Draft Interim Report

Air Quality and Emission Source Apportionment Studies for

Ten Cities of Maharashtra

MUMBAI CITY

Maharashtra Pollution Control Board

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January, 2020

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FIGURE

Chapter 1

1.1. City Profile

Mumbai is an Urban Agglomeration coming under category of Mega City. Greater Mumbai, an area of 603 Sq. Km consisting of the Mumbai City and Mumbai Suburban districts, extends from Colaba in the south, to Mulund and Dahisar in the north, and Mankhurd in the east. Of this, the island city spans 67.79 Sq.Km, while the suburban district spans 370 Sq. Km, under the administration of Municipal Corporation of Greater Mumbai (MCGM). Mumbai the capital city of Maharashtra is second most populous metropolitan city in India and fifth most populous city in the World, with an estimated city population of 12.44 million according to 2011 census. The population density of Mumbai is 27461 people per Sq. Km (excluding no development area). The living space is 4.5 square meters per person. The estimated projected population of 2016, 2020, and 2030 is around 12.91, 13.18 and 13.42 respectively. During the last decade, 2001-2011, Island City has shown a population decline of 262,620 whereas the western and eastern have shown an increase of 321,841 and 394,702 respectively. Ward P/N in the Western Suburbs has the highest population of nearly one million among all 24 wards, holding 7.5% of the total population. Whereas, ward B in the island City has the lowest population of 140,633 among 24 wards.

Of the total population within MCGM jurisdiction in 2011, 41.85% live in slums including the notified areas under Special Planning Authorities (SPA). The data shows that geographically, there is a clear variation in the distribution of slums in Greater Mumbai. 51.91%of the total population in the Eastern Suburbs resides in slums as compared to 42.69% of the total population in the Western Suburbs and 27.88% in Island City *(MCGM, City Development Plan, 2034).*

1.2. Climate

Greater Mumbai region is along the seacoast that experiences a tropical wet and dry climate. The region experiences three seasons, Summer (March to May), Monsoon (June to September) and Winter (October to February). The mean minimum temperature is 16.3°C and the mean maximum temperature is 32.2°C. The normal annual rainfall over the region varies from about 1800 mm to about 2400 mm. It is at a minimum in the central part of the district around Kurla (1804.9 mm) and gradually increases towards north and reaches a maximum around Santacruz (2382.0 mm). Majority of the rainfall is received in the South-West monsoon i.e., during the months of June to September. Rest of year remains dry with average relative humidity around 75%. The average wind speed in the region is in the order of 25 kmph and gusts upto 45 kmph. The maximum wind speeds exceed 150 kmph during tropical storms in the region *(NEERI, NAAQM, 2016).*

Chapter 2

2.1. Status of Air Quality

Mumbai's ambient air quality is being monitored under National Ambient Air Monitoring Program (NAMP), coordinated by Central Pollution Control Board (CPCB) and SAMP (State Ambient Air Monitoring Program) stations. The historical data analysis was carried out using the data provided by NAAQMS of these networks for criteria pollutants. The annual averages trend of the continuous air quality station operated by MPCB in Sion and Bandra and one NAMP station at Worli operated by NEERI are given in **Figure 1 (a to c).**

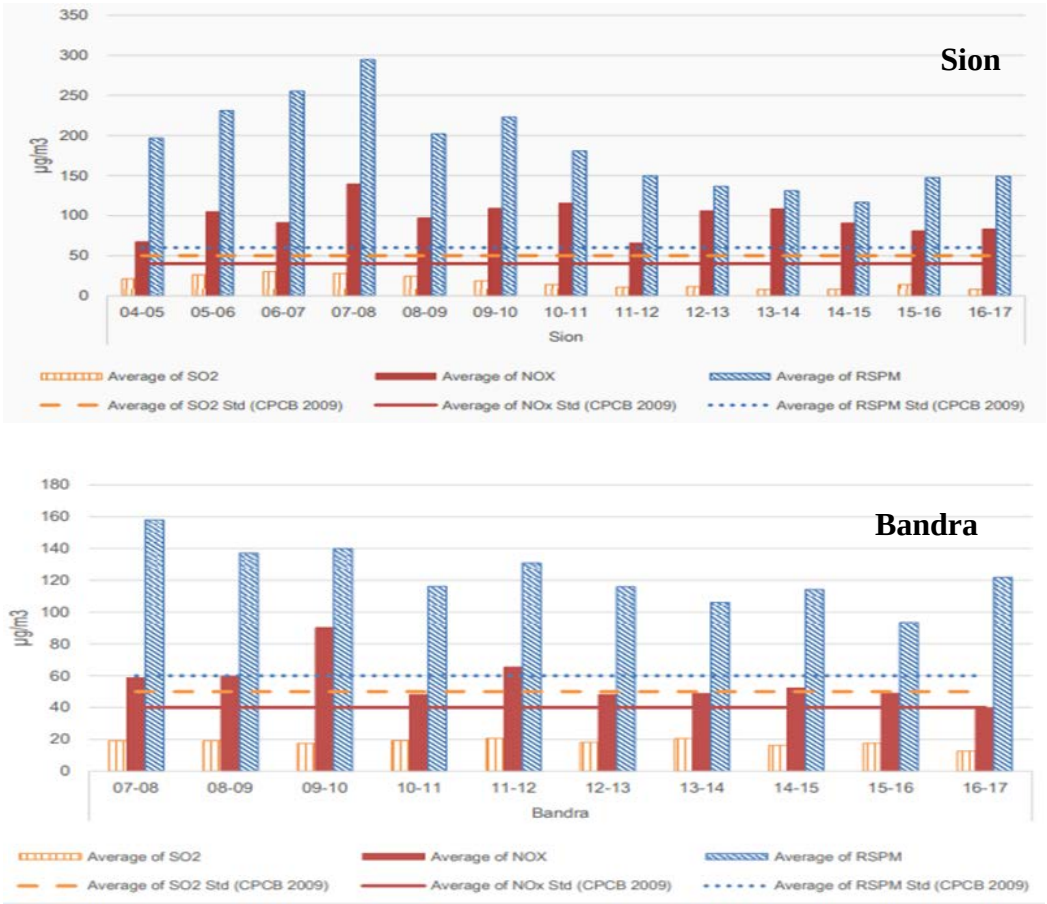


Figure 1a : Trends of Annual Averages for PM, NOx and SOx Over Period 2005 - 2017 in Mumbai (SAMP Station Operated by MPCB)

The annual average concentration of PM_{10} at Bandra is 124 µg/m^3 and 152 µg/m^3 at Sion during 2016-2017. Whereas, 13 µg/m^3 and 8 µg/m^3 for SOx and 40 µg/m^3 and 83 µg/m^3 for NOx

concentration were observed at Bandra and Sion respectively. The percentage exceedance of PM is around 50% at Bandra and 25% at Sion, similarly NOx concentration were also exceeding around 4% and 48% respectively at two stations. As per Air Quality Status Maharashtra report prepared by TERI for MPCB during 2017-18 shows that air quality index category wise distribution is as : Good (0-50) [42 (Bandra), 6 (Sion)], Satisfactory (51-100) [99 (Bandra), 50 (Sion)], Moderate (101-200) [94 (Bandra), 112 (Sion)], Poor (201-300) [63 (Bandra), 68 (Sion)], Very Poor (301-400) [3 (Bandra), 5 (Sion)]. The annual averages of pollutants monitored under NAMP Station operated by NEERI shows that the concentrations of PM_{10} at all the stations are above the NAAQS standard limit throughout the period. Whereas, SOx and NOx concentrations were compliance throughout the period. The averages shows during monsoon period the concentrations are reducing drastically.

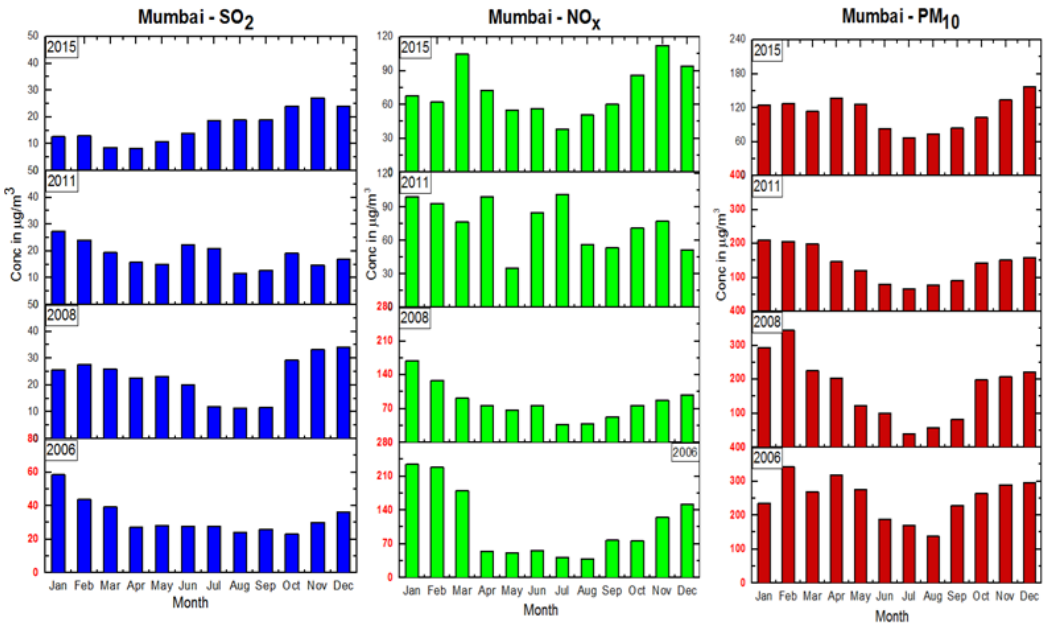


Figure 1b : Monthly Trends of Annual Averages for PM, NOx and SOx (2005 – 2015) in Mumbai.

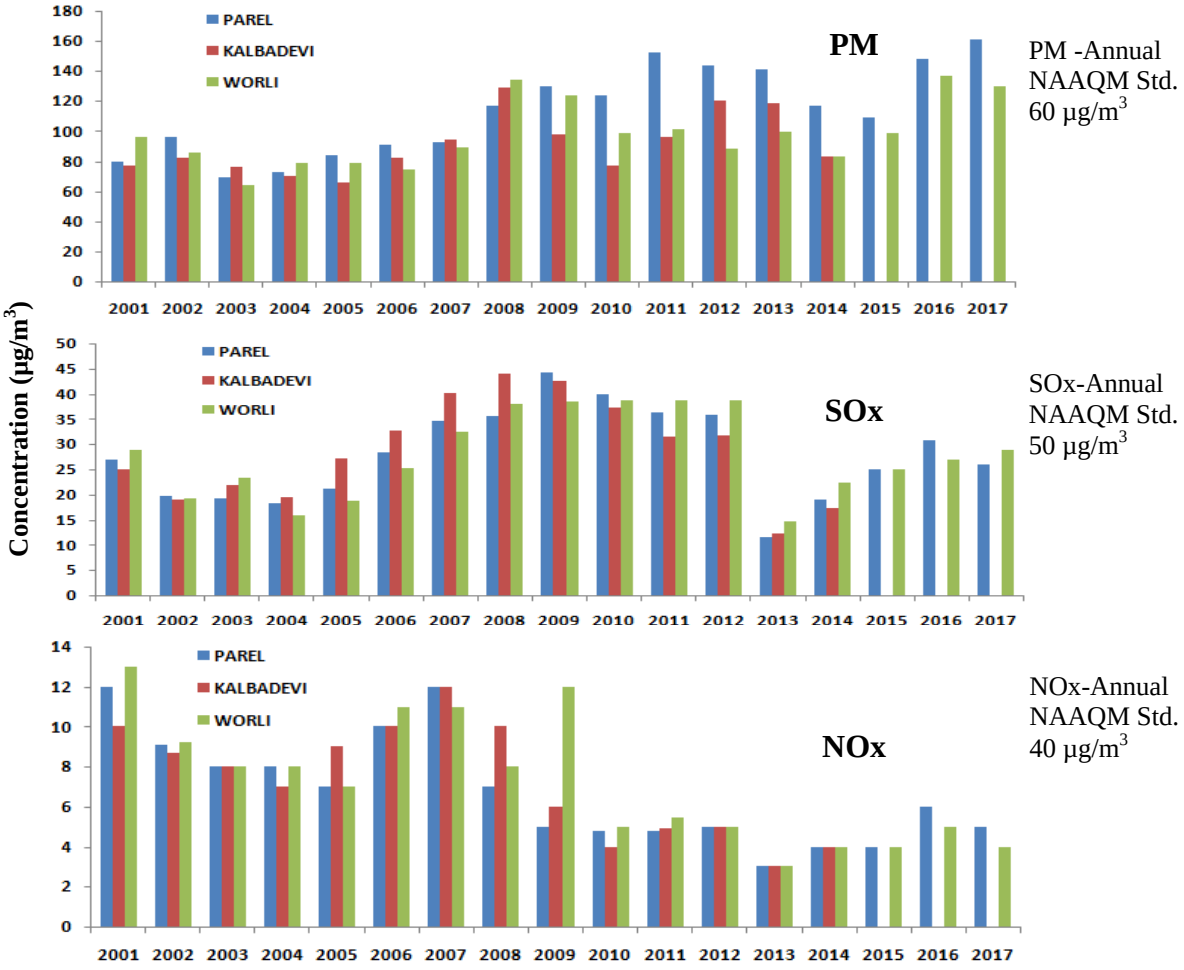


Figure 1c : Annual Average of PM, NOx and SOx Over Period 2001 - 2017 in Mumbai (NAMP Station operated by NEERI)

Chapter 3

3.1. Emission Inventory

Emissions inventory is the first exercise, under that identification and quantification of various sources are necessary to link them with the existing air quality levels measured at certain locations as well as predict air quality for whole region. Air pollution sources are broadly categorized as area (domestic and fugitive combustion type emission sources viz. domestic, bakeries, crematoria etc), industrial (point) sources and vehicular (line) sources. Emission inventory of different sources of air pollution has been prepared for 2 Km x 2 Km sizes for whole of Mumbai city for accurately identify and quantify emissions from different sources. Emission inventory has been prepared in terms of five major pollutants, viz. PM10, SOx, NOx, CO and HC. City emission loads from various sources are presented in **Table 1.**

Table 1 : Emission Load for Mumbai City from All Sources ** All values expressed in **Kg/day**.*

	PM Load	**% PM**	**SOx Load**	**% SOx**	**NOx Load**	**% NOx**	**CO Load**	**% CO**	**HC Load**	**% HC**
Bakeries	3271.3	3.5	43.8	0.5	286.7	0.2	23887.2	15.9	21642.2	25.4
Crematoria	569.4	0.6	15.0	0.2	85.3	0.1	4191.1	2.8	3774.0	4.4
Open Eatouts	21.7	0.02	32.7	0.4	18.8	0.01	250.0	0.2	67.1	0.1
Hotel Restaurants	1187.2	1.3	711.1	7.6	740.4	0.5	1176.3	0.8	44.6	0.1
Domestic Sector	1483.0	1.6	3153.1	33.8	26620.2	18.5	49294.1	32.8	12396.1	14.5
Open & Landfill B.	3436.6	3.7	215.0	2.3	1290.0	0.9	18060.0	12.0	9245.0	10.8
Construction Act.	7448.0	8.0								
Rd. Dust MumMetro	2943.8	3.2								
Aircraft	419.0	0.5								
Marine Vessel	3.7	0.004								
Total (Area) [A]	**20783.7**	**22.3**	**4170.7**	**44.7**	**29041.4**	**20.2**	**96858.7**	**64.4**	**47169.0**	**55.3**
Red_LSI	204.2	0.2	1976.1	21.2	22013.4	15.3	2986.8	2.0	543.0	0.6
Tata Power	826.1	0.9	268.2	2.9	49980.0	34.8	9216.0	6.1	4344.0	5.1
MSI & SSI (ROG)	54.1	0.1	2125.1	22.8	2177.7	1.5	582.3	0.4	110.8	0.1
Total (Point) [B]	**1084.4**	**1.2**	**4369.4**	**46.8**	**74171.1**	**51.6**	**12785.1**	**8.5**	**4997.7**	**5.9**
2 Wheelers	153.4	0.2	16.0	0.2	1769.5	1.2	8493.8	5.7	6134.4	7.2
3 Wheelers	1002.7	1.1			1614.5	1.1	5863.2	3.9	17504.6	20.5
Car Petrol	15.6	0.02	39.2	0.4	701.6	0.5	6548.6	4.4	944.7	1.1
Car Diesel	91.0	0.10	304.9	3.3	1697.8	1.2	363.8	0.2	489.8	0.6
Car CNG	20.8	0.02			2564.0	1.8	207.9	0.1	1609.5	1.9
Taxies	19.1	0.02			2351.4	1.6	233.1	0.2	1461.7	1.7
HDDV	3092.1	3.3	430.1	4.6	23190.7	16.1	14961.7	10.0	922.6	1.1
CNG Buses	47.0	0.05			6636.6	4.6	3975.5	2.6	4007.6	4.7
Paved Rd. Dust	24771.0	26.6								
Unpaved Rd. Dust	41939.0	45.1								
Total (Line) [C]	**71151.7**	**76.5**	**790.2**	**8.5**	**40526.1**	**28.2**	**40647.6**	**27.0**	**33074.9**	**38.8**
Line Source contribute – 4.77% (4441.7 Kg/d)										
Total [A+B+C] Kg/day	**93019.9**		**9330.3**		**143738.6**		**150291.4**		**85241.6**	
Total [A+B+C] Tons/Yr.	**33952.2**		**3405.6**		**52464.6**		**54856.4**		**31113.2**	

Percent contribution of pollutant due to different source categories is and all sources from whole of Mumbai city is presented in **Figure 2**.

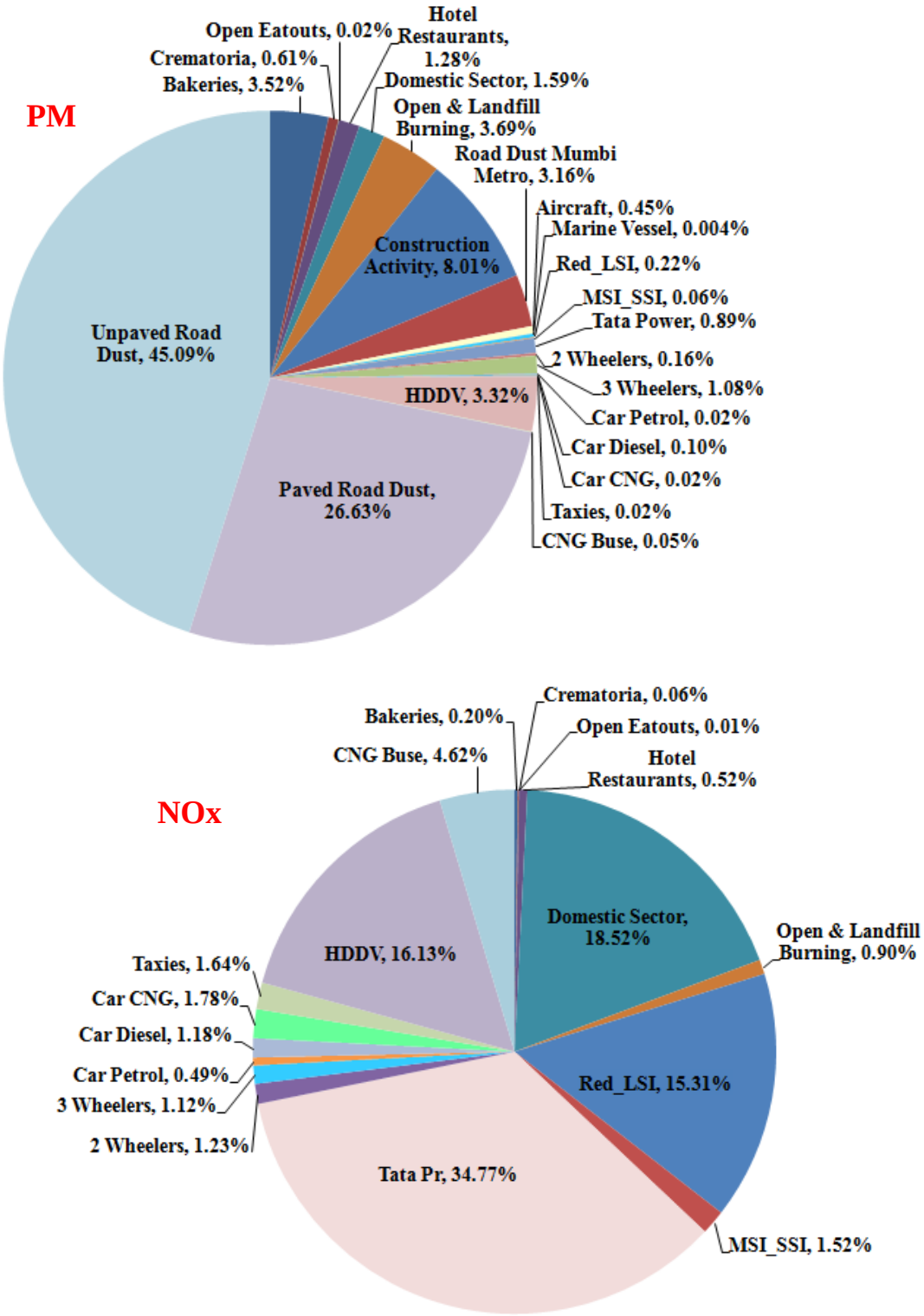


Figure 2 : Percent Contribution of PM and NOx in Mumbai City

Chapter 4

4.1. Action Plan for Control of Air Pollution

There are many sources of particulate matter emission impacting the ambient air quality of the city of Mumbai; however the major ones are resuspended dusts and industries. The impact of the industrial sector is reducing due to various reasons such as closure of industries, shift to clean fuel, better compliances and discharge of emission at higher elevations. Even small-scale industrial units are changing into commercial offices. The emission inventory discussed earlier indicates that though point sources contribution is reasonably high particularly due to power plant in terms of total load; however its impact on the ambient air quality is low due to emissions at a higher elevation, providing high dilution and dispersion.

Vehicle activity in the city has shown tremendous increase over a period of last 10 years. The mobile (line) source emissions are not only dependent upon the number of vehicles registered but also on the actual number plying on the roads, speed of movement and the conditions of vehicles besides many other factors. Vehicle kilometer travelled for the city has been showing consistent increase; however, at some junctions the traffic congestion is so high that VKT rise is ironically not so high but emission is high. Saturation traffic situation where average speed goes on decreasing, the VKT may not increase as vehicles are not crossing a point for a long time. Increased levels of vehicular activity and resulting high levels of air pollution have led to active anti air pollution campaign by the nongovernmental organization (NGO) and judiciary.

The area sources which emit at ground level also have significant impact on the PM levels in the atmosphere; however it could be more localized, particularly from the sources such as bakeries, crematories, construction, garbage burning etc. Some of these sources can have significant local impact on the ambient air quality for a shorter duration. Overall a city growth pattern indicates that domestic fuel has become cleaner, bakeries /crematoria situation have not changed so much. Construction/ demolition related emission has gone up; refuse burning has increase and road dust related emissions have also shown increase.

The action plan presented later therefore, makes an attempt to delineate strategies on the basis of understanding of the PM and NOx sources and their possible contribution to the ambient and kerb side air quality. Each of the strategies will have to be looked at from the point of view of its impact level in terms of reduction in PM and NOx emissions (low, medium, high); its feasibility from implementation and administrative point of view (easy, moderately difficult and difficult);

financial viability (low, medium and high costs) besides issues relating to their long and short term impacts.

4.2. Area Source

As per emission inventory percent contribution from area source emissions are high particularly for PM when compared with emissions from vehicular emissions. Other area sources though called area sources, are limited to small regions (viz. open eatouts, bakeries, crematoria and hotels) and therefore, their impact does not seem to be wide ranging and across the city. For example, open burning can be common all through the city with some variation based on locality; however landfill open burning is limited to Mulund and Kanjurmarg. During study period recent work going for Metro line development is also a time bound activity for at least 5 years, so as the dust emission. With the implementation of the short and long term scenarios, the total reduction in particulate matter from area sources would be more than 40-60%**.**

Measures Required

- Bakeries and crematoria emissions can be reduced through implementation of fuel shift combined with awareness programmes
- Open refuse burning and landfill site burning are the most important issues for the degradation of ambient air quality. This needs very quick and credible solution to stop these emissions.
- Road dust from paved and unpaved roads in the city is largely responsible for high PM. The rules/ code for road and pavement construction should be written well and implemented.
- Large scale construction and demolition of buildings in the city give high local dust contribution leading to health impacts. These practices need adequate rules and compliance to reduce emissions.

Some of the technologies developed by NEERI to curb air pollution load from area sources can be implemented phase wise. (Annexure I to III)

Emission Reduction Action Plan for Area Source (Short term – 2019 to 2021; Long Term 2022 to 2027)

Area Sources	Short Term	Long Term	Action Required
Domestic	25% of slums to use LPG/ PNG 50% of non slum to use LPG/PNG	50% of slum to use LPG/ PNG 100% same	Proper dispensing and easy availability of cylinder to the consumer of slum population should be made. Increase the infrastructure and availability of LPG/PNG to whole of Mumbai region. Ensure proper ventilation reforms to be implemented in kitchen to improve the indoor air quality. Awareness about the same should be disseminated
Hotel & Restaurants	50% of coal to replace by LPG	75% of coal to replace by LPG	Wood is mainly used in tandoors in restaurant, LPG/ electrically operated tandoors may be used. Hotels & Restaurants should be regulated for their operation and maintenance of chimneys. Designated areas should be designed for the coal and wood based operations within the premises. Options of fuel shift should be implanted in phase wise.
Open Eatouts	Since these operation is illegal, difficult to quantify		If we restrict the activities with proper rehabilitation or their conversion from traditional fuels to clean fuels, then per unit /day reduction of PM- 0.12, and NOx - 0.039 kg/day can be achieved, considering the large number of vendors and eat outs.
Bakeries	25% LPG /NG 25% Electric	50% LPG /NG 75% Electric	Clean fuels like LPG/NG or electricity can be attempted for bakery operations. Initial incentives and rebate should be provided for the conversion from traditional fuel. There are illegal and unaccounted small and mid-scale bakeries that have significant contribution to final emission load. They should be taken in confident by the regulatory bodies for their accountability, inventeriozation of their fuel consumption and conversion of their existing facilities. This will require change in current baking practices for which a separate study involving techno-economic feasibility is recommended.
If consumption of wood in a bakery is considered to be 500 kg/day, then emission load of pollutants are PM - 8.65 kg/d, CO - 63.15 kg/d, NOx -0.65 kg/d, HC-57.25 kg/d and if we manage to replace the wood quantity by other fuel i.e only 100 kg/days of wood is being used, there will be 80% reduction in load, with final emission per 100 kg will be PM -1.73 kg/d, CO -12.6 kg/day, NOx- 0.13 kg/d and HC - 11.4 kg/d. This conversion can be towards natural gas, as emissions from them are relatively much less than solid fuels.			

(Contd..) : Emission Reduction Action Plan for Area Source (Short term – 2019 to 2021; Long Term 2022 to 2027)

Area Sources	Short Term	Long Term	Action Required
Crematoria	50% Electric	75% Electric	There are sentiments involved in the activities that are carried out in crematorium. Still all crematoria should be provided with efficient pyres and chimneys with bag filters for release of emissions through stacks at appropriate height. Further, a study involving usage of NG burners in a closed furnace like electrical crematoria may be explored as substitute to existing practices. This will require participation of social organizations for increasing the awareness about need to change from the traditional methods. Concept like Green Crematoria should be explored.
Similarly, for wood consumption of 300 kg/body cremation at crematoria is replaced by electric or gas cremation, an overall PM-5.19, CO- 37.89, NOx -0.39, HC -34.35 and CO2 – 510 kg/yr of emission load reduction can be achieved per unit cremation			
Open & Landfill Burning	50% control on open burning 100% control of Landfill burning	100% control of Landfill burning 100% control on open burning	It has been observed that the unaccounted or mismanaged waste from SWM system, often are reported into road side open burning cases. As city is receiving 9970 tonnes solid waste per day, proper collection and disposal practices should be adopted on daily basis so that opening burning cases are not reported. Fast track steps for scientific SW management. Refuse of all types are burning from certain localities like Dharavi, Kurla where auxiliary and small scale industries are located should restricted. This practice needs to be stopped by planning of dumping till sanitary landfills are made. Treated water from Ghatkopar STP can be used effectively for any accidental fire for landfill sites. Strict vigilance by sensor base monitoring of the incidences and immediate attention is required for frequent fire movement at landfills.
If we restrict the activities of open and landfill burning we can reduce pollutant load per Tonne by PM -8, CO- 42, HC -21.5 kg/t			
Bldg. & Road Construction	50% control on dust emission	50% control on dust emission	Building construction/demolition codes need to be used with specific reference to PM control. UTTIPEC design manual has been recently created by Delhi Development authority for uniform roadside, drains, footpath and related design. The same should be adopted for all future design for roads and pathways. Road construction/repair uses wood for melting tar, this technology needs to be abolished as over a large period of time, emissions are high. During study period placing Metro Line is a temporary activity, but proper attention for dust control measures and muck disposal is required as an immediate action, because the activity is spreading across Mumbai.

(Contd..) : Emission Reduction Action Plan for Area Source (Short term – 2019 to 2021; Long Term 2022 to 2027)

Area Sources	Short Term	Long Term	Action Required
Paved & Unpaved Road Dust	Paving : 15% control on dust Unpaving: 15% of remaining road if any	Paving : 25% control on dust Unpaved : 100% of remaining road if any	99% of roads were considered to be paved. Pavement of road should be made wall to wall, especially the shoulders. The silt on partially paved shoulders of road are re-entrained, or resuspended, into air through vehicle-induced turbulence and shearing stress of the tires. A Road dust suspension is an increasing concern in terms of being a source of atmospheric PM. Better sweeping management system should be implemented. Major concreting works of road are already worked out in Mumbai, but if any 1% roads remain then it should be immediately deal with. Potholes and repair digging activities should be properly managed. Resupension of road due to vehicular movement is a cause of concern, a study should be done and viable solution should be identified. Use of mechanical sweepers should be initiated for large coverage.
Ports	Awareness and Management	Clean diesel programme should be initiated along with better engine I & M for small boats/ships. Bigger ships are controlled under MARPOL. Navy and BPT should be sensitized about use of clean fuel and emissions.	
Airports	Awareness and Better Inventory	As the traffic of Mumbai airport is day by day increases the proper inventorisation of landing and takeoff studies with respect to emission load. High HC and VOCs emissions due to aircraft movement need assessment and documentation with a view to adopt international guidelines (IATA/ UFTAA) to reduce emissions and also green house gases. Diesel and petrol consumption could not be computed for airport related vehicles such as loaders, buses, jeeps, food carts etc. Many of these remain operational throughout. These vehicles should be converted to run either on CNG or electric. Flight idling emissions should be reduced within time frame.	
Railways	100% on electric	100% on electric	The activities of shunting locomotives which was working on diesel should be replaced with electricity for all loco shades in Mumbai

4.3. Point Source

The industrial sector has been steadily declining in the city due to shifting development priorities and market forces. The major industrial units are located in Chembur- Trombay area. As per emission inventory the percent emission contribution is around 1.17% form industrial sector to the whole of Mumbai. Out of total emission load from all sources, Tata Power contributes 0.9% (826.1 kg/d), Red LSI shares 0.2% (204.2 kg/d) and all MSI & SSI adds 0.1% (54.1 kg/d) of PM to the city. If we consider only the industrial emission load (i.e. 1084.4 kg/d) then major contributor is Tata power 76%, Red LSI 19% (i.e. refineries, chemical and fertilizers companies) and MSI & SSI 5%. Tata Power Plant uses huge quantity of Coal and NG, though the PM and NOx emissions from the power plant is within the city limit, as the impact is not felt due to its dispersal at the far end of the city through stacks. Predominant meteorology of the city also favours its negligible impact on urban PM and NOx concentrations as established through modeling results (**Figure 3**)[#]. Other Red LSI as well as MSI & SSI industries use wide ranging fuels such as FO, LSHS, LDO, Coal and HSD, the quantities used are not very large; however, their local impact could be high. The short and long term reduction strategy is given in **Table 2**. (*Ref.# : NEERI, 2013 : Report on 'EIA of Proposed Modernization of Existing Unit#6 at Tata Power Company Ltd.')*

Measures Required

- Industries decline in the city has led to large decrease in air pollution; however, fuel shift in existing industries will further improve the ambient air quality. With fuel change, it will be decisive to study the feasibility of adopting the new technology. The MSI and SSI also need to get larger share of the natural gas for combustion processes to shift from FO and LSHS.
- The only power plant within the city, if it shifts to Natural Gas, major reduction in emission shall be achievable.
- Industries should adopt stack emission norms beyond those prescribed by CPCB Industries with QA/QC, the increase of most of the stack by large emitters can affect the air quality substantially as the prominent wind direction of the city to eastern part of Mumbai will disperse the pollution load.
- The data for small scale and unauthorized industries is scanty and at this stage to suggest the levels of contribution from these are difficult, which also need further investigation. These investigations of sources should be undertaken by MPCB/ GoM.
- There are many air quality monitoring stations located in limited area of Chembur-Mahul region. All these are managed by industries. This resource should be well distributed with centralized data linkage with MPCB, which will provide very useful data base for city air quality management.

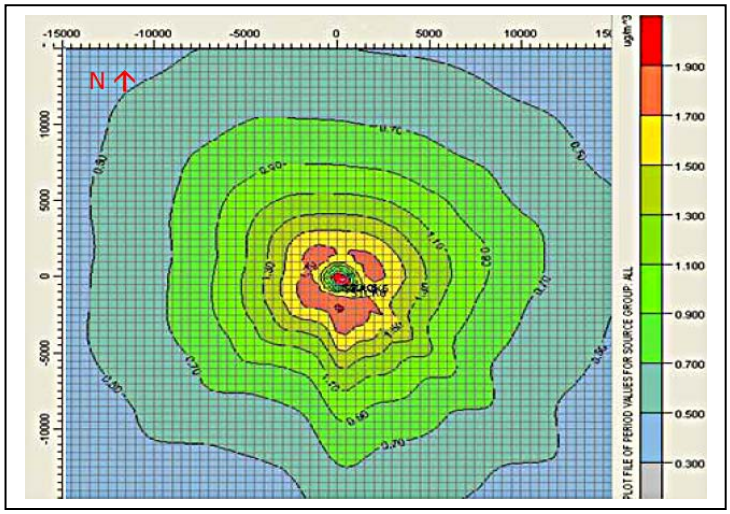
Due to consumption of subsequent quantity of fossil fuel there is large quantity of emissions from power plant, but a study conducted by NEERI shows that, emission through elevated stack heights of Tata power plant is dispersed to far areas. The metrological conditions of Mumbai favour the dispersal of these loads.

Stack Details after Proposed Modernization at TTPS

Sr. No.	Particular	Stack Height in meter	Stack Diameter in meter	Flue gas exit velocity m/s	Exit Flue gas temp °K
1	Unit #5	152.4	7.32	25	413
2	Unit #6	275.0	7.32	25	413
3	Unit #7	60.0	6.5	19	383
4	Unit #8	220.0	5.4	25	413

Pollutant Emission Rates Current Operations

Details		Unit #5	Unit #6	Unit #7	Unit #8	Total
Capacity	MW	500	500	180	250	
Fuel		Coal	Oil	Natural Gas	Coal	
Sulphur	%	0.2	0.17	-	0.2	
FGD efficiency	%	90	-	-	90	
Fuel consumption	TPD	6000	2800	700	3000	
SO_2 emission	TPD	24	10	-	12	
SO_2 emission After FGD	TPD	9.5	9.5	-	4.8	24 TPD



Maximum Average Concentration of TSP in winter is 1.9 µg/m^3

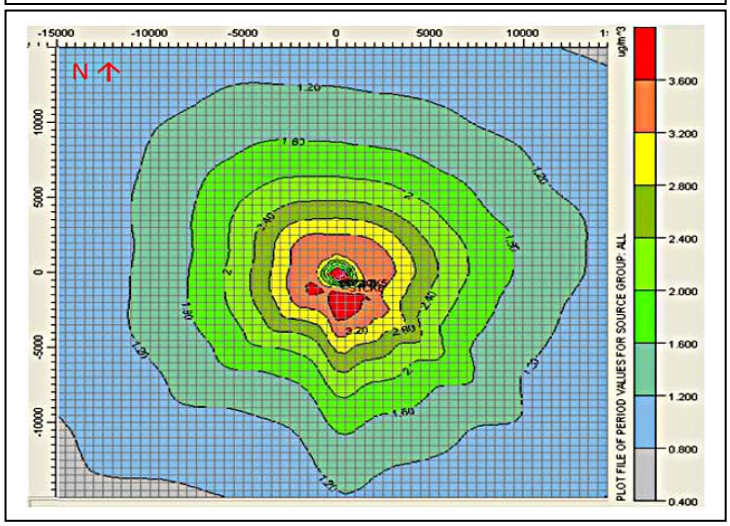


Figure 3 :

Ground Level Concentration of Tata Power Emits is Negligible (Eg. Point Source Action Plan)

Maximum Average Concentration of NO_2 in winter is 3.6 µg/m^3

(*Ref.# : NEERI, 2013 : Report on 'EIA of Proposed Modernization of Existing Unit#6 at Tata Power Company Ltd.')*

Point Source Strategies for Short and Long Term (Short term – 2019 to 2021; Long Term 2022 to 2027)

Point Sources	Short Term	Long Term	Action Plan
Power Plant Coal (8400 TPD) and (NG 3000 m^3/day) major contributors towards PM emissions	Shift to cleaner fuels i.e 50% Coal to NG Combustion technology up gradation for fuel change.	Shift in cleaner fuels from 100% to NG Feasibility of conversion of thermal power production to gas based system	For power plant the fuel change leads to technology change as well. However, newer technologies are more efficient and long term cost effective. The high quantity of fuel consumption is not much reflect in emission load from Tata Power as the stack heights are more and control options implemented. *(See Figure 15)*
Red (LSI) FO (1134 TPD), LSHS (378 TPD), Coal (1 TPD), LDO (20 TPD), HSD (280 TPD), and NG (3469396 m^3/day) are the major contributors towards PM emissions	Shift to cleaner fuels – 50% FO, LSHS, HSD to LDO Coal & Others to NG	Shift to cleaner fuels - 100% Low Fuel i.e LDO Nearly all to NG	• Shift to cleaner fuels from FO and Coal to Natural Gas (NG) as per the availability from M/s. Mahanagar Gas P.Ltd. • Feasibility of changing combustion technology to facilitate usage of gaseous fuels may be undertaken with financial incentives. • Use of continuous air pollution monitoring devices. • Identification of low cost and advanced cleaner technology for air pollution control with policy intervention at specific zones. • Industries should adopt stack emission norms beyond those prescribed by CPCB Industries with QA/QC • Hazardous Air Pollutant emitting units. They have been directed to install Leak detection & repair system (LDAR) within months. • Inventorisation of prominent industries with technological gaps and detailed feasibility study is required as dispersion pollution with modeling and formulate land use based policy. • Industries should take lead for plantation around industrial zone and premises and green belt development. • One tree will offset on average about 10 kg CO_2 each year. According to this we will need 500 million additional trees in 2020 and 1200 million trees in 2051.

(Contd..) : Point Source Strategies for Short and Long Term (Short term – 2019 to 2021; Long Term 2022 to 2027)

Point Sources	Short Term	Long Term	Action Plan
MSI & SSI (All Categories Red, Orange and Green) FO (82 TPD), LDO (52 TPD) HSD (630 TPD) NG (70 m^3/day) and LPG , LSHS and Coal (0.8 to 3 TPD) are the major contributors towards PM emissions	Shift to cleaner fuels – 50% FO, LSHS, HSD to LDO Coal & Others to NG Shift to cleaner fuels (from FO to LDO)	Shift to cleaner fuels – 100% Low Fuel i.e LDO Nearly all to NG .	• Shift to cleaner fuels from FO and Coal to Natural Gas (NG) as per the availability from M/s. Mahanagar Gas P.Ltd. • Inventorisation of prominent industries with technological gaps and make them available to change combustion technology to facilitate usage of gaseous fuels may be undertaken with financial incentives. • Reduction in use of DG sets by ensuring adequate power supply, and have stricter norms for DG set emissions. • Hazardous Air Pollutant emitting units. They have been directed to install Leak detection & repair system (LDAR) within months. • All the bulk drug and pesticides manufacturing units are being proposed to improve efficiency of their VOC scrubbers. • Energy Conservation Scheme should be encouraged in the industries that are not economically capable towards shifting to eco friendly fuel use or advanced clean technology. • Identification of Illegal SSI, MPCB should survey their levels of operation and their contribution of emission in each of the city grid.

4.4. Line Source

One of the major contributors to Particulate Matter (PM) and NOx emissions in Mumbai region is vehicular exhaust. Particulates present in vehicular emissions are especially harmful due to their small size (under PM_{10}) and even larger number below $PM_{2.5}$. The fine particles are also important due to their harmful chemical composition. The most prominent sources of vehicle particulate emissions are diesel driven and two-stroke petrol driven vehicles. Reduction strategies addressing both technical and non-technical issues presented here take into consideration the current ambient air quality standards; exhaust emission standards, emission inventory, vehicular population composition, infrastructure availability and the techno-economic feasibility in Greater Mumbai Region.

The discussion has been presented in following order:

- Improvement in fuel quality and alternate fuels
- Improvement in vehicle related components/technologies (After-exhaust treatment techniques and retrofitment)
- Synchronization of traffic signals
- Inspection & Maintenance programme
- Transport planning and traffic management
- Other options including phasing out old vehicles, revision of emission standards
- Encourage public transport, encourage non motorized transport and
- Reduce dust resuspension

Many potential emission reduction options have been considered based on viability in the city and the major issues are pertaining to the overall vehicular sector emission reduction have been discussed below :

Some of the technologies developed by NEERI to curb air pollution load from line source and resuspension can be implemented phase wise. (Annexure IV and V)

Line Source Strategies for Short and Long Term (Short & Mid term – 2019 to 2021; Long Term 2022 to 2027)

Area Sources	Short Term	Mid Term	Long Term	Action required
Reduction Emission per Unit of Fuel				
Sulphur reduction	S Reduction -10%	S Reduction -30%	S Reduction -50%	▪ Low S level in the metro cities (Mumbai at <350 ppm) used as diesel in HDDV and LDDV. Delineating tighter diesel fuel standards. ▪ Phasing out fuel subsidies, uniform pricing all over the state ▪ Measures which can dissuade truck operators from buying high S fuel should be stricter, reliable and reproducible inspection for smoke levels.
Fuel Adulteration	Strict Banning of Fuel Adulteration -50%	Strict Banning of Fuel Adulteration -80%	Strict Banning of Fuel Adulteration -100%	▪ At petrol pumps facility should be provided for identification of fuel adulteration by way of marker ▪ Oil companies should used colour codes on the tanker transporting the fuel, regular testing of the fuel before it is filled in the bunks and after. Show pro-activeness in promoting the better lubricants. ▪ Oil companies should also put their own manpower and machineries in checking effectively their products being sold from their outlets. (e.g. BPCL's Pure for Sure; HPCL's Club HP and IOC's Q & Q etc., which are being carried out in, limited way. ▪ Economic measures such as removing the disparity in petrol, diesel and kerosene prices will be required to remove incentives for such large scale malpractices, Fines and cancellation of license are the tools ▪ Ministry of petroleum has constituted anti adulteration cell for preventing the malpractices of fuel adulteration
CNG/ LPG	Privately operated Vehicles viz. OLA, Uber and other contract buses, public transport should be converted -30%	Privately operated Vehicles viz. OLA, Uber and other contract buses, public trans. should be converted -50%	Privately operated Vehicles viz. OLA, Uber and other contract buses, public transport should be converted -75%	▪ Taxies, 3 Wheeler and BEST Buses had already converted. ▪ Nearly 5000 cabs operated by Ola and Uber in Mumbai city which can be converted for clean fuel. The contract buses and intra city buses should promote for shifting of fuel through administrative orders and tax exemption. ▪ Incentive for new owners to buy CNG/LPG vehicles. ▪ Developed infrastructure for easy availability of fuel station for CNG refueling and availability of kits for such conversion to the older vehicles

(Contd..) : Line Source Strategies for Short and Long Term (Short & Mid term – 2019 to 2021; Long Term 2022 to 2027)

Area Sources	Short Term	Mid Term	Long Term	Action required
Reduction Emission per Unit of Fuel				
Banning of 15 year Old Commercial Vehicle	50% banning Encouragement by provision of incentives in form of scrap value.	70% banning	100% banning	▪ All vehicles should go through inspection and certification every two years. Incentive for an owner to phase out his vehicle after 15 years given in the form of low registration cost or direct subsidy ▪ Corporation and metropolitan authority should demark designated places for scrapped vehicles as such there is no provision in the city
Synchronization of traffic signals Sensor Based -Real time tracking	Major & minor roads, excluding feeder roads (or about 35% of the all arterial roads)	Major & minor roads, excluding feeder roads (or about 65% of the all arterial roads)	Major & minor roads, excluding feeder roads (or about 80% of the all arterial roads)	▪ Pre feasibility study should undertake for some hotspots. Detail study should be worked out on signaling network with sensor based monitoring and apply fuzzy logic, mathematical model gives the real time picture.
New Vehicle Standards	Currently BS-IV standards are in operation	Implement BS- VI from 2020 -50% (adopt progressive increment)	Implement BS- VI from 2020 -75% (adopt progressive increment)	▪ The government of India is planning to implement BS VI norm across all country in 2020, but due to recent events it has been only implemented in some regions like Delhi. ▪ Regulatory bodies can undertake prior feasibility studies for its successful implementation across region. This is major measure considering 90% reduction in fuel sulphur.
In-Use vehicle	Marginal improvement from newer vehicles except when implementation is for Euro V & VI. -25%	Newer vehicles implementation of standards -50%	Newer vehicles implementation of standards -75%	▪ Improvement and compliance system in existing PUC ▪ In-use vehicles emission reduction can be substantial ▪ Inspection and identification of highly polluting vehicles ▪ Augmentation of manpower and related infrastructure for Inspection and Certification ▪ Vehicle manufacturer should be asked to get the emission warranty for the complete period of the operation of the vehicle. The same may also be included in the MoRTH guidelines to be developed asking manufacturer to be proactive even when vehicles have been sold

(Contd..) : Line Source Strategies for Short and Long Term (Short & Mid-term – 2019 to 2021; Long Term 2022 to 2027)

Area Sources	Short Term	Mid Term	Long Term	Action required
Reducing Fuel Consumption Per Unit Distance				
Share of Electric vehicles in Total City Fleet*	Two wheeler: 5%, 3 wheeler and Taxi: 5% Public transport buses -5%	Two wheeler: 10%, 3 wheeler and Taxi: 10% Public transport buses -10%	Two wheeler: 10%, 3 wheeler and Taxi: 10% Public transport buses -20%	▪ Encouragement to public participation for taking share of electric vehicles. ▪ Easily availability of charging points, engine testing and repairs workshop. Incentive for buying and providing exchange offers mostly young generation and women.
Share of Hybrid vehicles in Total City Fleet*	(Gasoline powered four-wheelers only) – 10%	(Gasoline powered four-wheelers only) – 20%	Gasoline powered four-wheelers only) – 30%	▪ Hybrid vehicle particularly efficient for city traffic where there are frequent stops and idling periods also reduce noise emissions in comparison to conventional engine vehicles. ▪ Hybrid vehicles can reduce air emissions of smog-forming pollutants by up to 90% and cut carbon dioxide emissions in half
Retrofitment of Diesel Oxidation Catalyst (DOC) and Diesel Particulate Filter in HDDV	Retrofitting devices- 50% conversion for HDDV in city registered vehicles	Retrofitting devices- 75% conversion for HDDV in city registered vehicles	Retrofitting devices- 1000% (Excluding the heavy duty city outside vehicles)	▪ A pilot study is required to test the need and efficacy of emission control device and retrofitting it in the older vehicles ▪ As retrofitment of emission control devices also needs a certain levels of fitness of the vehicle, it would be desirable to follow the norm after developing the same through the inspection and certification procedures ▪ It will be helpful to Maharashtra State Transport Corporation, Old BEST buses, Contract carriers ▪ Impose restriction of truck movement in the city for plying without retrofitment to HDDV vehicles (base on age and engine type). ▪ Tighter diesel fuel standards particularly for Sulphur to bring down its level up to 50 ppm. Differential taxation to those with and without after treatment devices.

* The Central Government of India and some State Governments, provide tax incentives that treat hybrid and electric vehicles preferentially over conventional technologies. The administration should devise some incentives and rebate at local level.

The government is focusing on creating charging infrastructure and policy framework so that by 2030, more than 30 percent of vehicles are electric vehicles. The flagship program to boost electric technologies in India is the **Faster Adoption and Manufacturing of Hybrid & Electric Vehicles (FAME)** scheme from the Central Government, launched in April 2015.

Electric Vehicles: The FAME scheme offers a subsidy on the retail price of passenger cars. These subsidies range as follows: for electric vehicles, from INR 60,000 to INR 1,34,000. Subsidies are also available for two-wheelers, three-wheelers, light-commercial vehicles, buses, and for retrofit kits. There are 24 two-wheeler models, all battery-operated electric, registered to receive demand incentives under the FAME scheme.

The Central Government of India levies an excise duty of up to 30% on conventional car technologies while electric vehicles are subjected to flat duties of 6%. In the national FY 2016-17 budgets, the Central Government of India also subjected conventional motor vehicles to an infrastructure cess ranging from 1% to 4% of the vehicle price and exempted electric vehicles from this cess.

The Ministry of Heavy Industries recently gave its approval to the introduction of EV-based public transportation systems in 11 cities across the country. These include Delhi, Mumbai, Ahmedabad, Bengaluru, Jaipur, Lucknow, Hyderabad, Indore, Kolkata, Jammu and Guwahati. Same can be assessed at regional levels at their own capacity.

The life-cycle emissions intensity of electric vehicles in India is poised for substantial reductions in alignment with India's post 2020 climate action plans.

Hybrid Vehicles : Hybrids with efficient internal-combustion engines and other non-polluting power trains will contribute to a cleaner environment.

The FAME scheme offers a subsidy on the retail price of passenger cars. These subsidies range as follows: for mild hybrids, from INR 11,000 (USD 165) to INR 24,000 (USD 360); for strong hybrids, from INR 59,000 (USD 885) to INR 71,000 (USD 1,065). Subsidies are also available for two-wheelers, three-wheelers, light-commercial vehicles, buses, and for retrofit kits.

The Central Government of India levies a flat excise duty 12.5% to hybrid vehicles as compare to 30% on conventional car technologies. In the national FY 2016-17 budgets, the Central Government of India also subjected conventional motor vehicles to an infrastructure cess ranging from 1% to 4% of the vehicle price and exempted hybrid vehicles from this cess. Hybrid buses hold potential to gain significantly under FAME, as the allocations available cover a significant portion of the technology costs.

While the FAME scheme provides incentives for all market segments, presently only passenger car models appear to be taking advantage of the scheme. In 2012-13, around 42000 electric vehicles and close to 20000 hybrid vehicles were sold in India. Most of electric vehicles were low speed scooters.

(Contd..) : Line Source Strategies for Short and Long Term (Short & Mid-term – 2019 to 2021; Long Term 2022 to 2027)

Area Sources	Short Term	Mid Term	Long Term	Action required
Reducing Fuel Consumption Per Unit Distance				
Inspection and Maintenance	New I&M regulations (30% population of vehicles of a RTO region)	New I&M regulations (50% population of vehicles of a RTO region)	Full compliance - 100%	▪ The test design should have the basis of engine and overall vehicles fitness (roadworthiness). ▪ The Vahan-nagari area should be developed for I&M which is equipped with state-of-the-art testing set-up for all the types of emission as well as fitness testing ▪ Strict compliance for I&M programs that are difficult to cheat; computerized data capture of control of tests, strict enforcement with socially acceptable failure rates and penalties
Ban of odd /even vehicles	It is feasible to take trail for commercial / office areas - 20%	Identified the interlinking roads and traffic hotspots and implement for trail road -20%	Identified the interlinking roads and traffic hotspots and implement for trail road -50%	▪ Add and even numbered vehicles will run on alternate days. Alternate arrangements should be made to bolster public transport. ▪ All private vehicles even having registration numbers issued by neighboring states will have to follow the odd-even number formula
Reduce Vehicle Distance Travelled				
Regulating Road Site Parking	Road site parking to be reduced by 50% (On street parking spaces as per IRC: SP: 12:2015.)	Road site parking to be reduced by 75%	Road site parking to be reduced by 100%	▪ Parking on roads should be regulated along with a rule to allow purchase of vehicles only if parking place is available. ▪ All road side shop, commercial premises, busy lanes are parking their vehicles indiscriminately near the approach movement. Municipal Corporation should define designated space in the localities and develop elevated pay and park zones. Higher parking fee for longer period of time. ▪ The commercial vehicles for good transport should not be allowed in peak hours

(Contd..) : Line Source Strategies for Short and Long Term (Short & Mid-term – 2019 to 2021; Long Term 2022 to 2027)

Area Sources	Short Term	Mid Term	Long Term	Action required
Reduce Vehicle Distance Travelled				
Encourage Public Transport	Increase Public Transport -20% Which reflect 10% VKT reduction from private vehicles.	Increase Public Transport -50% Which reflect 40% VKT reduction from private vehicles	Increase Public Transport -75% Which reflect 60% VKT reduction from private vehicles	▪ Refer Comprehensive Mobility Plan for Mumbai City prepared by Lee Associate. Incorporate city specific proposals on public transport with respect to Metro/mono rail, BRT, large buses contingent etc with integration of sustainable development and management. ▪ It can be achieved by way of providing better frequency to reduce congestion during peak period, better bus quality in terms of sitting as well as standing space ▪ The public transport should be cross-supported directly from the personalized vehicles either being purchased newly or older one running on the road. Funds generated from measures such as higher car user charges, higher parking charges, high registration fees, higher taxes on private mode of transport etc. should be directly transferred to them to achieve the low cost, better comfort, better frequency and faster travel. ▪ Diesel or any fuel used for public transport should be sold at lower price to keep the bus fare lower. ▪ Exclusive bus lanes should be identified. There is a need to undertake a project to demonstrate effectiveness of such system in Mumbai at one or two road stretches

For example, for one km of travel, a car consumes nearly five times more energy than a 52-seater bus with an average load factor of 82 percent. The corresponding consumption factor for two-wheeler is 2.6. The comparative fuel costs of a car and two-wheeler are 11.8 and 6.8 times respectively for the same distance. Besides, the major issue is that a car occupies 38 times more road space compared to a bus for a kilometer of a travel. Two wheelers space requirement is even higher at 54 times that of a bus*.

Further, the emission from a two-wheeler equivalent to a bus could add 27 percent higher, whereas the cars would cause 17 percent more pollution. The age of the bus can be of no major concern, when we compare the benefits that it could give in terms of fuel savings, emission and safety.

* Report on the Expert Committee on Auto Fuel Policy, Chapter 15, Government of India, 2002.

Every stakeholders consulted during the process, have agreed the major focus of any future transport initiative should be based on low cost public transport.

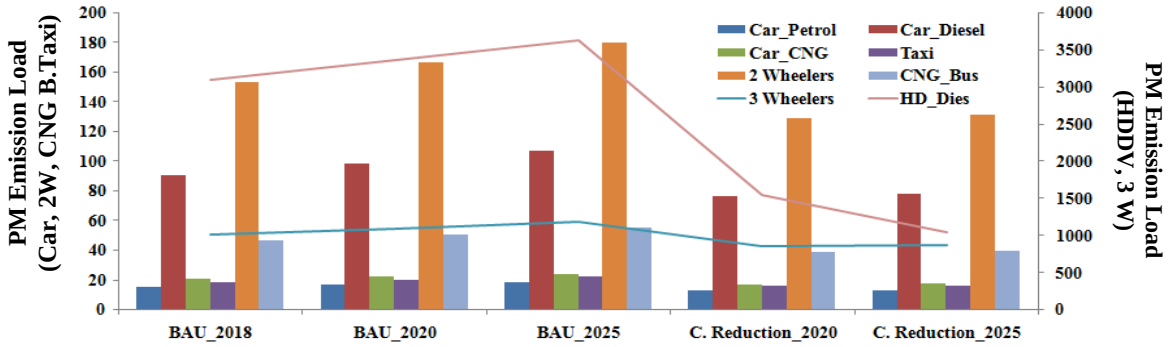
(Contd..) : Line Source Strategies for Short and Long Term (Short & Mid term – 2019 to 2021; Long Term 2022 to 2027)

Area Sources	Short Term	Mid Term	Long Term	Action required
Reduce Vehicle Distance Travelled				
Road and Traffic Control	Interlink age & accessibility of road to Station, Residential Blocks & Offices. Identify 10% area	Identify 50% area covering feeder and service roads	Identify 75% area covering service roads and arterial roads highways	▪ MUTP component for Station Area Improvement (SATIS) shall be able to provide the necessary augmentation of current conditions. Prepare plan for widening of road and improvement of infrastructure for decongestion zones. ▪ Interlink age of Western and Eastern Express Highways, City linkage node like Airoli, Mulund Dahisar and Sion Panvel Highway of Road need to address as per traffic flow in peak hours. New development of Metro lines will reduce the load of private vehicles to public mode of transport. ▪ Encourage car pooling resulting reduction in private occupancy of vehicles and generate open space, less congestion with easy traffic flow.
Encourage non motorized Transport	Define in every ward at least 2% area for walking and cycling track	Define in every ward at least 10% area for walking and cycling track	Every road should at least 3 m road for walking - 100% removal of road encroachment	▪ Pedestrian friendly walkways /Subways ▪ Introduce and define walking and cycle tracks during city development plan. Cycling should be promoted with safety, free parking lots for users, and free bicycle ride facilities stops outside all railway stations

(Contd..) : Line Source Strategies for Short and Long Term (Short & Mid term – 2019 to 2021; Long Term 2022 to 2027)

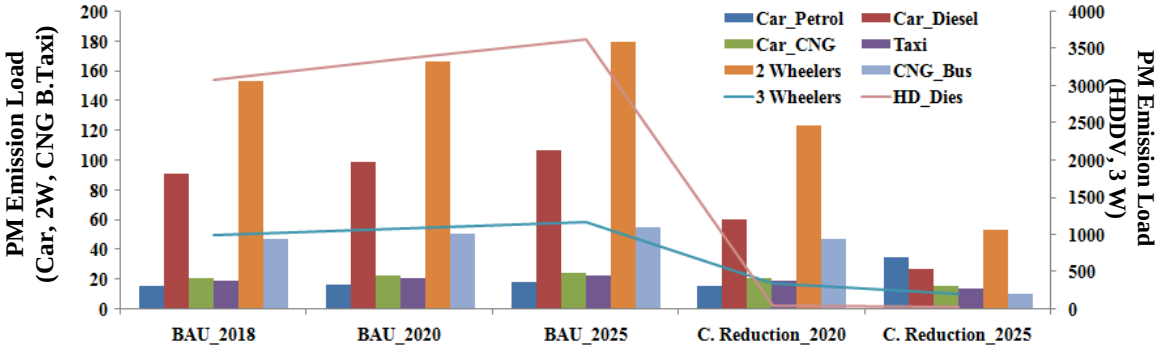
Area Sources	Short Term	Mid Term	Long Term	Action required
Reduce Vehicle Distance Travelled				
Reduce Dust Resuspension	Only some minor roads are unpaved in Mumbai city, but due to resupension of vehicles dust is the major issue. Paving of all road 75%	Paving of all road 75%	Paving of all road 100%	▪ Need for better construction practices and codes for roads and pavement construction. UTTIPEC design manual has been recently created by Delhi Development authority for uniform roadside, drains, footpath and related design. The same should be adopted for all future design for roads and pathways. ▪ Vehicle speed and volume and road condition should frequently monitor by Traffic department, potholes and repair digging activities should be properly managed. ▪ Dug-up pavements have shown that fine particles keep getting resuspended in the atmosphere as the pavements are either not maintained or after the digging, those are not brought back to their original conditions ▪ Encroachment of roads space by slums are one of the major reasons for slow down of traffic and leading to higher per unit emission due to congestion ▪ Coordination with all institution working in the area of road and pavement maintenance, digging for utilities etc. ▪ Standards for road construction specified in terms of guaranteed life of the road. Financial incentives to contractors using better technology for road construction. ▪ Treated water from Ghatkopar STP can be used for road washing where resuspension is high during road maintenance and in summer season.

On implementation of the control measures, significant reduction in emission loads can be observed. Some of the control measures are listed below as graphical representation to depict the efficiency of the reduction stretegies implemented as on 2020 & 2025 and compared with BaU 2018.



Synchronization of Traffic Signals

2020-Major & minor roads, excluding feeder roads (or about 65% of the all arterial roads)
2025-Major & minor roads, excluding feeder roads (or about 80% of the all arterial roads)



Implementation of BS IV -2020 & BS VI -2025

Complete implementation of BS - IV norms by 2019 and BS VI norms by 2025

A very comprehensive set of options have been examined for the purpose of understanding the issue of urban air pollution reduction. Implementations are highly influenced not only by the idea of the improvement alone but also by the nature of the recommendations, fiscal and administrative barriers, effectiveness, implementing agencies and acceptance from large group of stakeholders. Prioritization should be driven by the comparative account of short term and long term considering low cost with high effectiveness, low cost with shorter implementation period shall be a better option when compared with high effectiveness with high costs or long implementation period.

Resuspension from the building and construction activity is one of the prominent sources of PM emission load. As there are various infrastructural and development project going vide across Mumbai region, the resuspension attributed to these activities within their construction phase is severe but time being. The construction of Colaba to SEEPZ corridor for Metro Rail began last year and as per the EIA report prepared by RITES indicate that, after the introduction of metro rail system the reduction of vehicles and shift of ridership from road vehicle to the proposed system for the years 2016, 2021, 2031 and 2041 is given below. The reduction in number of vehicles gives benefits to economy by reduction in Vehicle Operating Cost (VOC), Fuel Consumption, and Pollution Load.

Table 2: Number of Vehicles Trips Kms With and Without Metro Corridor (Avg. Daily)

	No of Vehicle Trip KMs without C-B-S Metro			
	2016	**2021**	**2031**	**2041**
Car+ Taxi	55540150	64386256	78486486	95674589
2W	108595469	125891912	153461538	187068759
Bus	1609880	1866292	2275000	2773212
Auto	12082107	14006474	18823529	22945777
Total	177827607	206150934	253046554	308462338

	No of Vehicles Trip KMs with C-B-S Metro			
	2016	**2021**	**2031**	**2041**
Car+ Taxi	54634509	63278060	77141050	94060065
2W	105910475	122606396	149472663	182282109
Bus	1516800	1752394	2136719	2607275
Auto	11206062	12934493	17522061	21384015
Total	173267846	200571344	246272493	300333465

Table 3: Reduction In Vehicle Trip Kms With Metro Corridor (Avg. Daily)

Mode	**2016**	**2021**	**2031**	**2041**
Car+ Taxi	905641	1108196	1345437	1614524
2W	2684994	3285516	3988875	4786650
Bus	93080	113898	138281	165937
Auto	876045	1071980	1301468	1561762
Total	4559761	5579590	6774061	8128873

Source : EIA, Metro 3 prepared by RITES

Low fuel Consumption Due to reduction in Vehicle

There will be a reduction in number of vehicle trips on implementation of this project. Therefore, it is estimated that both petrol and diesel consumption will also get reduced. Table below provides information about the savings in fuel consumption due to reduction of vehicles in Mumbai for the years 2016, 2021, 2031 and 2041.

These fuel savings are valued at 2011 prices (Rs.67.00/L for petrol and Rs.41.00/L for diesel) the corresponding fuel savings for buses, Car + Taxi and 2/3 wheelers.

Table 4: Savings in Fuel Consumption Due to Reduction of Vehicles in Mumbai

Mode	Reduction in Vehicle Trips KMs with CBS Metro				Fuel Consumption Norm (Km/L)
	2016	2021	2031	2041	
Bus (Diesel)	93080	113898	138281	165937	6
Car +Taxi (Petrol)	905641	1108196	1345437	1614524	14
2 & 3 Wheeler (Petrol)	3561039	4357496	5290343	6348412	30

Table 5: Fuel Consumption and Money Saving Due To Reduction of Vehicles (Avg. Daily)

Mode	Reduction in Fuel Consumption (litres)				Monetary Value (Rs Lakh)			
	2016	2021	2031	2041	2016	2021	2031	2041
Bus (Diesel)	15513	18983	23047	27656	6.36	7.78	9.45	11.34
Car + Taxi (Petrol)	64689	79157	96103	115323	43.34	53.04	64.39	77.27
2-3Wheeler (Petrol)	118701	145250	176345	211614	79.53	97.32	118.15	141.78

Reduced Air Pollution

Reduction in traffic on Mumbai roads due to proposed metro rail could lead to reduce air pollution. The emission load was calculated in report is based on Emission factor of vehicles as per Euro-II norms the reduction level of different pollutants like PM, NOx, HC, CO and CO_2 for the years 2016, 2021 and 2031 and 2041 is given below.

Table 6: Emission Reduction in Traffic on Mumbai Roads Due to Proposed Metro Rail 3

Mode	PM				NOx				HC			
	Bus	Car	2/3 Wh.	Total	Bus	Car	2/3 Wh.	Total	Bus	Car	2/3 Wh.	Total
2016	1.7	9.9	97.5	109.1	29.6	66.1	389.9	485.6	93.4	82.6	909.9	1085.9
2021	2.1	12.1	119.3	133.5	36.2	80.9	477.2	594.2	114.3	101.1	1113.3	1328.8
2031	2.5	14.7	144.8	162.1	43.9	98.2	579.3	721.4	138.8	122.8	1351.7	1613.3
2041	3.0	17.7	173.8	194.5	52.7	117.9	695.2	865.7	166.6	147.3	1622.0	1935.9

Mode	CO				CO2			
	Bus	Car	2/3 Wh.	Total	Bus	Car	2/3 Wh.	Total
2016	22.4	654.5	2859.5	3536.4	35.2	43.1	52.3	62.8
2021	27.4	800.8	3499.0	4327.4	1028.5	1258.5	1527.9	1833.5
2031	33.3	972.3	4248.1	5253.8	4493.5	5498.5	6675.6	8010.7
2041	39.9	1166.8	5097.7	6304.5	5557.2	6800.2	8255.9	9907.1

* Emission Load, Tonnes /year

Similarly estimated benefit of Metro Line 2A (Dahisar to DN Nagar) and Metro Line 7 (Dahisar to Andheri) is reported in their impact assessment study conducted by Delhi Metro Rail Corporation reflect the reduction in pollution after completion of mass proposed transport system.

Table 7: Estimated Benefit of Metro Line 2A (Dahisar to DN Nagar)

Quantified Benefits in Horizon Years	**2019**	**2020**	**2021**	**2022**	**2023**
Annual Time Saved by Metro Passengers in Cr. Hr.	14.01	15.45	17.04	17.66	18.30
Annual Fuel Saved by Metro Passengers in thousand Tons.	23.56	27.26	31.62	33.11	34.62
Daily vehicles reduced (off the road)	19234	22052	25283	26215	27183
CO2 reduced in thousand tons	50.54	57.95	66.44	68.89	71.43
Other gases reduced in thousand tons	1.31	1.20	1.38	1.43	1.48
Reduced No of Fatal Accidents in Year	9.56	11.64	14.17	15.59	17.16
Reduced No of Other Accidents in year	68.64	83.54	101.68	111.93	123.20
Annual Vehicle km Reduced in Cr. Km.	35.91	41.17	47.20	48.94	50.74

Table 8: Estimated Benefit of Metro Line 7 (Andheri to Dahisar)

Quantified Benefits in Horizon Years	**2019**	**2020**	**2021**	**2022**	**2023**
Annual Time Saved by Metro Passengers in Cr. Hr.	7.20	7.44	7.69	7.95	8.22
Annual Fuel Saved by Metro Passengers in thousand Tons.	30.89	31.82	32.67	33.63	34.54
Daily vehicles reduced (off the road)	9922	10156	10396	10642	10893
CO2 reduced in thousand tons	26.07	26.69	27.32	27.96	28.62
Other gases reduced in thousand tons	0.81	0.83	0.84	0.72	0.59
Reduced No of Fatal Accidents in Year	4.12	4.22	4.32	4.42	4.53
Reduced No of Other Accidents in year	29.60	30.30	31.01	31.74	32.49
Annual Vehicle km Reduced in Cr. Km.	18.52	18.96	19.41	19.87	20.34

The Mumbai Coastal Road Project is a 35-kilometre-long road from Nariman Point to Kandivali in north Mumbai, is expected to reduce traffic congestion in the western suburbs of Mumbai. The Western Express Highway carries over 60 per cent of the city's traffic currently .The draft report has estimated a fleet size of 600 high-capacity buses to run on the coastal road. A BRTS can use existing road systems or be built with dedicated pathways and station systems, depending on available resources. It takes about an hour to travel from Marine Drive to Worli, but the coastal road will reduce the time to 20 minutes. A car taking the road would save a third of the fuel daily and reduce the carbon footprint by 1,826 tonnes of carbon dioxide per year.

All these proposed development will definitely affect by direct and indirect benefits to the transportation sector. The mass transport and change of travel demand will reflect the VKT of vehicles and reduction of pollution load over a period of time.

4.5.1. Mumbai Demography Base Control Measures

When it comes to the size and population of the city, Mumbai has an area of 603 sq. Km and population of 12.4 million making it the most populous city in the country. It has a density of 20,482 persons per Km. The 62 flyovers and the Bandra-Worli Sea link that came up in the last decade carry more cars than pedestrians. The sea link carries 37,336 vehicles daily, including city buses, against the eventual projection of 1,20,000 vehicles. Poor public transport, increasing cars and traffic jams, coupled with more and more roads that facilitate cars instead of people have brought Mumbai to a standstill. The Energy and Research Institute (TERI) says that in 2012, nearly 80 percent road accidents were due to the fault of the drivers of motor vehicles; only 1.2 percent accidents occurred due to the fault of cyclists. As for the receiving end, 57 percent of those who die in road accidents in India are pedestrians.

These plots total 17 percent of the Public Open Space left in the city. This appropriation of POS reduces per capita open space to a mere only 0.8 sq m. An that attempts have been made earlier to connect the three big grounds of south Mumbai, Azad Maidan, Oval Maidan and Cross Maidan, which are in close vicinity of both the Chhatrapati Shivaji Terminus (CST) and Churchgate stations of suburban rail. “Now with the Metro passing along the route, it is an excellent opportunity to integrate and link these spaces and have a walk though from a garden into the metro or to the suburban railway stations and vice versa.”

Thirty- five percent of the population that works within a distance of 7-8 km of the work place can walk or cycle to work, yet they commute by public transport or auto rickshaws, hire app-based taxis or take their own cars, adding to the traffic and increasing pollution.

Municipal Corporation of Grater Mumbai (MCGM) to create 85,891 hawking pitches in the city. “MCGM must map each section of every ward and remove encroachments and hawkers wherever possible to make footpaths walkable,” [*Unlike in Singapore, our policymakers have not introduced congestion tax, carbon footprint tax, etc.]*

“Indian cities are designed on the basis of the Indian Road Congress Codes and therefore we are designing cities as per highway standards. We need city-specific urban design manual and codes for cities with the following agenda: complete the network, design for universal accessibility and multiple capacities. Parking and hawking are parallel economies that need to be tackled for holistic development of the city. Today it is acceptable to park cars on roads, whereas it is public space and parking is allowed for free. Parking has to be off street, at public space and paid”. We need to de-

facilitate cars and reduce parking spaces, increase road tax from 10 percent to 25 percent. As against Rs 10 crore revenue from parking fees at present, we should aim at revenue of Rs 1,000 crore from parking within two-three years. This will reduce the number of cars, and enable revenue for good quality roads".

Public transport vehicles and non-motorized modes of transport are given preference in parking space allocation. The parking policy has to ensure that the city provides limited legal parking with a cap on further supply and prices it effectively and variably to reduce demand for parking and thus car ridership and ownership. City allows legal parking caps and it is regulated and priced. Some parking restraint like proof of parking is available. There has to be high penalty for illegal parking.

In Mumbai also green tax has been levied under Bombay Motor Vehicles Tax (Amendment) Ordinance, 2010. Public and private vehicles over eight and 15 years old pay a green tax every year. They should be revised and made co-herent with current situations.

To turn Mumbai into green urbanity few suggestions are: (a) remove encroachments for unrestricted flow of city buses with more bus services and lanes, (b) have a bus stop within every kilometre, (c) two car-parking facilities should not be closer than a kilometre, (d) at least 50 percent space of each road must be used for city buses, as against 5-10 percent today, and (e) cycling should be promoted with safety, free parking lots for users, and free bicycle ride facilities stops outside all railway stations. Additionally, short-distance fare for autorickshaws and taxis should be higher and long distance should be cheaper.

Less than 40' approach, which means no street should be wider than 40 metres and vehicles should not be moving faster than 40 km per hour. This can shift people to walking, bicycling and public transport. "If a footpath is absent or obstructed, people will walk on the vehicular carriage way. Maintaining a continuous footpath across the length of the street can not only help pedestrians but improve traffic efficiency as well capacity." Having too much of asphalt, steel, cement and building roads is not good for a city. Working on the same lines, WRI, India (NGO) has taken up a Junction Safety Improvement Programme along with MCGM and Mumbai Traffic Police on the busy SV Road- Linking Road junction and Nagpada junction. With small changes, junctions can be redesigned in two years.

Refocus policies to encourage public buses. “Convert BEST [BrihanMumbai Electric Supply and Transport Undertaking] buses into AC buses, encourage private players to ply from selected start points to end points, have a regulatory authority, make it a public corporation, list it on stock exchange and take it out of its [BMC’s] control”. “Rather than giving priority to the Rs 1,500 crore costal road allocated in the current budget which will be used by 200,000 cars at its optimum level, the government can buy 1,000 AC solar-powered, electric and hybrid buses which will be used by a very large number of people”. He says that there must be a single transport authority for the entire Mumbai Metropolitan Region (MMR) and the BEST committee can be converted into a separate transport committee for the city.

A bus can carry 79 people and it would require 60 cars to move the same number. Approximately 30 percent trips are short trips that can be done on foot or bicycle and can reduce 30 percent traffic on road. If buses are rationalized 20 percent traffic will reduce on roads.” The traffic problem can be solved overnight if on-street parking is stopped.

Intermediate Para-Transit (IPT) systems often fill in a very important role in a city’s mobility system by acting as a bridge between the travel requirements of users that the conventional public transport system cannot fulfill, such as last mile connectivity or point to point connectivity is needed.

However, it is also important to know that the central government has issued notification to leap directly to Euro VI emissions standards in 2020. This has serious implications for the implementation and compliance strategies at city level. Bharat Stage VI will bring in new genre of technology and fuel that will be subjected to a new compliance regime for the first time in the country. Only at Bharat Stage VI that will be implemented in 2020 will witness narrowing down of gap between petrol and diesel emissions.

PUC centres with central servers for automatic data transfer and minimize manual interference. Authorities should take steps to integrate on-board-diagnostic system with vehicle inspection programme.

Mumbai has to move beyond greening one or two lanes and take the credit for it. “In Delhi they set up an authority [Delhi Parks and Gardens Society] headed by a senior IFS officer which is now managing 20,000-odd parks and 10,000 green localities with all agencies coming together to adopt the UTPITEC [Unified Traffic and Transportation Infrastructure (Planning and Engineering)

Centre] guidelines on footpaths and greenery. Mumbai too needs micro planning right at the ward level. Green spaces and visitors corridors need to be created around spaces missing in Mumbai. A separate authority needs to be set up for greening Mumbai which cannot be done by the garden superintendent." The planned coastal road can include space for a jogging/ cycling track with green spaces. While spaces below flyovers are being converted into green spaces, more greenery can be created if we ensure open spaces are reserved for greenery, walking and cycle tracks during redevelopment.

Fugitive dust from mismanaged construction and demolition (C&D) waste contribute to particulate air pollution. On 29 March, 2016 MoEFCC has notified India's first ever rules construction and demolition waste management. The challenge now is to have these rules implemented and reduce generation of this waste to reduce fugitive dust in cities.

4.5.2 Clean Air Fund

Prioritization of Public Transport on Roads: Public transport and its importance in the city of Mumbai need to be maintained for one most important reason. Once, more and more people get used to personalized transport, it would be very difficult to bring them back into the fold of public transport users. The fact that personal vehicles are occupying more and more space on the road; it is felt necessary that disincentive mechanism should be developed for personal vehicle owners. There are many methods of carrying out this task, however, financial and space constraints can achieve the balance.

BUS Lanes: As the road space is limited in Mumbai, the efficiency of the public transport can be maintained only if priority is given to the public transport vehicles. The objectives of such a policy will be to give priority to the buses. Some of the suggestions are:

- Exclusive bus lanes should be identified. One of the major obstacles to this concept, which many suggest, is lack of road space for adopting dedicated bus lane system. However, as has been seen in many other countries even in a narrow two lane roads, public transport priority system has been seen to be effective. Therefore, there is a need to undertake a project to demonstrate effectiveness of such system in Mumbai at one or two road stretches.
- If one wishes to see higher bus utilization, it also has to see correspondingly higher service levels. This could be achieved by way of providing better frequency to reduce congestion during peak period, better bus quality in terms of sitting as well as standing space.
- Those vehicles which may travel in bus lanes will need to pay a sum to get the benefits

Cost of Bus Ride: The cost of the bus fare has been increasing at a steady pace. This is seen as a very common practice when there is an increase in the diesel cost announced by the Government. What it leads to, is that the bus fare for two-four persons becomes almost equivalent to either the taxi fare or attractive enough to own a private two or four wheeler. In such a situation, it shows that increasing bus fare and purchasing power is becoming the main responsible agent for higher private vehicles purchase. The other reason, such as better roads with flyovers (faster travel) makes it attractive for private vehicle ownership.

Public transport fare pricing, therefore, should not only be dependent upon the actual cost, but on some other sources of income. In the case of BEST, cross subsidization from its own electric supply division was considered a good example; however, the same is changing and BEST has to fend for itself for its bus operation costs. Modalities and options which can be adopted for no increase in bus fares are presented below:

- Bus fare reduction can be achieved from various means, but not alone from improving its own efficiency (as is normally believed).
- The public transport should be cross-supported directly from the personalized vehicles either being purchased newly or older one running on the road.
- An Air Quality Fund could be created which will have sources of funds coming from measures such as higher car user charges, higher parking charges, high registration fees, higher taxes on private mode of transport etc. should be directly transferred to them to achieve the low cost, better comfort, better frequency and faster travel.
- Diesel or any fuel used for public transport should be sold at lower price to keep the bus fare lower. The losses can be recovered from car-users.
- Certain areas of business district or identified regions of high congestion, free bus services can be provided. The cost can be recovered from parking, congestion and high fuel costs charged to personal vehicles. (For example Pilot feasibility study may be carried out in **Hotspots)**
- All malls must be asked to provide their own free service to nearest train and bus routes so that congestion due to their activities is reduced further. Alternately, all cars must pay an additional fee besides parking charges as congestion fee when they enter the mall. All such charges should be pooled and shared with the public transport company.
- All malls and institutions attracting outside car visitors levy a Rs. 10 per hour charges. This can either go to BEST or the fund

- Administration : Insurance cost should be inclusive of congestion charge every six months, buy sticker worth congestion charges. Annual insurance time each vehicle can pay a sum of Rs.500 extra, which can go to the fund. Collection responsibility will be with the insurance company.
- Vehicle manufacturers selling vehicles in state of Maharashtra must pay a ONE TIME air pollution tax towards the CAF

The key is that all such charges thus collected should be managed as '***Clean Air Fund'*** and should be passed on the public transport company, which could not only take care of its operational costs but also addresses other issues such as: Lower cost to passenger, Better bus quality, Faster services and Adequate growth in bus population for more people.

Emission reduction from transport sector can also be achieved by forming a 'Clean Air Fund' in co-operation with public private partnership which can operate on following guidelines:

Example of how a small levy can bring additional revenue as part of Clean Air Fund :

Table 8: Vehicle Km Travel in a Day for Mumbai City (2017)

	2 Wheeler	3 Wheeler	Car Diesel	Car Petrol	HDDV	Taxies
VKT	3512886	5244740	4775819	7161046	2025342	3555128
Cost (Rs.)	17,56,443	26,22,370	47,75,819	71,61,046	20,25,342	17,77,564
Rate, Rs./km	0.5	0.5	1.0	1.0	1.0	0.5

Total collection : 2,01,18,584 about 2 crores per day

The current VKT growth of the city ranges between 2-5% depending upon the region of the city.

Awareness programmes for policy makers, people, drivers-mechanic, traffic police, health professionals, academicians etc. will bring the importance of better air quality. Land use and transport planning need to be looked at seriously for future sustainability of the cities. In dense cities conglomerate of MMR, public transport saves valuable space and energy compared to private transport, and can make a healthy profit at the same time. But cities need to nurture their public transport by giving then some priority on the road over cars. If buses are always caught in traffic then a vicious cycle begins, with bus riders abandoning public transport and adding to the traffic jams. Various case studies from other places also indicate the importance of sustainable transportation. Strong leadership and governance brings radical change in achieving sustainable development of the city. The authorities responsible for the development of Mumbai Metropolitan Region (MMR) need to develop Integrated Environment Management Systems (IEMS). The goal of achieving a balanced development of the region through proper land use planning, strengthening

of infrastructure facilities and formulates policies and programmes that help in preserving the environment for sustainable development.

The prioritization of various options in all three categories have addressed mostly all the major reduction in the overall pollutants load reduction combined with ambient air quality improvement. However, many of these measures still may not lead to resolving very small area high concentration points which could be due to short term but high emission or high activity for a limited period and limited area. Such hot spots in the city of Mumbai could exists when a local road is dug up and/or being repaired, construction and demolition of buildings, biomass and refuse burning, industries emission short term emissions etc. All of such activities can be controlled and regulated through local efforts and constant vigil on the part of citizen, pollution control agency and respective responsible implementing agency.

One of the biggest issues for large metro city is land use pattern, which indirectly drives the growth pattern of the city and consequent vehicle increase. Frequent change in floor space index (allowing more built up per unit area) leads to large scale increase in vehicle ownership and their presence on road. Better air quality planning for the city also needs appropriate transport planning which is linked with land use.

All reductions planned will only reduce emissions from manmade sources; however, natural background and dust would continue to remain in the atmosphere. The benefits computed in the process described above will not only yield PM and NOx related pollution reduction but also co benefits of other pollutants (SOx, VOCs, HC, CO etc.) reductions as well. One of the other major co-benefits of these options (adoption of mass transport, use of cleaner fuel, efficient combustion etc) will provide large scale green house gas reduction. Mumbai as a big metro city will provide the impetus of overall mitigation of GHG. The benefits of air quality improvement plan suggested and delineated above again will not yield desired results if the adjoining urban centers and states do not adopt measures suggested for Mumbai as the objectives of clean air cannot be kept limited to the political boundary of Mumbai when it is in close proximity of major urban centers.

Chapter 5

5.1 Air Quality Dispersion Modeling

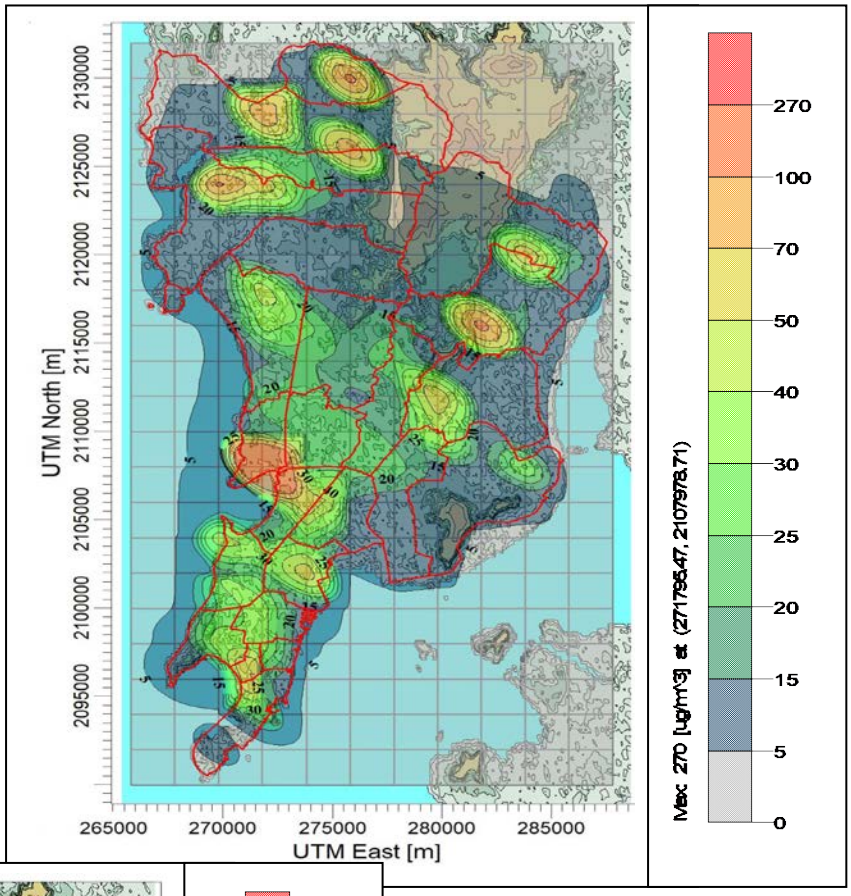
Air quality dispersion modeling exercise was also undertaken with a view to delineate the immediate sources and their impact on measurement locations. Dispersion modeling tool (AERMOD model) was used for the whole city air quality scenario generation for different emission loads of PM and NOx. The model runs were undertaken to establish the dispersion pattern of pollutants due to local meteorology, representative terrain influence height and emission from all possible sources.

Thus, elevations for all sources viz. line sources, point sources, area sources, both discrete receptors and receptor grids are computed by the terrain pre-processor. SRTM3 - Shuttle Radar Topography Mission (SRTM) 3 with resolution of 90 m was used as Terrain Data for running the model. A uniform Cartesian grid receptor covering 42 x 22 Km^2 of the study area was considered as input in the AERMOD model. The model was set to simulate the 24-h ground level concentrations (GLC) of at the selected receptor network.

The point sources used in the study were major stacks of the industries as obtained from MPCB database for 131 stacks. The physical properties of the stacks viz. height, diameter, location and gaseous emissions viz. gas velocity, temperature etc. used in the AERMOD model were obtained from Regional Office of MPCB, Mumbai. Similarly, line and area sources are inventoried and calculated emission rates are fed in AERMOD to get the ground level concentration (GLC) of pollutant upon dispersion. Area sources emission load inputs from 24 Mumbai Municipal Wards for bakery, crematoria, building construction, hotels and restaurants, domestic sector, open burning and open eatouts etc. were given to the model. As also from Line Volume (Major & Arterial Roads, connecting State & National Highways) of 254 Roads were considered for vehicle and road Dust source.

These predicted concentrations are in line with the ambient air quality of the monitoring sites in the Mumbai city. The comparison of concentrations for the scenario has been carried out by considering the highest ten concentrations. **Figure 4** shows the Annual predicted concentrations of PM and NOx due to all sources.

Figure 4a: AERMOD Predicted Concentrations of PM Due to All Sources – Annual (Mumbai City)



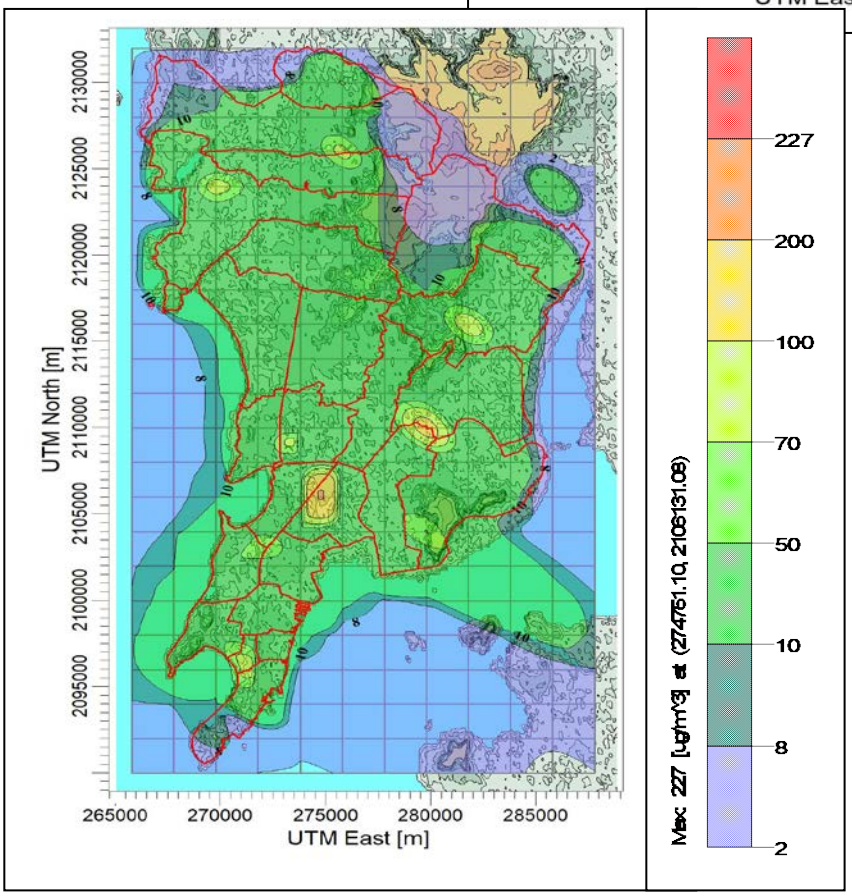


Figure 4b AERMOD Predicted Concentrations of NOx Due to All Sources – Annual (Mumbai City)

Draft Interim Submission

Annexure – I

Design of a Clean Tandoor Community Kitchen System (CTCKS)

Design of a Clean Tandoor Community Kitchen System (CTCKS)

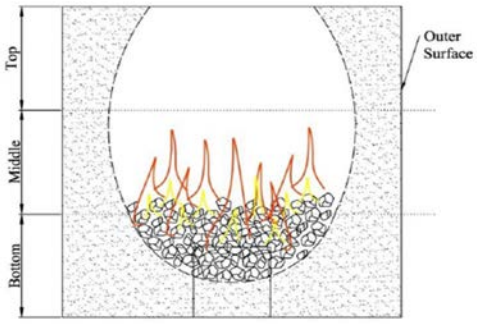
The objective of the experiment is to design a clean tandoor community kitchen system to reduce air pollution. There are no standards or guidelines to evaluate the performance of the tandoors w.r.t. its thermal efficiency, emissions and safety. While such standards are developed for the cook stoves however, tandoors are not considered probably due to their limited use. Also there is no BIS/ISI product Quality Mark for Tandoor in India to ensure quality of the tandoor even w.r.t. to material of construction. In most of the cases, it was found that there was no control devices installed at any tandoor facilities surveyed.

Air quality policies have so far focused on formulating and implementing abatement strategies for ambient (outdoor) air pollution, while indoor air quality sources (or human exposure) have not been adequately taken into account. To date, it is not clear whether measures implemented on outdoor air pollution will prove effective (and sufficient), once the total picture, that is the relative contribution of indoor and outdoor sources to total human exposure, is clear. Indeed, compliance with existing National Ambient Air Quality Standards (NAAQS), intended to protect public health, depends exclusively on outdoor measurements of pollutants. However, such measurements are subject to biases because most people spend much of their time indoors in different microenvironment than outdoor, and air pollutant concentrations are often much higher in these micro-environment than ambient with higher exposure conditions too, e.g. during cooking, etc. Therefore, estimates of human exposure to inhaled air pollutants are necessary for a realistic appraisal of the health risks these pollutants pose and for the design and implementation of strategies to control and limit those risks.

Based on the Material of Construction (MoC) the tandoor can be classified as Stainless Steel (SS), Sheet (Aluminium/Mild Steel) and Iron/Steel Drum (made from cutting the liquid fuel/oil drums etc.). The cost of the tandoor varies based on the MoC i.e. SS (Round/Square) Tandoor would cost between Rs. 16,000 – 22,000 or even higher, whereas the Sheet (Aluminium/Mild Steel) based are priced at Rs. 8,000 – 12,000 and Drum Based at Rs. 3,000 – 5,000. As per secondary data and surveyed tandoors it was found to be natural draft. The insulation material used at tandoor covers use of clay, glass-wool, ceramic, vermiculite, fire brick, mud etc. in order to retain heat for longer duration. It was observed that the cooking area is mostly outdoor (>92%). The tandoor was used “outdoor” primarily means that the tandoor oven for cooking purpose is placed beside but outside the compound walls of the restaurant premises under a shaded, however this is just adjacent to the seating area for customers and therefore emissions form tandoor can easily disperse inside the eating/seating area, unless a proper ventilation is provided. No control device to reduce the emission or ventilation to reduce the exposure

was present in over 90% of the surveyed restaurants thus showing least concerns on emission exposure. It was also observed that, the quantity of fuel used varies from 5kg to 40kg per day. Cost of the fuel lies in the range of Rs.20-40 per kg of coal (>70%). Over 41% of the tandoors were ignited in the morning for full day operation. About 0.11 to 0.35 kg of ash is generated by burning per kg of charcoal/coal for over 71% of the restaurants. The ash and un-burnt fuel was disposed in dustbin using polythene bags.

The thermal profile across the tandoor over was also recorded using Amprobe IR-750 Temperature Gun (n=139) to understand the temperature requirements of the tandoor surveyed, for effective cooking. The tandoor oven can be divided into 3 major sections: Top, Middle and Bottom as depicted below. The combustion of coal/charcoal takes places in the bottom section. The middle section transfers the heat to the top section where the food is cooked. The median temperatures at the top, middle and bottom sections were observed as 184°C, 383°C and 580°C respectively, where the median outer body temperature of the tandoor was 56°C owing the insulation layer between the tandoor oven and the outer body of the tandoor.



Classification of Temperature Zones in Tandoor Bhatti

A cleaner, efficient tandoor is proposed based on Pellet based fuel with forced Draft arrangement with an aim to design a clean combustion device in order to reduce the emissions, keeping in mind that functionality and feel of the tandoor doesn't change significantly in order to bypass any hurdle in the adoption of the proposed design. A tandoor system can be primary divided into two parts: firstly, combustion chamber section and oven section. Considering the combustion chamber section in the existing designs in it was observed that most of the tandoors were natural draft with insufficient air to fuel ratio. Therefore, in order to supply sufficient oxygen, a forced Draft fan is considered to increase the air to fuel ratio in order to improve the fuel combustion. Also the quality of coal used in tandoor is a major concern which is also responsible for higher emissions, keeping this in mind, low cost biomass pellets is suggested as an alternate fuel for heating the tandoor oven to reach the desired temperature. The advantage with using a pellet based forced draft combustion tandoor will be reduced emissions with increased thermal efficiency, which can be supported by retrofitting the commercial size forced draft improved Cookstove readily available in market and are tested by BIS 2013 to meet the efficiency and emission standards.

However, since these cookstove are designed for semi-commercial and community cooking, some modifications will be required, which can be done by the respective developer/manufacturer. These stoves are listed in ***Annexure*** and can be readily retrofitted to a tandoor oven to improve the combustion process. The design of the tandoor oven is kept similar to the available designs of tandoor, so that it doesn't affect the functionality issues or create any adoption hurdle. The selection of material of construction of tandoor should consider the following: clay for oven with high heat capacity material to retain heat for longer duration and body parts material for its long life and selection of low cost and effective insulation for tandoor oven.

Figure 1 to 4 below shows the concept design of the tandoor drawn not to scale as the size of the tandoor may vary based on required power output. The proposed tandoor system also incorporates a continuous pellet/fuel fed mechanisms so as to enable the uninterrupted and automatic supply of fuel to the combustion chamber for continued functioning of tandoor system. The proposed design of the tandoor can be fitted with chimney (natural or induced forced draft). However, the design of chimney will depend on the available space and vary from restaurant to restaurant. The design of chimney is not dealt in this study but it is recommended to use and install commercial available chimneys along with the proposed tandoor in order to reduce the human exposure. Although this would significantly reduce the pollutant exposure, however would anyway contribute to ambient air.

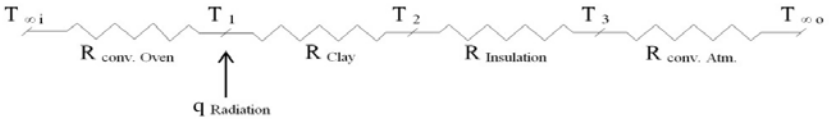
Advantages of pellet based tandoor also leads to reduced ash generation. Pellets based tandoor will also generate market for pellet industry and enable the use of agro-waste residues for development of an alternative fuel, promote employment generation in rural areas and would partly contribute to emission control and avoid disasters like smoke haze from stubble burning.

Design Methodology

The community tandoor involves different modes of heat transfer phenomena occurring simultaneously inside a tandoor, which can be described under three primary categories: Conduction, Convection and Radiation. The process of heat transfer involves heat transfer from the burning of fuel, convection within the hot gases, heating of the tandoor clay by convection and radiation; conjugate heat transfer between the heated gases inside the tandoor chamber and the tandoor clay; conduction of heat across the tandoor surface (clay and insulation); convection between the outer tandoor surface and the surrounding atmosphere. The process of heat transfer is dominated by radiation as compared to other modes of heat transfer. In a tandoor, three modes of heat transfer i.e. Conduction, Convection & Radiation are accounted together for minimizing the heat transfer through the walls and heat balance

Eq. (1) and Eq. (2).can be given as:

$$\dot{Q}_{cond.} + \dot{Q}_{conv.} + \dot{Q}_{rad.} = \dot{Q}_{total} \quad (1)$$



$$\frac{T_{\infty i} - T_1}{R_{conv\cdot oven}} + q_{rad} + \frac{T_2 - T_1}{R_{clay}} + \frac{T_3 - T_2}{R_{insulation}} + \frac{T_{\infty o} - T_3}{R_{conv\cdot Atm}} = \dot{Q}_{total} \quad (2)$$

The conjugate heat transfer between the hot gases (fluid) and the tandoor clay (solid) can be given by Eq. (3) and Eq. (4):

$$T_{w,s} = T_{w,f} \quad (3)$$

$$k_s \left(\frac{\partial T}{\partial n}\right)_{w,s} = k_f \left(\frac{\partial T}{\partial n}\right)_{w,f} \quad (4)$$

The heat transfer coefficient can be calculated using the existing relation in Eq. (5):

$$h = \frac{Nu_L * k}{L} \quad (5)$$

In order to minimize the heat losses and to prevent the heat transfer from the oven to the atmosphere, effective heat insulation material is needed in between the oven and the outer tandoor casing. Critical thickness of Insulation is determined, where thickness of insulation corresponding to the critical radius of insulation is calculated to decrease the heat transfer. If insulation thickness is beyond its critical radius, heat transfer rate increases. This radius at critical heat loss is given as Eq. (6).

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$$r_{cr} = \frac{k}{h} \quad (6)$$

Design of Forced Draft Stove

The following relations were used to design the pellet based forced draft cookstove.

Power Output: Power output rating is determined by the formula in Eq. (7):

$$P_o = F \times H_{fuel} \times \eta / 360000 \text{ kW} \quad (7)$$

Energy input: The amount of energy supplied by the fuel fed into the stove can be computed using the formula in Eq. (8):

$$FCR = \frac{Q_n}{CV \times \eta} \quad (8)$$

Combustion chamber diameter: The diameter of the combustion chamber is calculated by using the following formula in Eq. (9):

$$D = \sqrt{\frac{1.27 \times FCR}{SGR}} \quad (9)$$

Height of the combustion chamber: The height of the chamber is calculated by using the following formula in Eq. (10):

$$H_b = \frac{SGR \times T}{\rho} \quad (10)$$

Amount of Primary Air needed for gasification (Pa): According to Mukunda et al. (2010) primary air, which is mainly responsible for gasification is usually 1.5 times FCR as depicted in Eq. (11):.

$$P_a = 1.5 \times FCR \quad (11)$$

Area for Primary Air Requirement (Ap): The total primary area required for forced air flow is divided into two parts for design suitability. A primary window is provided at bottom to feed wood logs and other lower bulk density materials. Holes are provided at the top section of the combustion chamber for gasification of fuel. Therefore 13 holes were drilled throughout the circumference of the stove (Eq. (12)):

$$A_p = \frac{P_a}{\rho_{air} \times v} \quad (12)$$

According to Mukunda et al. (2010) secondary air, which is mainly responsible for combustion is usually 4.5 times FCR as given in Eq. (13):. Velocity was assumed as 1 ms-1 for penetration of air into the reactor (Witt, 2005).

$$S_a = 4.5 \times FCR \quad (13)$$

Tandoor Design Details

The material of construction for proposed tandoor may vary across different manufactures but it is recommended to use mild steel, stainless steel and Iron based alloys for all primary purposes of constructions. The use of these materials for tandoor fabrication will enable the tandoor to be economically viable and it is within the budget of potential users. The design has been optimized

keeping the user requirements in mind. As such, no further training or skilled trainer is required for use of proposed product design. The material details for different child parts of pellet based tandoor are tabulated in Table below. The conceptual designs of Clean Tandoor Community Kitchen System (CTCKS) are depicted in Figures 1-4 (Not drawn to scale). Based on design value, from expression for diameter, height, combustion chamber and air requirement, design specifications of improved pellet stove is tabulated in Figure. The detailed design of the different child parts along with their dimensional details required to fabricate the CTCKS is delineated below.

Illustrative materials for different parts of CTCKS

Part Name	Material	Thickness
COOKSTOVE	Stainless Steel Mild Steel Cast iron	Min. 1 mm Min. 1.6 mm Min. 6 mm
OVEN	Mud Clay	As per existing tandoor
HOPPER	Sheet Metal Aluminum Alloy	Min. 1.6 mm sheet Min. 1 mm sheet
BAFFLE PLATE	Stainless Steel Mild Steel Cast iron	Min. 1 mm Min. 1.6 mm Min. 6 mm
CASING	Sheet Metal (Aluminum) (1.5 mm) Stainless Steel (1.6mm)	Min. 1.5 mm sheet Min. 1.6 mm sheet
INSULATION	Sand Ceramic wool Liquid Foam	Min. 50 mm Min. 16 mm Min. 10 mm

NOTE: Dimensional tolerances shall be ± 3 percent. Various components of the tandoor shall be manufactured as per standard engineering practices. The construction of the tandoor shall be sturdy as per the given design details, so that while in actual use on level floor they should not get shaky or fall with little impacts

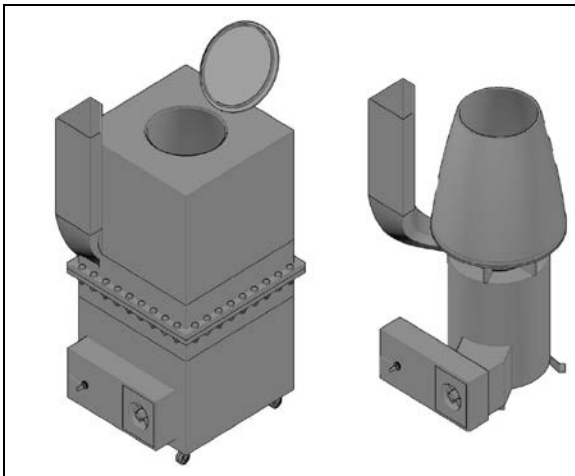


Fig.1 Pellet based Forced Draft Clean Tandoor Community Kitchen System (CTCKS) (a) With outer casing (b) Without outer casing

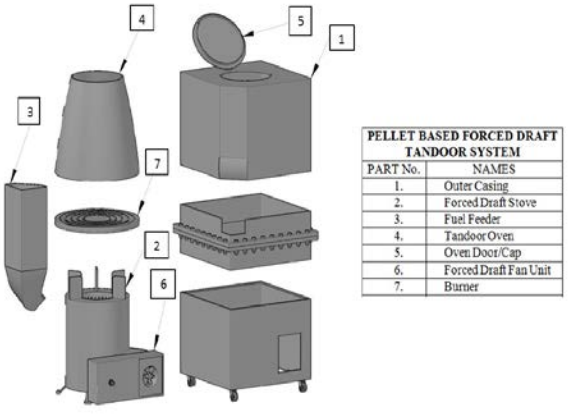


Fig. 2 Exploded view CTCKS: Inner Assembly & Outer Casing

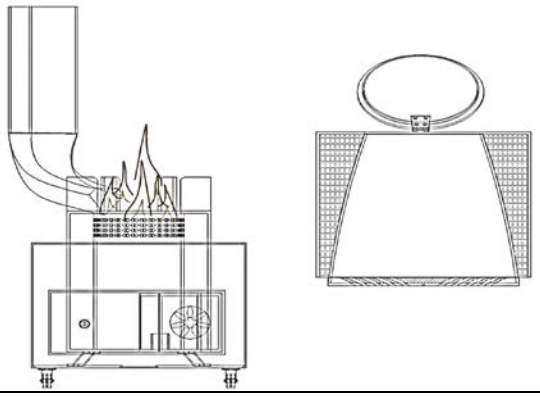
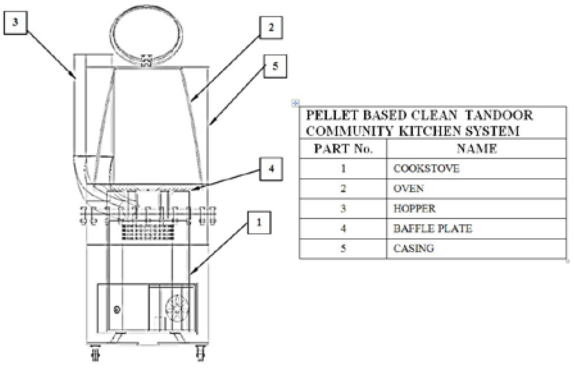
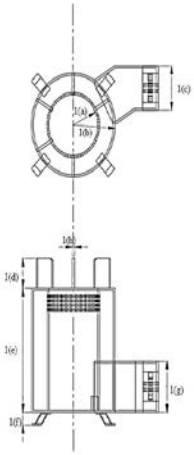


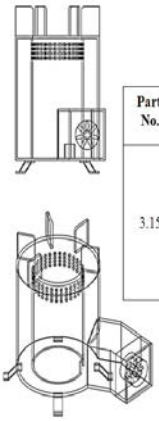
Fig. 3 Line diagram of CTCKS showing Combustion unit and Oven section (Dimensions not to scale)



PELLET BASED CLEAN TANDOOR COMMUNITY KITCHEN SYSTEM	
PART No.	NAME
1	COOKSTOVE
2	OVEN
3	HOPPER
4	BAFFLE PLATE
5	CASING

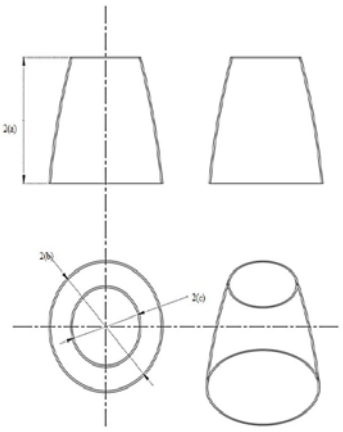
Fig. 4 Line diagram of CTCKS





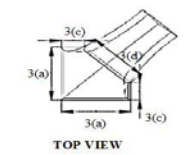
Part. No.	Dimensions (mm)	
3.15	a	170
	b	250
	c	80
	d	50
	e	400
	f	40
	g	80
	h	4

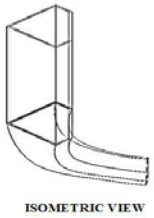
Fig. 5 Child Parts of CTCKS: Cookstove

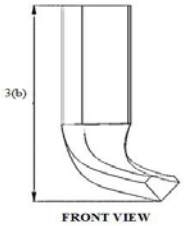


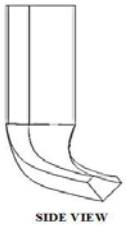
Part. No.	Dimensional Range (mm)	
3.16	a	450 – 500
	b	680 – 700
	c	300 – 350

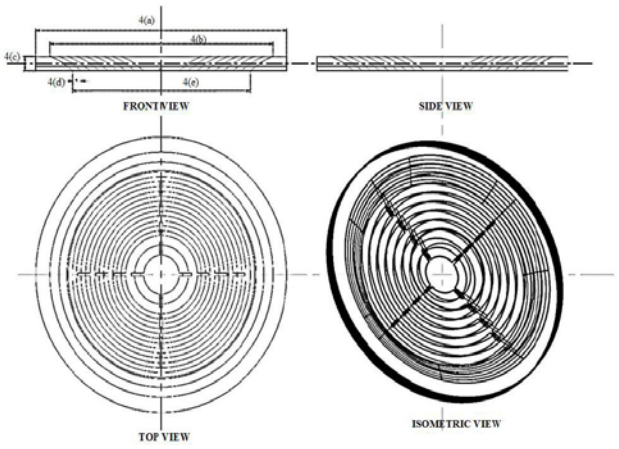
Fig. 6 Child Parts of CTCKS: Oven









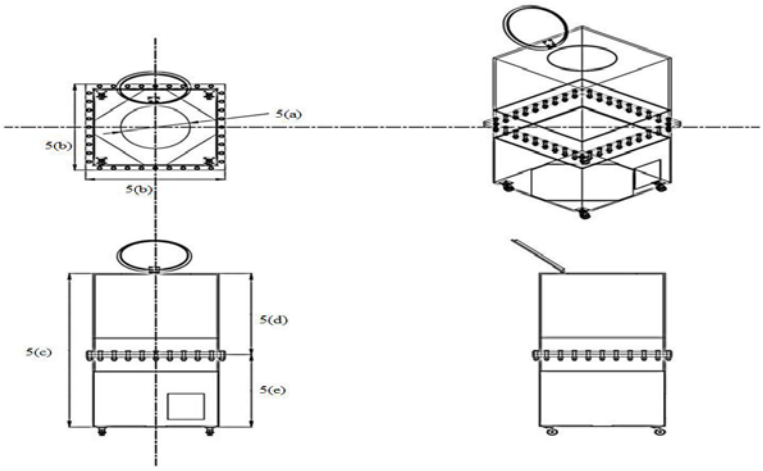


Part. No.	Dimensional Range (mm)	
3.17	a	160 – 180
	b	600 – 700
	c	80 – 100
	d	170 – 200

Fig. 7 Child Parts of CTCKS: Hopper

Part. No.	Dimensional Range (mm)	
3.18	a	680 – 700
	b	580 – 600
	c	35 – 40
	d	20 – 30
	e	540 – 560

Fig. 8 Child Parts of CTCKS: Baffle Plate



Part. No.	Dimensional Range (mm)	
3.19	a	300 – 350
	b	750 – 820
	c	850 – 900
	d	450 – 500
	e	550 – 600

Fig. 9 Child Parts of CTCKS: Casing

In order to assemble the child parts of Clean Tandoor Community Kitchen System as per there construction, the following sequence shall be followed:

The forced draft cookstove (Fig. 5) shall be mounted by a baffle plate (Fig. 8), which will act as guided vanes to divert the flames of the stove (generated from the burning of pellets) to heat the inner wall of the tandoor called as oven (Fig. 6). A hopper (Fig. 7) can be attached in the space between the baffle plate (Fig. 8) and forced draft cookstove (Fig.4) in order to maintain continuous fuel feeding to the combustion chamber for its continued operation. This assembled unit thus formed is depicted in Fig. 4. The assembled unit will be inscribed in an outer casing (Fig. 9). The insulation material is provided between the tandoor oven (Fig. 6) and outer casing (Fig. 9) in order to prevent the heat loses from the tandoor oven (Fig. 3.16). An oven door/cap (Fig. 9) is provided to cover the tandoor oven (Fig. 3.16) when the tandoor system is not in use. This will prevent heat/energy losses and will save fuel, as already practiced in conventional tandoors.

Although it appears that the contribution of tandoors to ambient air quality is not very significant, however considering the exposure risks as well as number of unregistered restaurants, it will be worth introducing an improved tandoor for such application. It is therefore expected that the improved design of Clean Tandoor Community Kitchen System will bring air quality improvement as well as health benefits in the entire region, if implemented in large scale. Following actions are recommended for implementation in hotel/restaurant enterprises:

- All the restaurants/hotel enterprises of sitting capacity more than 10 should not use coal/charcoal and shift to pellets as a primary fuel to fire the tandoors. The use of pellets in tandoors will reduced the air emissions significantly while also reducing the fly ash generation.
- The tandoor manufacturing is quite an unorganized sector while there are no emission norms for this commonly used combustion cocking device. It is therefore recommended that similar to improved cookstove, emission norms and test protocols should be developed by responsible agencies for tandoor.
- Pellet based tandoor will also generate market for pellet industry and enable the use of agro-waste for development of an alternative fuel, promote employment generation rural areas and pollution from stubble burning can be significantly avoided, as it has already become a matter of great concern. In this way, introduction of pellet based tandoor become an effective option also to reduce indirect pollution load.
- The crop residue burning from nearby areas can be partly minimized by turning local biomass to pellets and with introduction of improved tandoor even in these localities for local consumption of pellets.
- The use of electric or gas-based tandoors may also be promoted in small capacity restaurants/hotel enterprises (less than 10 customers) as well as those can afford the same. Pellets are also economically viable option with cost to CV ratio of approx. Rs 2/- per 1000 calorie energy output (CV) as against Rs 4/- per 1000 calorie energy output for charcoal (considering cost as Rs 8/kg for pellets and Rs 30/kg for charcoal). The advantage of charcoal is slow burning rate (smoldering combustion) without forced draft. This can be partly compensated with an automatic pellet feeder and controlling air to fuel ratio through forced draft flow rate.

Its widespread adoption in crop burning states will create local demand for stubble based pellets and other fuels, thus reducing air pollution from open crop/stubble burning.

Annexure :

MNRE's Approved Models of Community Size Cookstoves - Natural Draft/ Forced Draft

III. Community SizeCookstoves - Natural Draft				
1.	Shri Vikram S. Kale, Proprietor, Vikram Stoves & Fabricators. A-37, MIDC, P O Box No.25 Osmanabad-413501, Maharashtra Telefax : 02472 228401. (M) 09422465477,9922157 777,9422465457 vikramskale@rediffma il.com www.vikramstoves. com	Vikram Jumbo Bio Super, top feeding	Thermal Efficiency : 28.10% CO : 1.15g/MJd TPM :123.67mg/MJd Power Output : 3.64 kW	
2.	Digvijay Sales & Engineering Works, IshkrupaVidyanagar, Parali Vaijinath-431515, Beed-431515(MS) Manufacuturing Unit: VimalUdyog B-110, Additional MIDC, Harangul, Latur-413512, Maharashtra (M) 9869254891 digvijaysalesengworks @rediffmail.com	Digvijay Community Chulha Top feeding	Thermal Efficiency : 30.28% CO : 1.73g/MJd TPM :168.85mg/MJd Power Output : 4.209 kW	
IV. Community Size Cookstoves - Forced Draft				
1.	Shri Ashwin Patel, DirectorAlpha Renewable Energy Pvt. Ltd.At. & Po. Vasna (Borsad), Ta. Borsad, Dist. Anand, Gujarat, India-388 540 Tele:02696-290380; (M):09904184849 info@alphaindia.co.in, ap@wallguard.net	XXXL Plus Stove	Thermal Efficiency : 35.52% CO : 1.97g/MJd TPM : 78.93mg/MJd Power Output : 3.78 kW	
2.	Shri Sashidhara B T, Proprietor Sacks Right Energy InnovationsNo.83/84, Kempegowda Circle 14th A Cross, Thigalarapalya Main Road, Peenya 2nd Stage, Bangalore - 560 058 (M): 9900241276,98864258 79 Email: wedesignforyo u2000@gmail.com Sin_e@yahoo.co.in	Ojas - M06 (Fuel-Pellets)	Thermal Efficiency : 35.11% CO : 1.05 g/MJd TPM : 69.01 mg/MJd Power output : 5.43 kW	

3.	Mr. Sandeep Kashyap, M/s. Navitas Green Power(Fuel Management) Pvt. Ltd. Udyog Vihar, Gurgaon Ph- 0124-4987400 124-4987499(Fax) Mb: 9910402185 Email- sandeep.kashyap@sar-group.com	Navshakti Cookstoves, Model: NSTF10 (Fuel -Pellet)	Thermal Efficiency : 42.80% CO : 1.03g/MJd TPM : 68.45mg/MJd Power Output : 12.2 kW	
		Navshakti Continous Cookstove, Model No. NSCF10	Thermal efficiency : 35.42% CO : 1.34 g/MJd TPM : 123.28mg/MJd Power output : 11.46 kW	
4.	Teri, PMU Lab Jagdishpur, Amethi, U.P	IMPMETAL TERI SPFB_0514b	Thermal efficiency : 37.12% CO : 1.59 g/MJd TPM : 105.62mg/MJd Power output : 9.11 kW	
5.	M/s. Supernova Technologies Pvt. Ltd. Gujarat Tel: +91 2692 237037 sntgstove@yahoo.com , sntgujarat@gmail.com www.supernovawindsolar.com	Supernova-SGDCM	Thermal efficiency : 36.10% CO : 4.63 g/MJd TPM : 112.17mg/MJd Power output : 4.62 kW	
6.	M/s TERI , Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi-110003	IMPMETAL-TERI-SPFC-1114	Thermal efficiency :36.49 % CO : 1.71 g/MJd TPM : 133.65mg/MJd Power output : 3.36 kW	
		IMPMETAL-TERI-SPFM-0414N	Thermal efficiency :35.41 % CO : 1.889 g/MJd TPM : 116.63mg/MJd Power output : 4.256 kW	
7.	M/s Phoenix Udyog (P) Ltd., Nahan Road, Moginand, Kala-Amb-173030, Dist. Sirmour (Himachal Pradesh) Tel: 09816103575 Email: phoenix.hp@rbsgroup.in	TERI SPFB-0514C	Thermal efficiency :37.32 % CO : 0.830 g/MJd TPM : 92.38 mg/MJd Power output : 9.05 kW	
		TERI SPFM-0414E	Thermal efficiency :35.75 % CO : 2.22 g/MJd TPM : 138.73mg/MJd Power output : 4.26 kW	

Draft Interim Submission

Annexure – II

Design of Air Pollution Control System for Open Pyre Type Green Crematorium

Design of Air Pollution Control System for Open Pyre Type Green Crematorium

A short term and localized air pollution control system is proposed in terms of design of air pollution control system for green crematoria. Cremation is the combustion, vaporization and oxidation of dead body with wood/fuel to basic chemical compounds, such as gases, ashes and mineral fragments retaining the appearance of dry bone. Normally wood, kerosene and dung cake is used for subjecting the dead bodies to flame in these crematoria. The emissions from it contain various pollutants due to incomplete / intermittent and complete combustion of fuel as well as flesh during the process. These ranges from PM, VOCs, CO, NOx, SOx, heavy metals (cadmium, mercury, and lead), dioxins and furans. Their presence in large numbers in an urban area creates lots of air pollution in the surrounding areas. These emissions can represent significant acute (short term) and chronic (long-term) health hazards to nearby residents. These health effects include irritation of the skin, eyes, and mucous membranes, central nervous system depression, respiratory effects and cancer. In view of this, there is a need to reduce the emissions from these units through design of air pollution control system for green crematoria.

The burning takes about 8-10 hours in which the flesh and wood is burnt. About 250-300 kgs of wood is required per body. Particles and gases from the cremation sites can be carried over long distances by wind and then settle on ground or water and other receptors. The effects of this settling include: making lakes and streams acidic; changing the nutrient balance; depleting the nutrients in soil; damaging sensitive forests and farm crops; and affecting the diversity of ecosystems.

There are two main types of crematoria found in urban environment depending on the type of fuel:

- Open pyre crematoria using wood as fuel (found in abundant) and
- Crematoria using electricity /Natural gas as fuel.

Most of these types are not having any air pollution control systems attached to it. In developed countries these crematoria's are fired by fuel and have primary/secondary combustion chambers for increasing the performance of combustion process. The air pollution control system is usually attached to these units. The emission control options for crematoria's are can hence be categorized as by use of clean fuel, change in technology and application of air pollution control systems.

Electric Cremation vs The Traditional Funeral Pyre

Electric cremation commissioned as a part of the Ganga Action Plan. The basic idea was to serve the purpose of river friendly cremation. Electric cremation is comparatively less expensive. Relatives can take the mortal remains within a few hours of cremation. In electric cremation, wood is not burned and there are no gas emissions. It is no doubt an unconventional way of cremation

but it helps in saving resources like wood (500-600 kg of firewood), kerosene (three litres of kerosene), some prefer desi ghee, and 300-400 cowdung cakes per dead body. It is the most economical option for funeral.

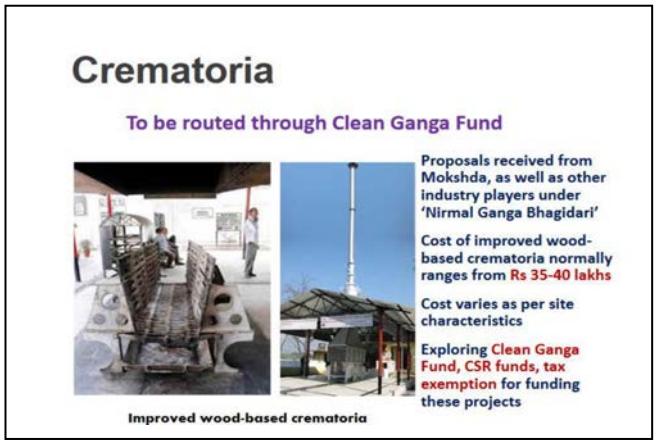
There has always been a controversy on the use of the electric crematoriums due to rituals as most persons follow the traditional burning of the bodies. In metropolitan cities it is promoted by the Government, private NGOs and environmentalists, but not to a great extent and most of these have failed due to finance and religious reasons.

According to a report, all the year round, around 50 to 60 million trees are burned during cremations in India. While burning the wood, there is also emission of million tonnes of carbon dioxide gas which is not good for the environment. Also, cremation in open grounds generates large amounts of ashes, which are later thrown into rivers and water bodies, especially the Ganga river, thereby polluting the water. These are all environmental threats caused by cremation.

However, electric cremation has not been popularized much in India, as Hindus still do not want to shed away their traditional belief. Orthodox families believe that a electric crematorium, which also is a covered crematorium, won't allow the soul to be released from the body and thereby it mingles with other souls and the concerned person will not be reincarnated again.

Green Cremation system

It is an alternate method of cremation in which the Hindus can also follow all their traditional rituals. It is affordable, energy efficient, and generates less water and air pollution, while all the religious needs of Hindus are taken into consideration. Cremation is done by cow dung are significance to the scarcity of wood. Although, other gases evolving due to cow dung need further study, particulate matter may drastically reduce.



In the Green Cremation system, a man sized metal grate is constructed beneath a roof and a chimney, and woods are placed on the metal base. The use of chimney enables better air circulation and reduces heat loss. It uses much lesser amount of wood (around 150-200 kg) to burn a body as compared to the wood (500-600 kg) used in the traditional funeral pyre. Also, it takes less time for the entire cremation, somewhere around 2 hours, as compared to 6-8 hours in the traditional cremation. While the emissions are reduced by 60%, the cost is also reduced significantly. Further the

emission control system attached to the hood of the open pyre shed and dome constructed may help in reducing the emissions vis a vis ambient air quality around the cremation unit. Detailed diagram of emission control system for open type with side enclosed crematoria **(Figure 1)**.

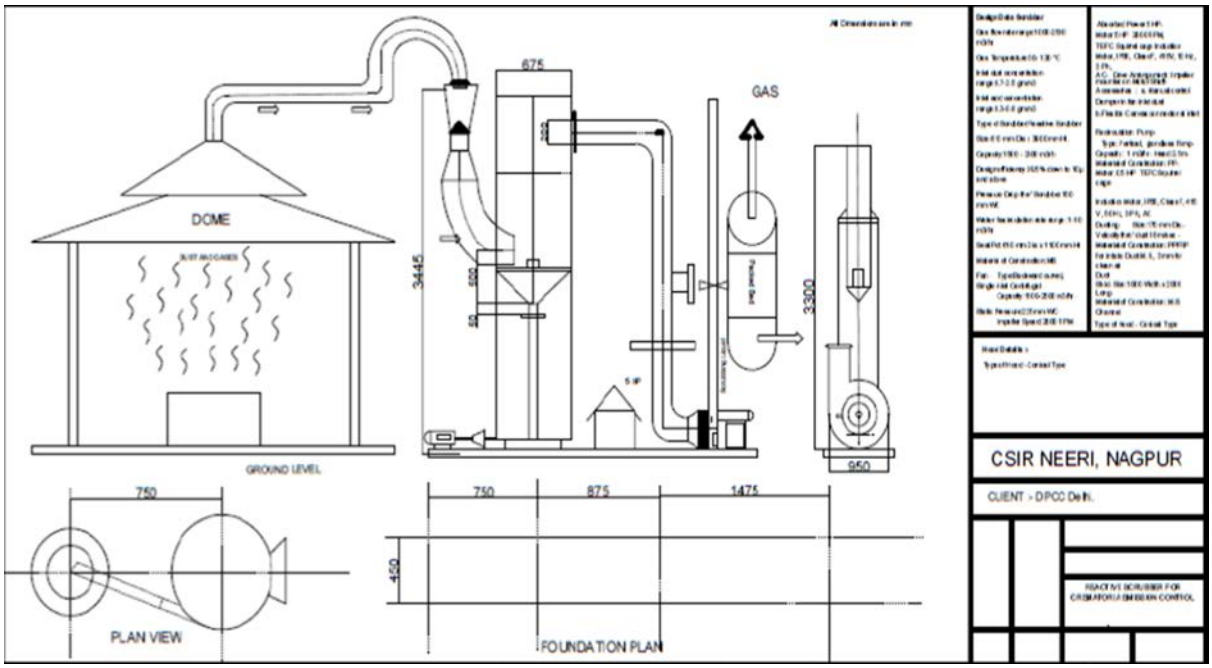


Figure 1 : Detailed diagram of emission control system for open type with side enclosed crematoria

Past Studies for Single Open Pyre Crematoria Emission Control at Nagpur, undertaken by CSIR-NEERI, Nagpur

Many technology including clean fuel, electricity etc were installed in various parts of country. However due to religious faith etc, these are not preferred. Hence the National Air Quality Standards for PM_{10} (100 µg/Nm^3) and other gases is not possible to comply without installation of adequate pollution control device. Regarding control option for such high emissions throughout the period, installation of bag filter is not advisable because of the high temperature of the flue gas, presence of smoke and volatile and larger space requirement for bag filter. The concept of wet scrubbing may be preferred for both dust and gases emission control. CSIR NEERI, Nagpur under in its 12^{th} plan project on National Clean Air Mission has undertaken a demonstration study of emission control system at single chamber open pyre crematoria at Mokshadham, Nagpur Aug 2014. Under this study, various field evaluation were made for sizing and selection of emission control options like velocity and temperature profiling, emission and AAQ monitoring, feasibility and sizing/selection of hood, ducting and emission control system.

The performance of the reactive scrubbing emission control system of NEERI was tested to handle gases over a wide temperature range and inlet particulate concentrations (1500 to 2,000 mg/m^3) typical for crematoria offgas. Tests showed that the scrubbing process is very efficient and easily

reduces these emissions to less than 350-400 mg/m^3. The ability to control solids loading in the scrubber liquid was also accomplished in this scrubber. The advantages of using this type of separation device are its compact size, low equipment cost, as it is constructed entirely of MS that can tolerate the corrosive nature of the scrubber solution. Tests done with a various oxidizing agents like with lime showed that the scrubber was able to remove nearly 70 percent of the particle matter along with acidic gases. The Velocity and temperature profile studies were undertaken around the cremation site during burning process as per **Figure 2**.

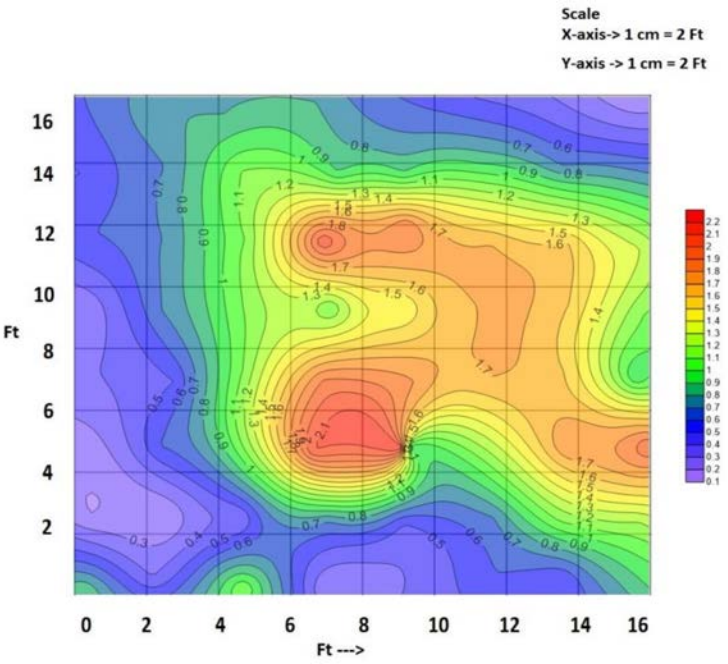


Figure 2 : Velocity profile of fumes during cremation

According to the velocity profile and temperature profile studies a hood and ducting was sized and installed at the shed of the single chamber open pyre crematoria and emission monitoring was undertaken to monitor various types of emissions during cremation of a dead body in a crematorium because of burning of wood, use of diesel, kerosene, cow-dung cakes and flesh burning. The hood is provided over the cremation in order to cover maximum area of dissipation of gases. Emissions like PM, CO, NOx, SO_2, NH_3, HC, etc. were monitored apart from flue gas hydraulic data. The emission load is estimated based on the input received from some crematoria and along with off gas flow, velocity and temperature profile, a hood and ducting followed by a reactive venturi scrubber is sized and installed as given in **Figure 3 and 4**.

These off gases are sucked at varying rates from and are further contacted with the liquid in the venturi scrubber to get maximum reduction by efficient gas /liquid contact **(Figure 5)**. Plain water and lime are used to study the performance. The suction capacity is adjusted depend on the emission rate from the burning, wind flow. The liquid to gases ratio are basis of maximum liquid

droplet contact with the incoming gaseous pollutant. The dust and gas pollutant get absorbed into the liquid and collect into the receiver. Recycle of liquid are also provided with the help of pump to maximize use of slurry/water. The distribution of particle size tends to be heterogeneous, ranging from some very large ash particles greater than 200 microns to fine dusts less than 75 microns. There may also be emissions of sub-micron metal salts (metal fume) and sub-micron particulate material formed from the condensing products of incomplete combustion. Visible smoke emissions are closely related to total particulate matter. Dark smoke is associated with sub-micron particles, formed from condensing products of incomplete combustion. Modern, secondary, combustion control cremator units should be able to absorb these species effectively into the solvent. In this study total particulates are monitored and their scrubbing efficiency was observed.

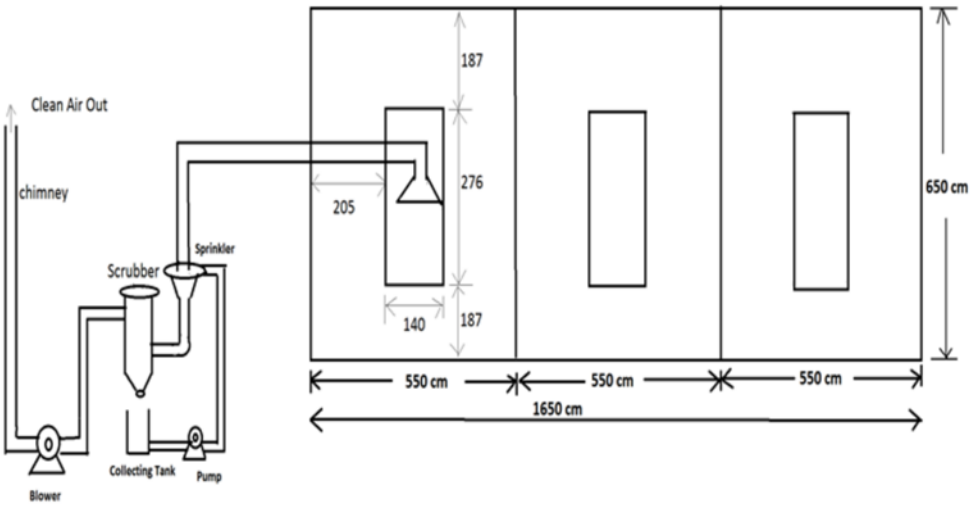


Figure 3 : Schematic view of Air Pollution Control System installed at Mokshadham Crematoria, Nagpur

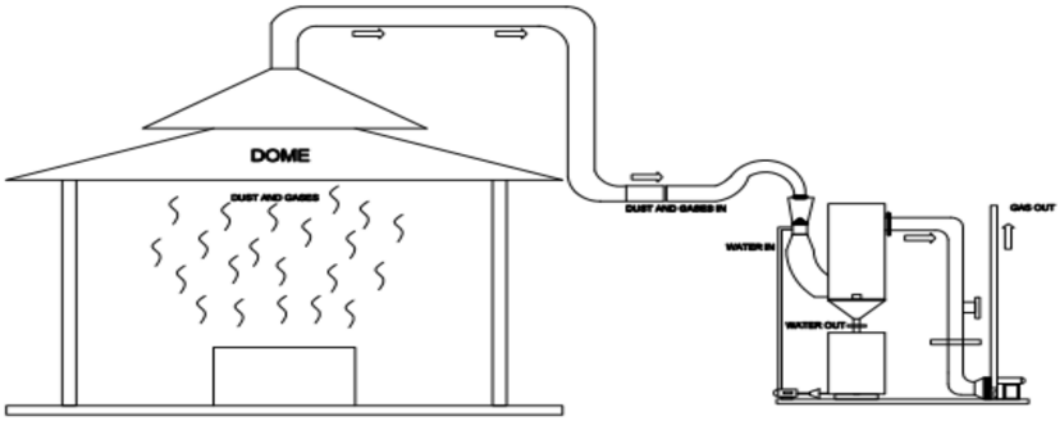


Figure 4 : Schematic view of Air Pollution Control System

The salient feature of Emission Control System installed in single chamber open pyre crematoria for demonstration as given in **Figure 1** is as follows:

- Hood size = 2500*2500*1000m height
- Ducting = 250 mm diameter 10m
- Scrubber Flow Rate = 8000m3/hr.
- Diameter of scrubber tank = 1200mm,
- Blower capacity = 7.5hp @1440rpm, variable speed
- Rotary air lock valve arrangement
- Water Pump capacity : 1 HP variable speed
- Material of Construction: mild steel of 4mm thickness
- The hood is supported by structural channel.
- Electrical 3 phase connection is required for 10 HP load
- Civil work for foundation of blower & Scrubber is required.
- Stack of 10 m height
- Capital Cost Approx. Rs. 8-10 Lakhs

Application of such emission control system in the single chamber Mokshada type crematoria at Mumbai may be done after the field evaluation studies of off gases emanating from such units.

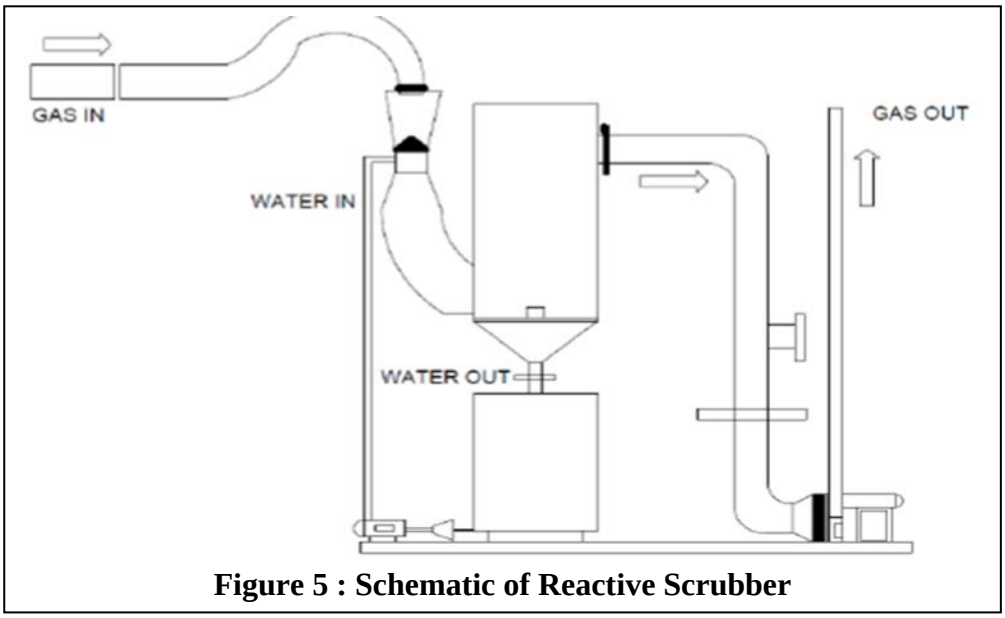


Figure 5 : Schematic of Reactive Scrubber

Gaseous Emission Control System

As crematoria flue gases contains higher percentage of organic, inorganic matter and particulate dust material which can be removed efficiently by Venturi Scrubber. Gases from the Venturi Scrubber outlet are further fed into a packet bed demister-cum-aerosol trap which serves dual purpose of removing water droplets as well as condensed fumes. This bed can be recycled at regular intervals of time. It can work on longer period though, if the flue gas contains less moisture. Cleaned gas escapes into the atmosphere from the last unit through an I.D. fan

Design of APC System Emission capture system

In order to capture the existing fugitive emissions from the open pyre systems. The rectangular and canopy hood needs to be used. The gases emitted from the platform, needs to be sucked at a sufficient height in order to accommodate the plume width at the height of the hood. Since the open pyre combustion is an intermittent emission source, it is necessary to establish the maximum or peak plume flow rate conditions that can be expected during the course of process operations.

The canopy hood volume is expressed by the following equation:

Hood Volume = T_d (Qp-Qs) Where,

T_d = duration of plume surge (s)

Qp= peak plume flow rate (m^3/s)

Qs= hood exhaust flow rate (m^3/s)

Equation used to find Dimensions. $Dc = 0.5 * X_c^{0.88}$

Where:

DC = column diameter at hood face.

XC = y +z = the distance from the hypothetical point source to the hood face, ft

Y = distance from the process surface to the hood face, ft

Z = distance from the process surface to the hypothetical point source, ft

$Z = (2 * D_S)^{1.138}$

Where:

DS = diameter of hot source, ft

Emission control system

The emission control system is proposed to be attached to the emission capture system. This reactive wet scrubbing system is used for emission control. The necessary liquid to gas ratio,

$Q_L/Q_G = [1.09(dd-0.0050/\mu g)]^{2/3}$

Q_L= liquid volumetric flow rate (m^3sec^{-1})

Q_G = gas volumetric flow rate (m^3sec^{-1})

d_d = droplet diameter, m

μg= gas viscosity, ($msec^{-1}$)

After scrubbing, the outlet gas contains few percentage of moisture which can be further eliminated by demister. Generally, Souder's equation as used for phase separator or for knocks out drums. That is,

Vd = k x [(L-G)/G]^0.5

L & G are liquid & gas densities.

Where k is the important part & is called the capacity design factor. It depends on type of de-mister pad. Selection of a too low or too high k is always having a negative impact in case of demisters as the efficiency greatly depends on velocities.

In case of lower velocities, droplets have low momentum to get path impingement & coalescence & therefore avoid capture into bigger drops & thus escape from the pad. At higher velocities the vapors have sufficient kinetic energy to re-entrain them. Therefore, correct range of k selection is necessary.

Based on past experiences & designs a value of k = 0.42 is most suitable for many applications. So after choosing k get the design velocity & then find out the diameter of separator.

Many of the Municipal Corporation is taking initiatives for shifting from traditional way of cremation to Green Crematoria. Ingenuity will be coming through public awareness and extensive efforts will require from all stake holders and NGOs for change in mindset.

Draft Interim Submission

Annexure – III

Design of Passive Gas Venting System for Landfill Sites

Design of Passive Gas Venting System for Landfill Sites

In developing countries, such as India, inventory estimation of methane (CH_4) emission from landfills has large uncertainties due to inadequate data availability on MSW management and emissions. During the cradle to grave process, MSW management process passes through various stages, such as sorting of recyclable and compostable materials before final disposal to landfills. These stages may change the quantity and properties of waste ultimately reaching the landfill sites, thereby influencing GHG emissions. Therefore, in-situ measurements of GHG emission fluxes from the landfill are important to reduce uncertainties in inventory estimates from this important GHG source. Many researchers have earlier reported about CH_4 emission estimates from MSW handling at national and city levels.

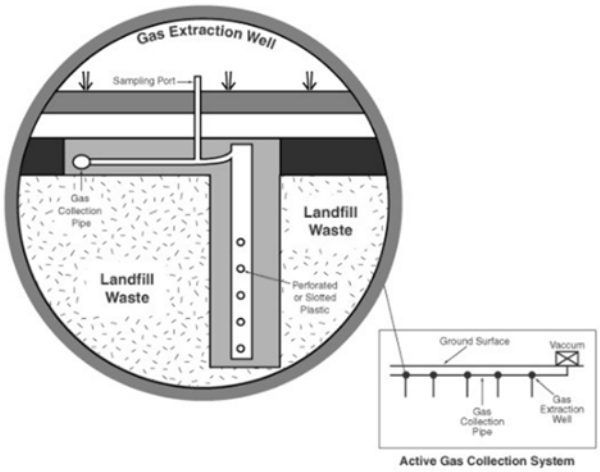
Most of the MSW generated is disposed of non-scientifically in open dumps, which causes a serious threat of landfill gas (LFG) emissions. The present note will focus on the landfill sites for the LFG emissions and designing the appropriate gas venting for the landfill sites.

Landfill Gas Collection System

Landfill gas can be collected by either a passive or an active collection system. A typical collection system, either passive or active, is composed of a series of gas collection wells placed throughout the landfill. The number and spacing of the wells depends on landfill specific characteristics, such as waste volume, density, depth, and area. As gas is generated in the landfill, the collection wells offer preferred pathways for gas migration. Most collection systems are designed with a degree of redundancy to ensure continued operation and protect against environmental hazards.

Active Gas Collection System

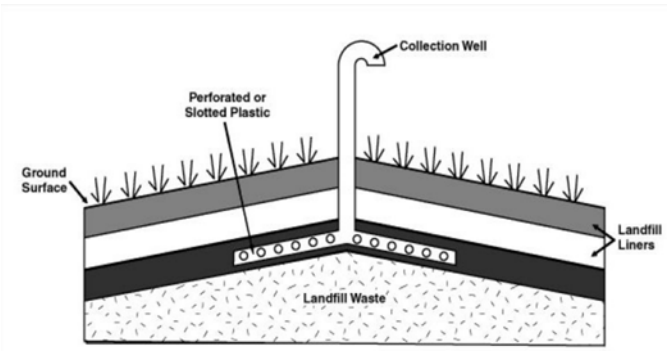
Well-designed active collection systems are considered the most effective means of landfill gas collection (EPA 1991). Active gas collection systems include vertical and horizontal gas collection wells similar to passive collection systems. Unlike the gas collection wells in a passive system, however, wells in the active system should have valves to regulate gas flow and to serve as a sampling port. Sampling allows the system operator to measure gas generation, composition, and pressure. Active gas collection systems include vacuums or pumps to move gas out of the landfill and piping that connects the collection wells to the vacuum. Vacuums or pumps pull gas from the landfill by creating low pressure within the gas collection wells. The low pressure in the wells creates a preferred migration pathway for the landfill gas. The size, type, and number of vacuums required in an active system to pull the gas from the landfill depend on the amount of gas being produced. With information about landfill gas generation, composition, and pressure, a landfill operator can assess gas production and distribution changes and modify the pumping system and collection well valves to most efficiently run an active gas collection system. The system design should account for future gas management needs, such as those associated with landfill expansion.



Active venting systems

Passive Gas Collection System

Passive gas collection systems use existing variations in landfill pressure and gas concentrations to vent landfill gas into the atmosphere or a control system. Passive collection systems can be installed during active operation of a landfill or after closure. Passive systems use collection wells, also referred to as extraction wells, to collect landfill gas. The collection wells are typically constructed of perforated or slotted plastic and are installed vertically throughout the landfill to depths ranging from 50% to 90% of the waste thickness. If groundwater is encountered within the waste, wells end at the



Passive Venting Systems

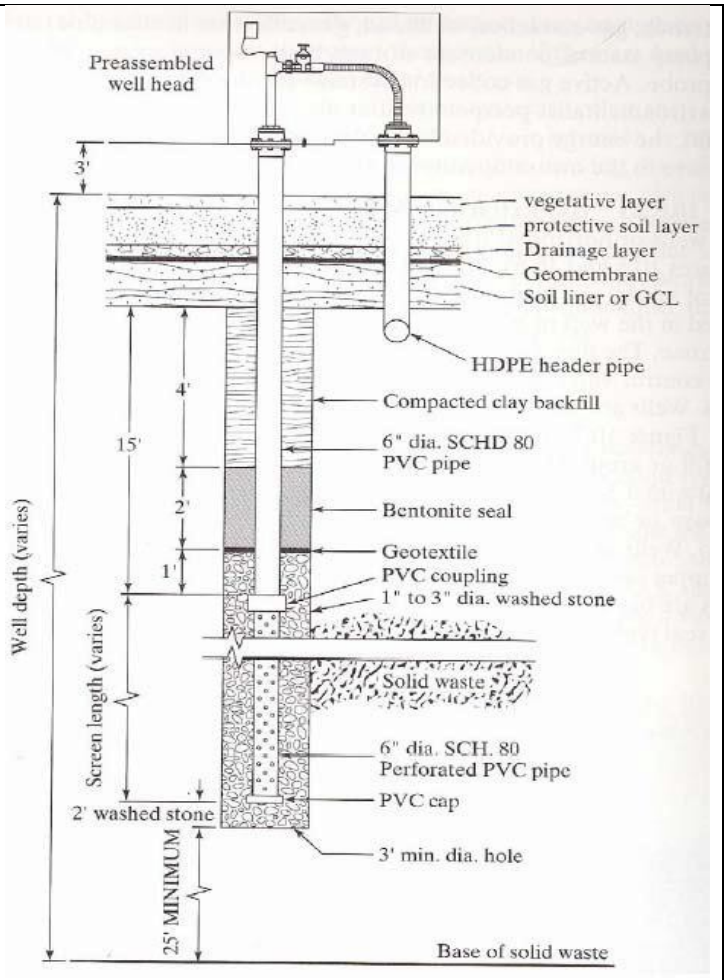
groundwater table. Vertical wells are typically installed after the landfill, or a portion of a landfill, has been closed. A passive collection system may also include horizontal wells located below the ground surface to serve as conduits for gas movement within the landfill as shown below. Horizontal wells may be appropriate for landfills that need to recover gas promptly (e. g., landfills with subsurface gas migration problems), for deep landfills, or for active landfills. Sometimes, the collection wells vent directly to the atmosphere. Often, the collection wells convey the gas to treatment or control systems (e.g., flares).

Criteria and Process Diagram of Passive Vents

Passive venting of low quality landfill gas or other CH_4 gas sources can be effectively controlled by the installation of passive venting systems. They consist of a horizontal network of slotted HDPE pipes connected together and fed to vertical venting columns. The columns are normally fitted with a rotating aspiromatic cowl to provide a small vacuum and increase the efficiency of the extraction. Other static type cowls are also available. The typical design of passive gas venting system is shown below :

The typical components of passive gas collection system are as follows:

- Vertical HDPE vent pipe
- Protective steel vent stack
- Rotating Aspiromatic cowl
- Static vent cowl
- 'Chinaman's Hat' cowl
- Bird protection cage
- High strength embedment lugs
- Anti flash-back gauze
- Bentonite seal
- Horizontal HDPE slotted pipe
- Vertical HDPE slotted pipe
- HDPE tee
- HDPE couplers
- Stone filled trench
- HDPE capping membrane



Typical Design of Passive Vent System

Data Requirement and Design of Passive Vent System for Landfill Sites

✓ ***Data Requirement***

The data required to estimate LFG generation in a landfill includes the following:

- Design capacity of the landfill
- Quantity of waste in landfill or the annual waste acceptance rate the landfill
- Rate of decay of organic matter
- Efficiency of gas collection systems (if any)
- Duration of operation

LandGem model can be used as an estimation tool for quantifying LFG generation and recovery from landfill sites. The model requires historical data for landfill opening and closing years, waste disposal rate, average annual precipitation and collection efficiency.

✓ ***Proposed Design of Passive Gas Venting System***

Depending on the potential impacts of LFG and local regulatory criteria, gases are either dispersed into atmosphere or collected and treated. Before designing the gas venting system, following should be taken into consideration:

- Size and depth of landfill
- Nature of waste and potential of producing CH_4 and other gases
- Age of dumped waste
- Existing gas collection and monitoring system
- Hydro-geologic conditions surrounding the landfill

After evaluating the above points by collecting information from concerned authority and also through experimental studies, the appropriate design of passive venting will be proposed for the landfill sites of Mumbai.

Methods to Treat Landfill Gas

Some passive gas collection systems simply vent landfill gas to the atmosphere without any treatment before release. This may be appropriate if only a small quantity of gas is produced and no people live or work nearby. More commonly, however, the collected landfill gas is controlled and treated to reduce potential safety and health hazards. Common methods to treat landfill gas include combustion and non-combustion technologies, as well as odor control technologies.

Combustion Methods

Combustion is the most common technique for controlling and treating landfill gas. Combustion technologies such as flares, incinerators, boilers, gas turbines, and internal combustion engines thermally destroy the compounds in landfill gas. Over 98% destruction of organic compounds is typically achieved. Methane is converted to carbon dioxide, resulting in a large greenhouse gas impact reduction. Combustion or flaring is most efficient when the landfill gas contains at least 20% methane by volume. At this methane concentration, the landfill gas will readily form a combustible mixture with ambient air, so that only an ignition source is needed for operation. At landfills with less than 20% methane by volume, supplemental fuel (e. g., natural gas) is required to operate flares, greatly increasing operating costs. When combustion is used, two different types of flares can be chosen: open or enclosed flares. Some public concerns have been raised about whether the combustion of landfill gas may create toxic chemicals. Combustion can create acid gases such as SO2 and NOX. The generation of dioxins has also been questioned. Because of the potential imminent health threat from other components of landfill gas, landfill gas destruction in a properly designed and operated control device, such as a flare or energy recovery unit, is preferable to uncontrolled release of landfill gas.

Non-combustion Methods

Non-combustion technologies were developed in the year 1990 as an alternative to combustion, which produces compounds that contribute to smog, including nitrogen oxides, sulphur oxides, carbon monoxide, and particulate matter. Non-combustion technologies fall into two groups: energy recovery technologies and gas-to-product conversion technologies. Regardless of which non-combustion technology is used, the landfill gas must first undergo pre-treatment to remove impurities such as water, NMOCs, and carbon dioxide. Numerous pre-treatment methods are available to address the impurities of concern for a specific landfill. After pre-treatment, the purified landfill gas is treated by non-combustion technology options.

It is feasible to go for comprehensive primary data collection at all the landfill sites in Mumbai to develop more realistic venting systems required to be installed at landfill sites.

Annexure – IV

Dust Control Measures

Dust Control Measures

The environmental impacts of dust emissions can cause widespread public concern about environmental degradation and/or a decline in amenity. The nature and extent of the problem and significance of the effects usually depend on the nature of the source, sensitivity of the receiving environment and on individual perceptions. For example, the level of tolerance to dust deposition can vary enormously between individuals. However, individual responses can also be affected by the perceived value of the activity producing the dust. For example, people living in rural areas may have a high level of tolerance for the dust produced by activities such as ploughing or top-dressing, but a much lower tolerance level for dust from unsealed roads.

Many forms of dust are considered to be biologically inert, and hence the primary effects on people relate to our sense of aesthetics. Dust directly causes eye irritation, lung disorders, health issues etc. Dust may also contain toxic metals like mercury and lead which can be carcinogenic in nature. Dust could settle on the window glass, ledges, flowers, fruits and vegetables, leaves etc. thereby reducing the aesthetic value. In New South Wales maintenance of dust deposited houses were estimated about ranging from $500–$1000 with an average value of $90 per annum. This really affects the property value. Dust also affects the visibility, thereby affecting the air quality level. Dust can also affect the growth of plants through:

- Reducing photosynthesis due to reduced light penetration through the leaves. This can cause reduced growth rates and plant vigour. It can be especially important for horticultural crops, through reductions in fruit setting, fruit size and sugar levels.
- Increased incidence of plant pests and diseases. Dust deposits can act as a medium for the growth of fungal diseases. In addition, it appears that sucking and chewing insects are not affected by dust deposits to any great extent, whereas their natural predators are affected.
- Reduced effectiveness of pesticide sprays due to reduced penetration.
- Rejection and downgrading of produce

Dust Control Agents

Water is one of the most primitive agents which are used as dust control measure. But it is less effective as compare with other chemical agents. Foam based system are also used to reduce dust. Lastly, one can reduce dust emission by reducing the production. Variety of chemical dust suppressant is available to suppress fugitive dust emissions. But they are being more expensive that of water. Comparing to water, they are more effective in suppressing dust and are applied much less frequently. Examples of dust suppressants include the following:

- liquid polymer emulsions
- agglomerating chemicals (e.g., lignosulfonates, polyacrylamides);
- cementitious products (e.g., lime-based products, calcium sulphate);
- petroleum based products (e.g., petroleum emulsions); and
- chloride salts (e.g., calcium chloride and magnesium chloride).

While the application of water and chemical dust suppressants are proven and effective options for mitigating dust, they have to be applied judiciously. Their usage, while mitigating dust, can trigger hazardous environmental consequences. It is important to keep these environmental consequences in mind when deciding on the extent to which water and chemical dust suppressants are to be utilized.

Selecting dust control agents

When selecting materials for dust control consider these basic requirements:

- environmentally compatible
- easily applied with common road
- maintenance equipment
- workable and responsive to maintenance
- reasonably effective at controlling dust
- not degrading to ride quality
- relatively harmless to vehicles using road
- posing little hazard or inconvenience to adjacent residents
- cost competitive

The most common dust control agents are chlorides, asphalt products, and lignin. Calcium- Magnesium Acetate (CMA) and $MgCl_2$ has been proposed as dust binder and its application on paved roads in Sweden, Austria, Germany and UK in order to mitigate road dust emissions *(Norman and Johansson, 2006; Barratt et al., 2012)*. These previous studies showed that in most cases a reduction of kerbside PM_{10} concentrations was reached. The effectiveness of CMA in binding deposited particles seems to be closely related to the degree of road moisture *(Gustafsson et al., 2010)*. This is a crucial aspect, mostly when evaluating the potential effectiveness in South European environments, where the higher solar radiation might further reduce the life-time of the air quality benefit. $MgCl_2$ has been also proposed and tested in Norway as a possible dust suppressant due its high hygroscopic and deliquescent properties. CMA and $MgCl_2$ were used in combination in a South European city, characterized by a relatively dry climate. In this scenario, emissions of road dust were estimated to reduce PM_{10} and $PM_{2.5}$ background levels by 16-17% and 6-8% respectively, as annual average between 2003-2009. Road cleaning activities (using $MgCl_2$) have been recently tested in one of the commercial district of Barcelona, resulting in a daily reduction of PM_{10} measured at traffic site by 7-10% and larger decrease for specific tracers of mineral and brake dust. Application rate for CMA and $MgCl_2$ has been given in **Table 1**.

Table 1: Application rates of dust control chemicals

Chemica	Applications	Where to used	Reference
$MgCl_2$	20 g/m^2	Barcelona, Spain	Querol (2013)
	30% solution at 0.5 gal./sq. yd.	Madison, Wisconsin, US	Wisconsin Transportation (1997)
CMA	20 g/m^2	Barcelona, Spain	Querol (2013)
	10 g/m^2	Klagenfurt, Austria	Gustafsson (2012)

Methods of Application

Dust control agent can be applied through vehicles and sprinkling on the road side (**Figure 1**). Also while transferring the materials (either via trains or trucks), they should be covered with tarapaulin. At the same time, dust control agent must be sprayed to reduce the emission of dust. This should be the responsibility of the owner rather than transportation agencies.

Figure 1 : Road side sprinkling of dust control agents

Covered vehicles must be used for transportation of coal and materials. One could use covered vehicles like dumpers for transportation of materials **(Figure 2)**. This would aid in reduction of fugitive dusts

Figure 2 : Covered transportation vehicles

Other references

- Gustafsson, M. (2012). PM10 reduction by the application of liquid Calcium-Magnesium Acetate (CMA) in the Austrian and Italian cities Klagenfurt, Bruneck and Lienz, presented at *Redust seminar, Helsinki*.
- Normana, M., Johanssona, C. 2006. Studies of some measures to reduce road dust emissions from paved roads in Scandinavia, Atmospheric Environment 40, 6154–6164.
- Querol, X. (2013). Methods used in Barcelona to evaluate the effectiveness of CMA and $MgCl_2$ in reducing road dust emissions, AIRUSE, LIFE11 ENV/ES/584.
- Wisconsin Transportation Bulletin. (1997). Dust Control on Unpaved Roads. Annexure

In order to achieve the maximum effect in terms of dust control and to reduce the environmental and other impacts; CSIR -NEERI has developed dust suppressant. It has been validated through laboratory studies and field trials under Indian conditions and scenarios.

Specifications/ Application

- CSIR - NEERI's dust suppressant need to be mixed with water with proportionate amount (10 - 15% depending on source of pollution; i.e., for road side dust 10% is enough while for coal mines, 15% is preferred).
- Application rate is 2 litre per unit area
- It is white (solid) and can be used as mist as well
- This chemical is based on hygroscopic salts like Magnesium Chloride and Calcium carbonate along with bio additive (name undisclosed, under stage of patenting).

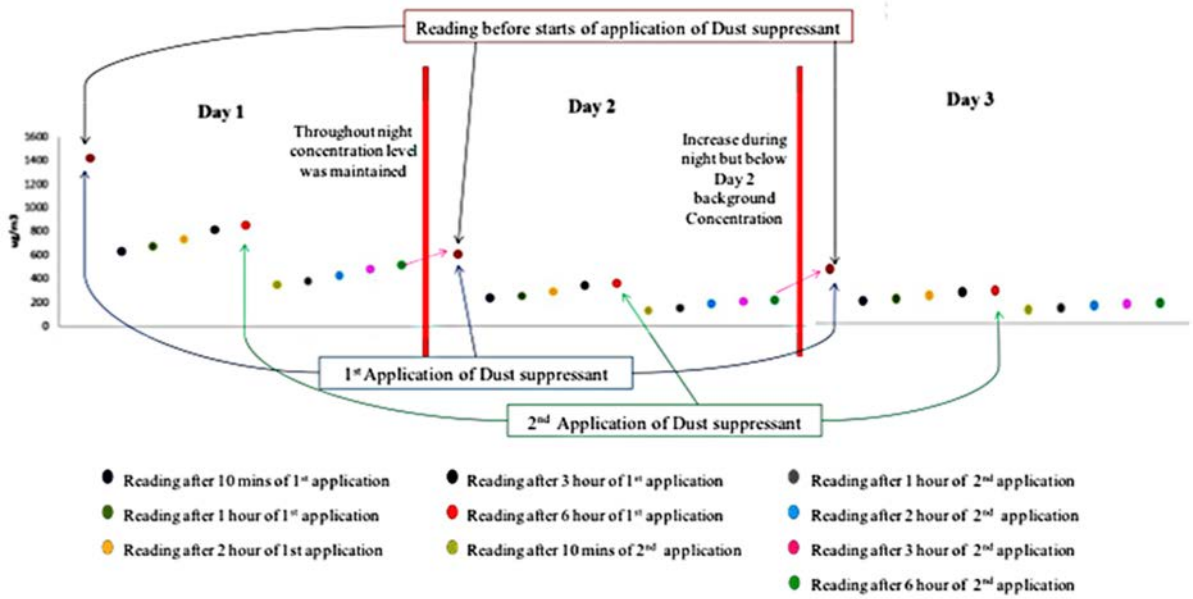
Advantages

- It is prepared, tested and applied as per Indian climatic conditions
- Treated water can be used for this purpose
- It is 40 to 60 times more effective than water
- While comparing with other dust suppressant, NEERI's suppressant showed better results
- No harmful byproduct is produced (tested and field trials conducted)

It has been tested by Enviro Policy Research India Pvt Ltd (EPRI) at three different construction site of Delhi.

Application of Dust Suppressant using Tanker at Delhi

The Effectiveness of Dust Suppressant: It showed 60 – 65% reduction from base concentration.



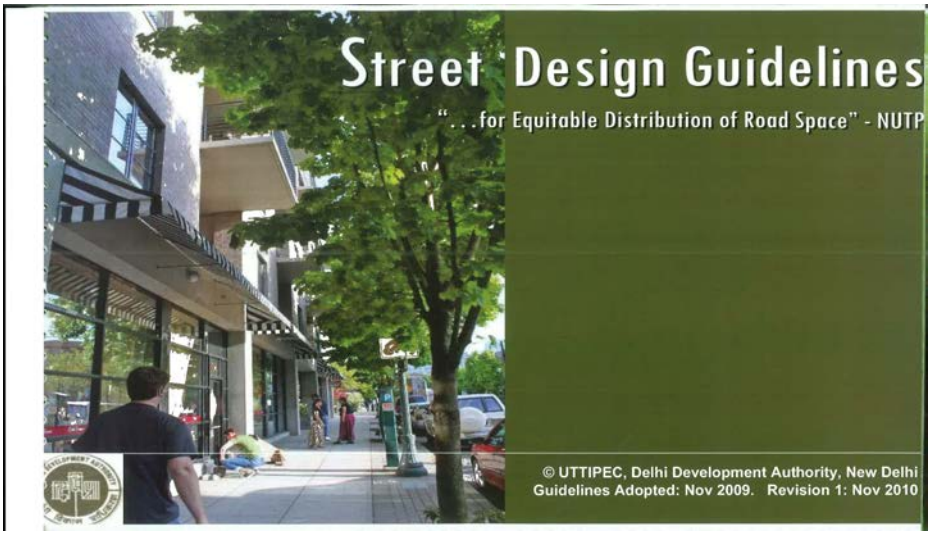
Bioswale : System for Storm Water and Dust Suppression Road Side

A biological filtration canal is a shallow depression created in the earth to accept and convey storm water runoff. A biological filtration canal uses natural means, including herbaceous vegetation and soil, to treat storm water by filtering out contaminants being conveyed in the water. Canals require shallow slopes that drain well, and function best under light to moderate runoff conditions.

Purpose: Storm water treatment and management, road side pollutant removal (SPM, suspended solids, nitrogen, phosphorus) by vegetation uptake, vegetation slows flow down and encourages sedimentation, cleans water and air by biota consumption, encourages infiltration into the subsurface zone, which reduces flow volume. Optimum design of channel dimensions, longitudinal slope, type of vegetation, and use of check dams will improve pollutant removal rates.

Building construction/demolition codes need to be used with specific reference to PM control. **UTTIPEC design manual has been recently created by Delhi Development authority for uniform roadside, drains, footpath and related design.** The same should be adopted for all future design for roads and pathways. Road construction/repair uses wood for melting tar, this technology needs to be abolished as over a large period of time, emissions are high.

Water spraying on the tires of trucks at the entry/exit point through construction of water pit. Appropriate barricading of the under construction site to avoid dispersion of the dust and particulate matter in the ambient air.



The Construction and Demolition (C&D) Waste Management Rules, 2016 was notified vide G.S.R. 317(E) 29th March, 2016 by the Ministry of Environment, Forest and Climate Change (MoEF&CC). building materials, debris and rubble resulting from construction, re-modeling, repair and demolition of any civil structure which delineated specific guidelines for waste generator, Service Provider and their Contractors, Local Authority, State Pollution Control Board or Pollution Control Committee, State Government or Union Territory Administration, Central Pollution Control Board and Criteria for Site Selection for Storage and Processing or Recycling Facilities for Construction and demolition Waste.

A) National Clean Air Programme (NCAP)

A time-bound national level strategy, National Clean Air Programme, was launched by Government to tackle increasing air pollution. The NCAP is envisaged to be dynamic and will continue to evolve based on the additional scientific and technical information as they emerge. Some of the measure and technologies developed for control of air pollution under NCAP are as follows.

Dust management

- Road dust and dust arising from construction and demolition are the major contributors to the pollution in Indian cities. City specific Plans need to evaluate the options of mechanical sweeping, greening and landscaping of the major arterial roads, identification of major impact roads including national high ways etc. Spraying of water twice per day (before peak hours of traffic) is very effective in reducing air borne dust load. Grassing of open spaces with native grasses also prevent dust pollution and clean air.

The mechanical sweepers were introduced in Delhi as manual sweeping by brooms blow more dust particles in air than it cleans off the ground. There is no proper mechanism or standard operating procedure (SOP) on how to dump the dust collected so that they don’t return to the city after disposal.

- The Government has notified Construction & Demolition Waste Management Rules, 2016 which had been an initiative towards effectively tackling the issues of pollution and waste management. Basis of these Rules is to recover, recycle and reuse the waste generated through construction and demolition. Segregating construction and demolition waste and depositing it to the collection centres for processing is now be the responsibility of every waste generator. Local bodies are to utilize 10-20% material from construction and demolition waste in municipal and government contracts.
- It was noted that there was no regulation prescribing preventive measures to be taken for management of dust including road dust and C&D dust that arises during construction. Taking note of increasing air pollution and to keep dust material under control in towns and cities, the Ministry of Environment, Forest and Climate Change has issued a Dust Mitigation notification in January 2018 under EPA, 1986; making mandatory dust mitigation measures in infrastructural projects and demolition activities in the country. This would help to keep dust under control to reduce air pollution in metros and cities. The notified rules inserted 11-point

measures in the existing Act, empowering the ministry to issue notices against local authorities and state agencies for non-implementation of those actions.

Way Forward

- Introducing mechanical sweepers on the basis of feasibility study in cities;
- Evolve SOP for addressing the specific issue of disposal of collected dust from mechanical sweeping, taking into consideration all the above cited factors;
- Stringent implementation of C&D Rules, 2016 and Dust Mitigation notification, 2018 of Government of India;
- Wall to wall paving of roads to be mandated.
- Control of dust from construction activities using enclosures, fogging machines, and barriers-stringent implementation.
- Greening and landscaping of all the major arterial roads and national highways after identification of major polluting stretches.
- Maintenance and repair of roads on priority.
- Sewage Treatment Plant (STP) treated water sprinkling system having PVC (Polyvinyl Chloride) pipe line along the roads and at intersecting road junctions and spraying of water twice a day before peak traffic hours.

B) Dust Mitigation Notification by MoEF-CC

Ministry of Environment, Forest and Climate Change vide notification dated January 25, 2018 has amended the Environment (Protection) Rules, 1986. Vide this amendment in Schedule-I –New serial number '106' has been inserted which relates to Mandatory Implementation of Dust Mitigation Measures for Construction and Demolition Activities for projects requiring Environmental Clearance:

- No building or infrastructure project requiring Environmental Clearance shall be implemented without approved Environmental Management Plan inclusive of dust mitigation measures.
- Roads leading to or at construction sites must be paved and blacktopped (i.e. metallic roads).
- No excavation of soil shall be carried out without adequate dust mitigation measures in place.
- No loose soil or sand or Construction & Demolition Waste or any other construction material that causes dust shall be left uncovered.
- Wind-breaker of appropriate height i.e. $1/3^{rd}$ of the building height and maximum up to 10 meters shall be provided.
- Water sprinkling system shall be put in place.
- Dust mitigation measures shall be displayed prominently at the construction site for easy public viewing.

New serial number '107' has been inserted which relates to Mandatory Implementation of Dust Mitigation Measures for all Construction and Demolition Activities:

- Grinding and cutting of building materials in open area shall be prohibited.
- Construction material and waste should be stored only within earmarked area and road side storage of construction material and waste shall be prohibited.

- No uncovered vehicles carrying construction material and waste shall be permitted.
- Construction and Demolition Waste processing and disposal site shall be identified and required dust mitigation measures be notified at the site.

The serial numbers 106 and 107 above shall apply to cities and towns where value of particulate matter 10/ particulate matter 2.5 exceeds the prescribed limits in National Ambient Air Quality Standards

Use of Ready Mix Concrete

The Ready Mix Concrete (RMC) industry in India is still in its early stages with cement consumption of just 8-9 per cent of total production. This is evident from the fact that in the West, the RMC consumes 60 per cent of total cement production. However, over a period of time the demand for RMC is expected to grow exponentially. Godrej is a part of the Ready Mix Concrete Manufacturers Association (RMCMA) and actively participates in preparing guidelines for helping penetrate the use of RMC through forums and discussions. Use of RMC leads to time and cost efficiency since the construction does not need additional space to store the concrete. Since only the right amount of concrete mix is delivered hence it results in no wastage and reduces dust, dirt emissions. Godrej supplies range of ready mix concrete and sold under the brand name of TUFF. This mainly includes products like Enviro TUFF eco-friendly concrete, Recycled concrete blocks, Solid recycled concrete, Poro TUFF pervious concrete. These blocks are mainly made from industrial byproducts.

Autoclaved Aerated Blocks have also been introduced in Indian Market. These are manufactured by using fly ash mixed with cement, lime, water and an aeration agent placed in an autoclaved chamber. Godrej has introduced Autoclaved Aerated Blocks under the brand name of TUFF blocks AAC. As per the company's claim, TUFFBLOCKS AAC decreases over 50% greenhouse radiation & integrated energy and utilizes at least 70% environmental waste.

Annexure – V

Wind Augmentation and purifYing Unit (WAYU)

‘Wind Augmentation and purifYing Unit (WAYU)’

The air quality at traffic intersections is one of the worst as vehicles typically undergo long idling, acceleration and deceleration there. This increases the quantity of air pollutants emitted by the vehicles at intersection. A numerical emission model run by Margarida et al. (2005) estimate an increase of 34%, 105% and 131% in NO, HC and CO emissions, respectively due to traffic signals at vehicular intersections.

India has experienced substantial increases in vehicle miles traveled (VMT) in recent years. The increased traffic has resulted in increased pollutant emissions and the deterioration of environmental quality and human health in several major cities in India. Pollutant concentrations near major intersections and roadways in the city are exceeding the Indian national ambient air quality standards (NAAQS). Thus, users (motorists, pedestrians, residents, etc.) in these corridors are exposed to unhealthy pollution levels. Exposure to vehicular air pollution directly affects respiratory, nervous and cardiovascular systems of humans, resulting in impaired pulmonary functions, sickness, and even death.

People standing stagnantly at a position, or moving slowly than usual average walking speed is more exposed than people passing by, because the time spent in a polluted microclimatic environment is much more, which increases the cumulative exposure to pollutants. As pedestrians pass by several types of human activities present on or beside sidewalks, they are affected by the pollution emitted by those activities. The breathing rate becomes factual in calculation the dose from exposure, and adds to the cumulative intake of air pollutants.

IIT Bombay, National Environmental Engineering Research Institute (NEERI) and Maharashtra Pollution Control Board (MPCB) have come together to address the issue of air pollution at traffic junctions. A device known as ‘Wind Augmentation and purifYing Unit (WAYU)’ to improve the air quality at urban intersections has been developed and integrated in a way that it can work with solar power. This device works basically on two principles:

- Wind generation for dilution of air pollutants
- Active Pollutants removal

Air pollution is a local problem and its solution can be derived from technologies coupled with local conditions and requirements. Creating change in meteorological parameters like wind with the help of devices such as fans and also removal of the pollutant near to the source may help in reducing ambient air pollutant concentrations. Creating turbulence in the air with the help of turbo machines will disperse and dilute the pollutants. Trapping the pollutants with the help of suction units installed near to the source and purifying it will also have a sizable amount of impact. This can be done where the population density is high which is typically found in India near the traffic junctions.

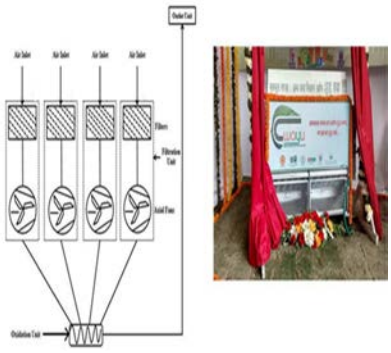
The device uses low speed wind generators, appropriate size filters for long operation cycle with reasonable efficiency. It also has an oxidizer unit for removal of Carbon-monoxide and Hydrocarbons including VOCs. The air is passed through the filters where the particulates are removed. The air generators without filter can help in augmenting wind turbulence in near zone so that dilution takes place (like in nature).

In the next level where active pollutants are removed, filters and thermal system are used. The air is heated inside the specially designed with appropriate surface and retention time, within the thermal oxidisers where the carbon monoxide, hydrocarbons, VOCs get converted to carbon dioxide. At the outlet of the device, the discharged air has some exit velocity. This velocity of air creates air mixing and turbulence in the atmosphere which thereby helps bringing down the pollutant concentrations by the method of dispersion.

The WAYU device has a potential to lower the ambient concentrations of PM and VOCs by 50-70%.The effectiveness and influence zone of the WAYU device can be affected by the prevailing wind conditions. During the various experiments conducted was conducted inside closed boxes of various sizes, it was observed that the pollutant concentrations decreased rapidly by 90-95% within 15 minutes. The device can be powered with the help of solar power very efficiently. In this way the device becomes self-sustainable in its operation.

The primary treatment consists of filters of 10 microns and which is followed by oxidation systems. The oxidation systems consist of specially designed UV- TiO_2 adsorption, photo catalytic oxidation technology. In brief this technology can be explained as follows. Small particles of titanium dioxide (TiO_2) act to catalyze oxidation of adsorbed molecules in the presence of above-bandgap ultraviolet light (UV, wavelengths smaller than 390 nanometers). The particle size is usually in the range of 5 to 50 nm. The absorption of UV light produces electron-hole pairs in the titanium dioxide particles. The hole reaches the particle′s surface to react with hydroxyl (OH-) ions from adsorbed surface water and

form highly reactive hydroxyl radicals. These radicals form when an OH- group loses its electron during an encounter with a hole. They are electrically neutral but highly reactive chemically. Airborne pollutant molecules can be adsorbed on the TiO_2 particle surface, at which time they react with adsorbed hydroxyl radicals. Ideally, reaction products remain on the surface until they are fully oxidized. The process just described represents the essence of catalytic photo-oxidation, but it should be understood that variations on this theme are encountered.



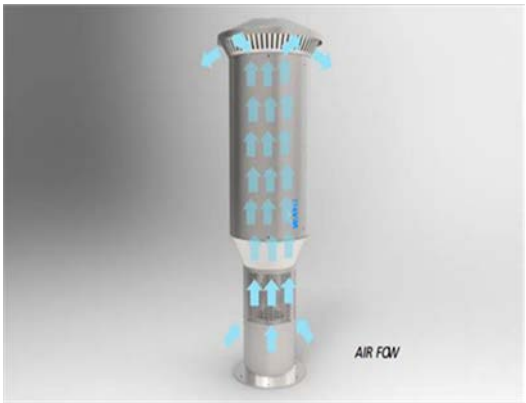
UV- TiO2 adsorption-photocatalytic oxidation has a lot of advantages. They are very efficient in removal of VOCs. Pichat et al. (2000) have shown that ozone can be directly eliminated by TiO_2 nanoparticles in a process that is promoted by both heat (in the ambient temperature range of 0° to 50°C) and by UV light. The catalytic activity of present-day TiO_2 anatase nanoparticle materials is sufficient to remove some VOCs from the air. Both the components of smog (ozone and particulate matter) are the result of emission of VOCs that can potentially be reduced by the active photocatalytic oxidation technology under consideration.

The unique design of the arrangement of the various components of the UV-TiO_2 activated carbon gives WAYU the edge for performing complete oxidation and satisfactory reduction in VOC concentrations.

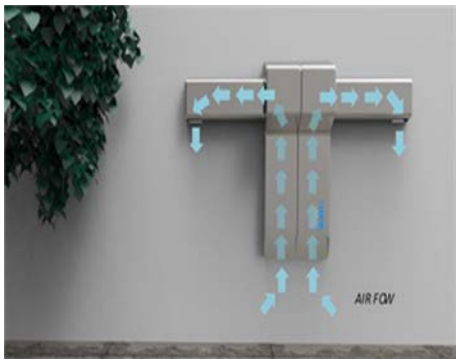
WAYU is a device jointly developed by IIT-CSIR-NEERI focused on controlling pollution in ambient air. WAYU has been successfully tested in a pilot project of 25 devices in Mumbai in collaboration with Maharashtra Pollution Control Board (MPCB). With an aim to solve the ever rising menace of air pollution in the national capital and other parts of India, CSIR-NEERI believes WAYU would be a vital cog in the armory to combat this menace.

Different Models

WAYU comes in various shapes and sizes. Various designs have been incorporated to suit according to different scenarios. These include improved design for traffic junctions, Bus shelters, traffic roundabouts, wall mounted models for flyover pillars, pedestrian pathways. In the scenario of Flyover pillars play a vital role. So a



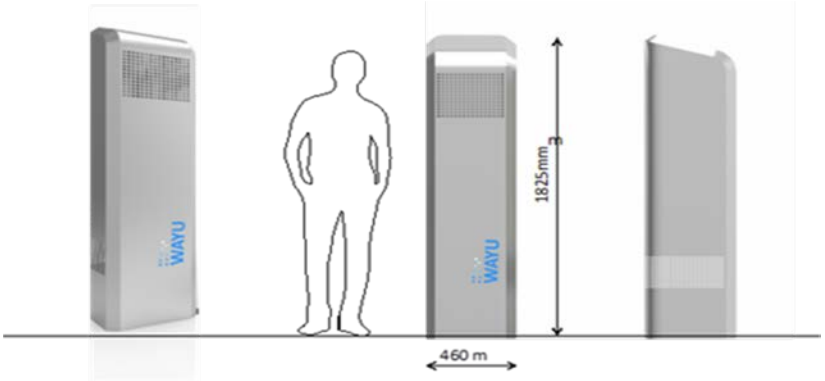
WAYU device improved design



Wall mounted/ Flyover Design

design which could be wall mounted was ideated. The design basically consists of a blower fan at the main extrution where the air is sucked at the bottom of the extrution and thrown to the right or left of the outlet which consists of linear activated carbon trays. These trays could be easily accessed from the front and could be changed once in a month. Here there are two UV tube lights which are basically of one feet and has been placed vertically in particular intervals to attain maximum level of treatment. The air is sucked from the bottom at 625mm height and the purified air is pushed out at 1825mm.The modularity of this concept leads to a futuristic look with stainless steel as its material used. Here the form could be easily manufactured because of its minimal bending profiles.

The design initiation started with the scenario of pedestrian was there is a constant flux of people moving around the environment. The design was finalized at a space that is closer to the road & the pedestrian paths were the Unit would be placed. The standalone device is of approximate 1825mm. The overall design is made in a very similar minimal approach with small continues chamfers which could be manufactured easily with stainless steel and laser cut technologies. There are three two- feet UV tube lights, which is been attached to the phases of the unit.



Bus shelter design

Traffic Roundabouts design

At Bus shelters stand-alone modules should be vital phase. Since each bus shelter has different design of the shelter we arrived at a very minimal

half T -Section stand-alone module which could be fixed and two or one end of the bus stop. The air is sucked form a particular height and released from the top as shown in Figure 18.The overall dimensions were optimized for the easy accessibility of activated carbon filters and UV Tube light. This is a purifier, which could a public installation. The roundabouts are spaces where the vehicle – people ratio is very high. The design added in new features like an additional solar panel, which could make the standalone device run itself.

A polygon was taken in consideration, the octagon was chosen initially for the design as the bottom inlet could capture all the polluted particles and left out as clean air through the top. An extruded octagon was considered which could gradually reduce at the bottom too look like a tree. The inner details of this purifier are mainly three phases as the air purifier which is prototyped with cassettes at each sides. These trays would be filled with activated carbon and there is four feet tube lights at the center. The polluted air is sucked from the bottom and released at the top. This is a self-sustainable standalone device which requires no Power.

Why WAYU?

WAYU has the following advantages:

- Relatively cheaper than most devices in market for similar purpose
- Low power consumption facilitating the use of solar power
- Easy operation and maintenance
- Removes gaseous pollutants along with particulate matter unlike most of the devices which focus only on particulate matter
- Can be easily modified to suit any scenario and volume of air
- A range of designs in its portfolio makes it an attractive option for solving air pollution in spaces of all kinds
- An indigenously developed technology that propels MAKE IN INDIA initiative

Though commercial data for similar devices are not available, it is quite confidently estimated that the cost of per unit of WAYU is one of the cheapest devices for ambient air pollution control. The basic advantages besides the ones listed above include simplicity in construction and operation. The ability to couple with different energy sources such as solar make WAYU commercially a very viable option. With thoroughly tested technology WAYU is one of the most robust air purifiers that can be installed in both indoor and outdoor spaces. Aesthetically designed WAYU blends into the ambient environment and thus is not an eye-sore unlike other devices.