 months, the pollutants tend to settle down with raindrops and hence get removed from air, resulting in significant lowering of their concentrations in the ambient air. From 3 years data (Table 2), it is seen that with respect to the non-monsoon season, the average concentration of PM_{10} and $PM_{2.5}$ in the monsoon season gets reduced by 74%, while average concentration of SO_2 and NO_2 in the monsoon season gets reduced by 41%. This indicates that in the monsoon season the removal due to settling down with raindrops is more for particulate matter as compared to SO_2 and NO_2. ENCs for total mortality for non-monsoon season were 6.3–7 times that of monsoon season and ENCs for total morbidity for non-monsoon season were 6.9–7.8 times that of monsoon season. Figure 5 shows that with respect to the non-monsoon season, the ENCs of total mortality and total morbidity in the monsoon season get reduced by 85%.

It is evident from the results that PM_{10} had the maximum health impacts attributable to it, which is supported by the results of other similar researches carried out [20, 21]. Figure 5 shows that the variations in ENCs between monsoon and non-monsoon seasons follow a similar trend across the 3 years duration, signifying the consistency of the results.

There are certain limitations associated with this methodology.

1. Relative risk values adopted for this study have been taken from the previous studies carried out in the other regions. However, according to [14], this is, however, not objectionable if, "there is no compelling evidence that the evidentiary population and target population differ in response to air pollution."
2. Intermixing and interactive effect of pollutants due to coexistence is not considered in the methodology. Superposition principle is applied while calculating the contribution of individual pollutants to the various health impact categories under consideration.
3. The framework assumes that the considered pollutant concentration levels represent the actual concentration levels that people are exposed to.

5 Conclusion

In the present study, AirQ+ software, developed by WHO, has been used to evaluate the seasonal variations in short-term human health impacts caused by the SWDF to the population exposed in its vicinity. This study aimed at analyzing the variation pattern in the human health impacts between the monsoon and non-monsoon seasons, and the consistency of the results obtained suggest that the seasonality should be taken into consideration while carrying out the human health impact assessments. The information regarding the excess number of cases of various health effects due to critical pollutants may help the concerned authorities to analyze the feasibility of the current infrastructure with respect to the health impacts caused by it, and hence to make the necessary augmentations in technology and policy-making that would reduce the impacts of the facility on human health.

Although this methodology involves certain assumptions with the availability of site-specific data, this methodology offers a quick and effective way to carry out the human health impact assessment. To achieve this, intensive time-series epidemiological studies should be undertaken across the world in order to develop the dose-response function. With the development of site-specific relative risk values for different pollutants, availability of statistics for baseline incidence for different health points and monitoring of key pollutants at critical locations, the human health impact assessment can be carried out with very low level of uncertainties.

Compliance with Ethical Standards

- The authors declare that they have no conflict of interest.
- This chapter does not contain any studies with human participants or animals performed by any of the authors.
- Since the study does not involve any individual participants, any kind of Informed Consent is not applicable.

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