METHODS AND MATERIALS
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This study focuses on two important environmental issues confronting regions experiencing unprecedented population growth as well as the process of unplanned urbanization. The two aspects that have been taken into consideration are: i) the quality of air over parts of Mumbai and ii) the problem of solid waste management.

SECTION A – AIR QUALITY IN MUMBAI

The first section of the study tries to explore if any relation exists between the quality of air, especially the concentration levels of Respirable Suspended Particulate Matter (RSPM), Suspended Particulate Matter (SPM), Nitrogen Dioxide (NO₂) and Sulphur Dioxide (SO₂) in parts of Mumbai; and the number of vehicles registered in the city as well as suburbs.

For this purpose, information related to air quality is obtained from the Central Pollution Control Board (CPCB) website, National Environmental Engineering Research Institute (NEERI) office as well as the Air Quality Monitoring & Research Lab, Khar (Mumbai). NEERI has three monitoring stations at Worli, Parel and Kalbadevi, whereas the Air Quality Monitoring & Research Lab at Khar has seven ambient air monitoring stations for which concentration levels of various pollutants are monitored on an hourly basis and also on a 24-hourly basis. The daily air data was obtained and the annual average was calculated for each of the parameters for the selected monitoring stations.

On the hand, the total number of vehicles registered during the past few years was obtained from the Motor Transport Statistics, made available by the Transport Commissioner, Maharashtra State. The percentage increase/decrease in the total number of vehicles registered for select years was taken into consideration to arrive at a conclusion if the increasing number of vehicles is leading to air quality decline. The map of Mumbai is superimposed with the air and vehicle population data in an attempt to explore if a correlation exists.
Keeping in mind all the findings of various studies conducted by the Environment-related agencies, data has been compiled and collated; and an attempt is made to objectively analyze the average concentration of the chief air pollutants. The data for the total number of motor vehicles registered in Mumbai is also taken into consideration to get the exact figures of the total vehicular population of Mumbai.

In an attempt to understand the increasing or decreasing trend in the number of vehicles in the Greater Mumbai region as well as to get a clear picture about the vehicle population in Mumbai, data has been collected for the period beginning from 1980 to 2011. The source of this information is the Motor Transport Statistics of Maharashtra, Govt of Maharashtra, 2007-2008; 2009-2010.

The data for the number of vehicles using diesel, petrol, LPG and CNG in the Mumbai region have been taken into consideration. The data was available for the years 2008, 2010 and 2011.

The percentage of diesel-run vehicles to the total is calculated in an attempt to get a clear picture regarding the percentage growth in the years 2008, 2010 and 2011. This is done as it has been understood from various studies that diesel-run vehicles are more responsible for the release of air pollutants. This assumes importance because air pollutants released from vehicles using diesel as fuel release six times the amount of SO2, double the amount of Particulate Matter, double the amount of NOx and ten times the amount of Carbon Monoxide as compared to vehicles dependent on petroleum (Environment Status Report of Brihan Mumbai 2010-12); and are also very are harmful to the health and well-being of residents exposed to it.

The data for the above was obtained from the NEERI office, Zonal Lab, Worli (Mumbai) and also from the CPCB Report on Air Quality in Metropolitan cities of India. The data for Mumbai was extracted and graphs made for the annual average concentration values for RSPM, SPM, NO₂ and SO₂ as indicated for Khar, Bhandup, Andheri, Maravali, Borivali, Parel, Worli and Kalbadevi areas. The consequent percentage of violation of National Ambient Air Quality Standards (NAAQS) based on 24 hourly averages is also graphically represented for Worli, Parel and Kalbadevi sites. The graphs clearly reveal the situation existing at the monitoring sites selected for the purpose of study.
Ambient air quality standards (both short term, i.e., 24 hourly, and long-term, i.e., annual) have been laid down for industrial, residential/rural/other, and sensitive areas with respect to pollutants such as SO$_2$, NOX, SPM, RPM, Lead (Pb), Ammonia (NH$_3$) and Carbon Monoxide (CO).

The tables specifying the ambient air quality standards have been also stated so that comparison can be made. This data is obtained from the Central Pollution Control Board website.

The annual average concentration in $\mu$g/m$^3$ for RSPM, SPM, SO$_2$ and NO$_2$ for the three monitoring stations was arrived at from the daily values. The data for the above was obtained from the NEERI office, Zonal Lab, Worli (Mumbai) for the years 1999, 2000, 2004, 2005, 2006, 2009 and 2010. All values are objectively analyzed and graphs drawn. The trend is observed for each of the stations and the results are superimposed on the corresponding region demarcated by the Motor Transport Department for Mumbai to find if any link can be observed.

Emission Load of air pollutants for Mumbai from different sources was obtained from NEERI report, 2010. For the sake of analysis and clear understanding of the total vehicular exhaust on the quality of air, the air transport, rail and sea transport are all taken into consideration all vehicle-related emissions are categorized under the Line source.

Data related to number of vehicles registered in Mumbai during the period 1961 to 2011 was collected to study the growth pattern in the number of vehicles in the central, eastern and western zone of the Greater Mumbai. The percentage increase or decrease in the total number of vehicles registered region-wise is calculated to get an insight into the growth trend between the period 1980 and 2010.

Information from both the findings of the air quality over the three different locations and the growth in the vehicular registrations in the three different zones demarcated by the transport department was taken up simultaneously to see if any comparison could be made in the light of the findings.
SECTION B – ISSUES SOLID WASTES IN MUMBAI

In the second section, the issue of solid waste management is studied to understand the various aspects of the problem with reference to the Greater Mumbai region. In this section, the amount of solid waste generated at a ward level and area-level was obtained to derive the spatial and temporal analysis by calculating the concentration index. The population data at an area level as well as ward level for select years is taken into consideration to understand if population growth is solely responsible for the increasing amount of solid waste that is generated in the Greater Mumbai region.

Apart from this the level of employment profile is also taken into account to find if employment growth existing in the various wards of Mumbai could be a causative factor for the increasing volume of the floating population which could consequently be responsible for the generation of the excessive solid wastes in the study region. The data related to various demographic parameters was obtained from the Census Department, Government of India.

The data related to solid waste was collected from the Solid Waste Management Cell of the Municipal Corporation of Greater Mumbai which has the responsibility of collection and disposal of solid waste and night soil generated by the city every day. The overall figures of solid waste generated for the Municipal Corporation of Greater Mumbai as a whole were collected for select years. For the years 1991-92 and 2011-12, data were collected at the ward level to get an insight into the spatial variations in generation of solid waste within the city.

With the help of the overall figures it was possible to relate the amount of solid waste generated to the population at different time periods. The ward level data for two time periods was utilized for determining the difference in the city and the suburbs; the differences between eastern and western suburbs were also analyzed.

In both the sections, secondary data is mostly collated and analyzed. Studies undertaken by various Government agencies are also taken into consideration. The Government Agencies from which data was obtained were NEERI, CPCB, Solid Waste Management Department of MCGM, All India Institute of Local Self Government, Motor Transport Department of Maharashtra State, Air Quality Monitoring & Research Laboratory, etc.
Method used for Analysis: For analysis of spatial variation at the ward level a concentration index was derived which may be expressed as:

\[
\frac{SW_i}{P_i}/\frac{SW_j}{P_j}
\]

Where,

- \(CSW_i\) = Concentration index of solid waste in the ith ward
- \(SW_i\) = Solid waste in the ith ward
- \(SW_j\) = Total solid waste in Greater Mumbai
- \(P_i\) = Population in the ith ward
- \(P_j\) = Total population of Greater Mumbai

If the ratio between \(SW_i\) and \(P_i\) and ratio between \(SW_j\) and \(P_j\) is the same then \(CSW_i = 1\). If \(CSW_i > 1\), it indicates a higher generation of solid waste per capita than for the city as a whole, while if \(CSW_i < 1\), it indicates less generation of solid waste per capita as compared to the average conditions of Greater Mumbai.
The concentration index was calculated for the island city as well as for suburbs as a whole. Suitable maps and graphs have been inserted at relevant places to represent the findings. All maps have been drawn using MapInfo Software Version 9.

Throughout the duration that the data was being collected from various sources, personal interactions with persons involved in the respective departments and offices has been of great help in bringing more clarity to the understanding of the various issues related to the topic.