Draft Interim Report

Air Quality and Emission Source Apportionment Studies for

Ten Cities of Maharashtra

NASHIK CITY

Maharashtra Pollution Control Board

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FIGURE

Chapter 1

1.1. Preamble

Nashik city is situated on the banks of Godavari River, making it one of the holiest places for Hindus all over the world. Nashik has a rich historical past, as the mythology has it that, Lord Rama, the King of Ayodhya, made Nashik his abode during his 14 years in exile. At the same place, Lord Laxman, by the wish of Lord Rama, cut the nose of 'Shurpnakha' and thus city was named as 'Nasik'. Nashik is city of mythological, historical, social and cultural importance.

Nashik, the Headquarter of Nashik Administrative Division (comprising of Nashik, Ahmednagar, Nandurbar, Dhule and Jalgaon districts), is situated about 180 Kms; from Mumbai by the National Highway No.3, i.e. Mumbai- Agra Road which passes through the developed part of the city, while National Highway No. 50, i.e. Pune-Nashik road enters the city from Nashik-Road side and meets the Agra road near Dwarka Square. Nashik City lies on both side of the river Godavari, Panchavati lying across on left bank with Tapovan on side of it & the old Nashik on right bank. The main functional areas of the city are, the Nashik core area (the Nucleous), Satpur, Ambad Industrial areas and the second functional area is the Nashik–Pune road area with Nashik-Road railway station, supported by the industrial activities at Eklahara Thermal Power Plant, Railway Traction Factory etc. Satpur Industrial area is towards west. The MIDC Satpur Industrial Estate is mainly responsible for industrial and commercial growth of Satpur area. The Civic Administration area of 267.48 square kilometer (26747.75 hectares) is managed by Nashik Municipal Corporation.

1.2. Population

On the basis of 2011 census figures, the population density of Nashik Municipal Corporation is 5556 persons per sq. km. The municipal corporation is divided into 61 wards. The highest gross density of 250.13 persons per hectare is in village Kamathwade. The lowest gross density of 4.22 persons per hectare is in village Dadhegaon. It is a fast developing area and has tremendous development potential in view of its advantageous situation of being located in Mumbai-Pune-Nashik Golden Triangle. This has made Nashik city an ideal place for location for new industrial and commercial establishments. As per the 2011 census, the total population of the entire area of Nashik Municipal Corporation, was 14,86,053 souls as against the 2001 census population of 10,77,236 souls, indicating the growth rate of 37.95% during 2001-2011 decade. Similarly, population for 1991 was 7,33,000 souls indicating decadal growth of 46.96%.

1.3. Climate

The climate in Nashik is quite pleasant and moderate. The year in Nashik could be divided into four seasons. The cold season from December to February, followed by the hot season from March to May and the monsoon from June to September followed by the post monsoon season during October to November. The annual average rainfall is around 600 to 700 mm, the maximum reported in June and July months. The minimum Temperature reported in January around 4-5^{0}C and maximum in May around 45-40 ^{0}C. The area is very humid during the south- west monsoon season. In the post monsoon, in cold and summer season, air is generally dry. The summer season is the driest period of the year with relative humidity between 30 and 35 % in the afternoons. The sky is heavily clouded during the monsoon season. During rest of the year, the sky is mostly clear or lightly clouded.

The winds are generally light to moderate with some strengthening in the wind force during the latter part of the summer season and in the monsoon season. In the post monsoon season, winds are light and variable in direction, north easterly in the morning and easterly in the afternoon. In the cold season, winds blow from directions between south- west and north-west in morning and between north and east in the afternoons. In the hot season, winds are from directions south-west and north-west. Some of the storms and depressions from the Arabian sea in the latter half of summer and post monsoon season affect the area causing widespread rain. Thunderstorms occur in the latter half of the hot season and in the post monsoon season.

Chapter 2

2.1. Status of Air Quality

In Nashik district MPCB is carrying out monitoring at 8 different locations viz. (Residential : Old BJ Market, Girna Water Tank, RTO Colony, NMC Nashik and SRO Office), (Industrial : MIDC Jalgaon and MIDC Satpur) and one at Nashik CAAQMS station. The annual averages of criteria pollutants with respect to NAAQM Standards are presented in **Figure 1 a to d**.

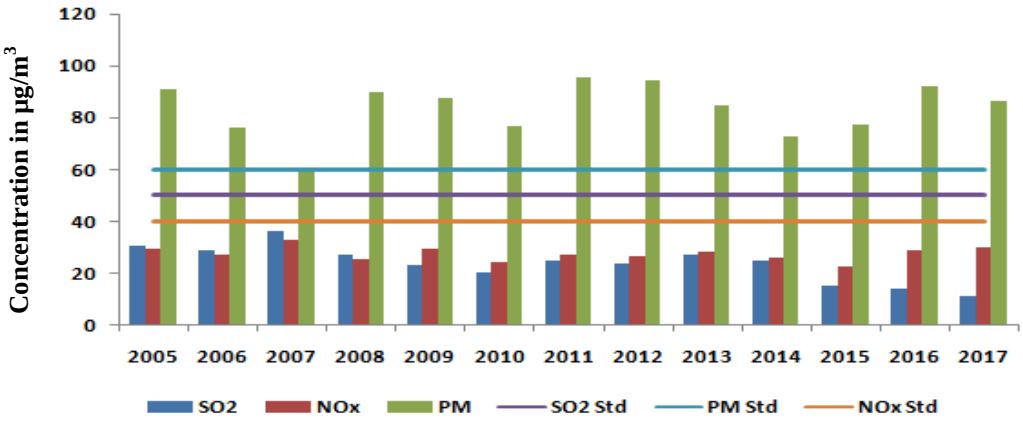


Figure 1a : Trend of Annual Concentrations of Criteria Pollutant in Nashik City

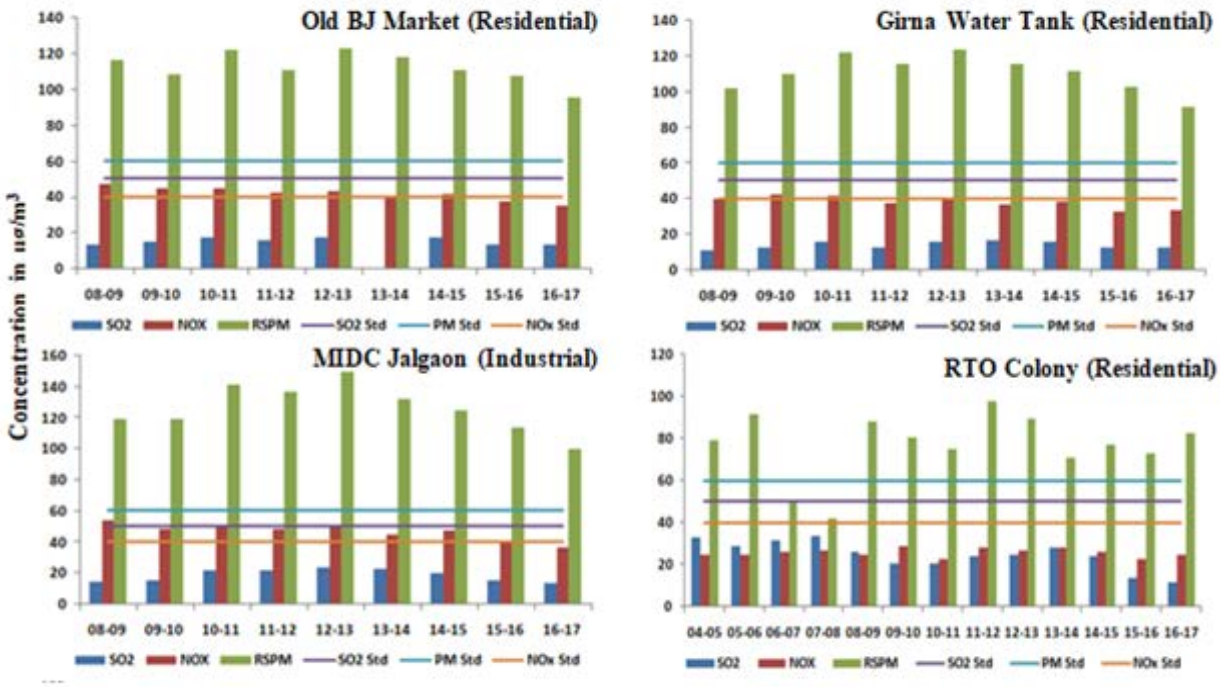


Figure 1b (Contd..) : Trend of Annual Concentrations at Different Monitoring Locations in Nashik City (MPCB Sites)

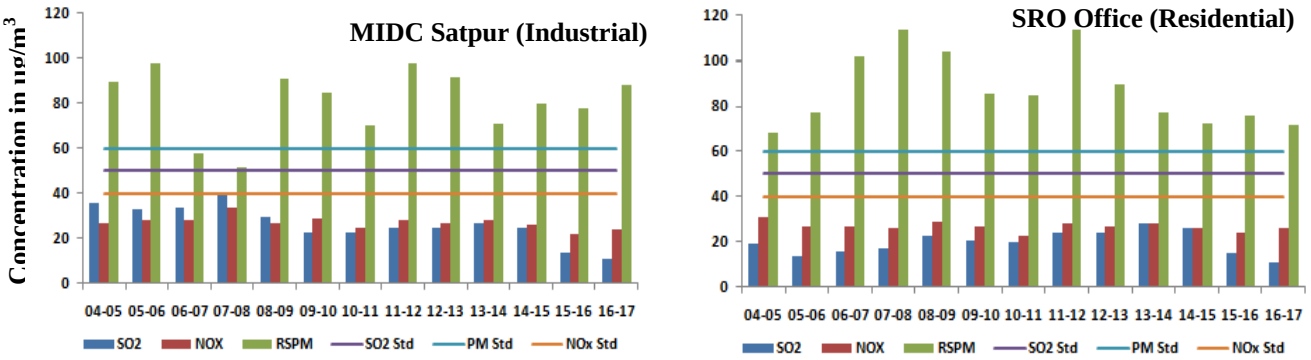


Figure 1b (Contd..) : Trend of Annual Concentrations at Different Monitoring Locations in Nashik City (MPCB Sites)

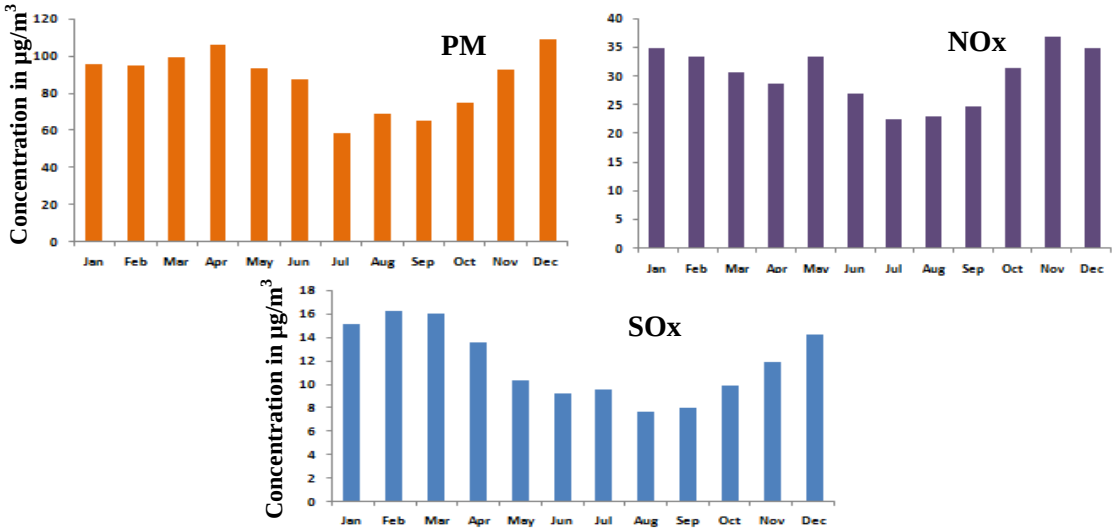


Figure 1c (Contd..) : Monthly Variation Trends for PM_{10}, SOx, and NOx (2017)

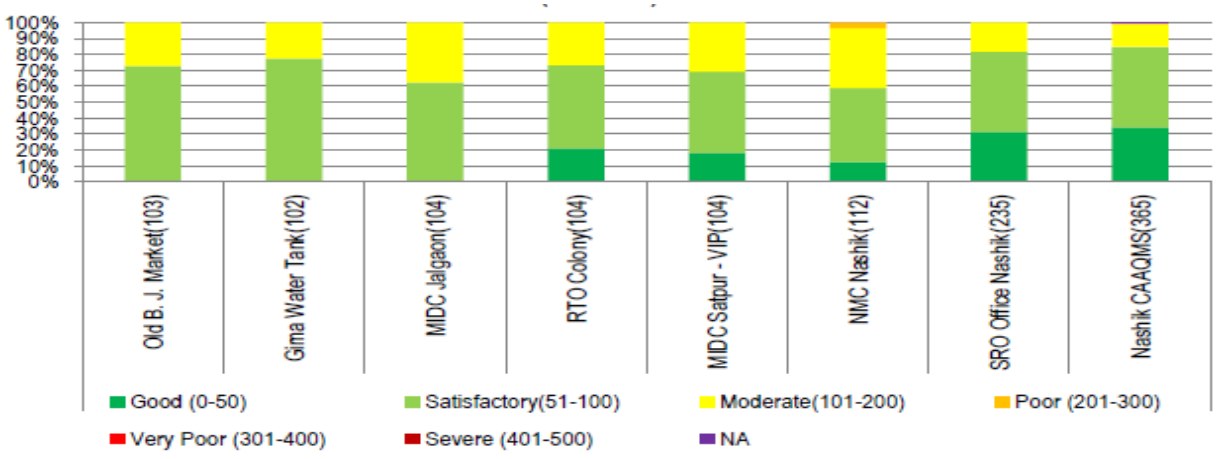


Figure 1d (Contd..) : Percentage Occurrence of Composite AQI of AQQMS in Nashik (2016-17)

In recent report was prepared by TERI -'Air Quality Status of Maharashtra' during 2016-2017 shows that the PM concentration of Nashik City is around 115 to 150 µg/m3, which is higher than the CPCB standards of 100 µg/m3, as the vehicular and industrial impacts are more. While the NOx concentrations were below the annual standard, the concentration ranges for NOx is around 30 to 40 µg/m3. The overall low concentration of SO2 is observed at Nashik city, ranging from 15 to 20 µg/m3. The decadal annual averages from 2004 to 2017 of RSPM at residential sites shows that, the concentration of 90 to 120 µg/m3 for RSPM, whereas for NOx it was 30 - 50 µg/m3 and for SO2 it gives 20-30 µg/m3. Among them Old BJ Market, Girna Water Tank and SRO Office are represent as higher concentrations. The industrial site MIDC Satpur and Jalgaon, the RSPM ranging from 98-150 µg/m3, similarly NOx moves around 30-50 µg/m3 and SOx gives 20-40 µg/m3. Average AQI represents around 30% as moderate and 40% are satisfactory for the Nashik City. The overall reduction of pollutant was observed after monsoon (July to September) and it was higher at winter.

Chapter 3

3.1. Emission Inventory

As the city is overwhelming expanding and population and vehicular growth is increasing day by day. The identification of pollutant loads and to prepare the strategic action for plan for controlling them is the need of the hour. 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 Nashik city for accurately identify and quantify emissions from different sources. Emission inventory has been prepared in terms of five major pollutants, viz. PM_{10}, SO_2, NOx, CO and HC. City emission loads from various sources are presented in **Table 1**.

Table 1 : Nashik City wide Emission Load from All the Sources

Sector	PM	%	NOx	%	SOx	%	HC	%	CO	%
Bakeries	44.8	0.12	4.1	0.01	1.8	0.11	286.0	1.12	317.8	0.04
Hotels	27.9	0.08	11.6	0.03	26.8	1.64	1.1	0.00	49.2	0.01
Open Eatout	3.2	0.01	4.4	0.01	1.3	0.08	0.5	0.00	2.4	0.00
Crematorium	130.6	0.36	17.8	0.05	3.3	0.20	865.7	3.37	962.7	0.12
Slum - Domestic	193.4	0.53	55.5	0.14	60.6	3.70	743.5	2.90	930.2	0.11
Non Slum-Domestic	689.2	1.88	317.9	0.82	68.9	4.21	2320.7	9.05	2587.8	0.32
Open Burning	186.9	0.51	70.1	0.18	11.7	0.71	502.4	1.96	981.3	0.12
Building Const.	3330.9	9.07								
Total Area (A)	**4606.9**	**12.55**	**481.35**	**1.24**	**174.39**	**10.65**	**4719.78**	**18.40**	**5831.39**	**0.72**
Red LSI	12397.1	33.77	9210.0	23.79	828.6	50.60	11966.2	46.65	722522.8	89.20
Red MSI	122.9	0.33	216.2	0.56	38.6	2.36	216.0	0.84	3045.3	0.38
Red SSI	212.0	0.58	156.2	0.40	65.5	4.00	1131.8	4.41	16722.6	2.06
Orange LSI	347.8	0.95	736.1	1.90	154.4	9.43	43.6	0.17	5302.7	0.65
Orange MSI	120.4	0.33	14.3	0.04	6.5	0.40	687.2	2.68	11590.9	1.43
Orange SSI	173.5	0.47	50.9	0.13	29.1	1.78	1091.2	4.25	16314.2	2.01
Green LSI	13.9	0.04	245.2	0.63	248.0	15.15	4.4	0.02	23.3	0.00
Green MSI	0.4	0.00	27.8	0.07	14.6	0.89	0.9	0.00	5.2	0.00
Green SSI	71.0	0.19	80.7	0.21	77.4	4.73	440.9	1.72	6534.6	0.81
Total Point (B)	**13459.0**	**36.67**	**10737.5**	**27.73**	**1462.6**	**89.32**	**15582.2**	**60.75**	**782061.6**	**96.56**

Table 1 (Contd..) : Nashik City wide Emission Load from All the Sources

Sector	PM	%	NOx	%	SOx	%	HC	%	CO	%
Car_Petrol	4.4	0.01	198.1	0.51	0.011	0.0007	264.1	1.03	1848.7	0.23
Car_Diesel	3.9	0.01	58.0	0.15	0.013	0.0008	20.7	0.08	15.5	0.00
Car_CNG	0.8	0.00	75.8	0.20			59.6	0.23	7.8	0.00
2 Wheelers	42.7	0.12	493.3	1.27	0.004	0.000268	1710.0	6.67	2367.6	0.29
3 wheelers	128.5	0.35	206.8	0.53			2242.5	8.74	751.1	0.09
HDDV	3528.8	9.61	26465.8	68.36	0.488	0.0298	1052.9	4.10	17074.7	2.11
Total Line (C)	**3709.0**	**10.10**	**27497.8**	**71.02**	**0.52**	**0.0315**	**5349.8**	**20.86**	**22065.5**	**2.72**
Paved Rd. Dust	**2805.8**	**7.6**								
Unpaved Rd. D.	**12125.9**	**33.0**								
Total of Resuspension Dust 14931.7 kg/d (40.7 of Total PM)										
Total (A+B+C) Kg/day	**36706.6**		**38716.7**		**1637.5**		**25651.8**		**809958.5**	
Total Tons/Yr.	**13397.9**		**14131.6**		**597.7**		**9362.9**		**295634.9**	

** Values of Concentrations are in kg/d*

Percent contribution of pollutant due to different source categories for PM and NOx and percent distribution of all pollutant is presented in **Figure 2.**

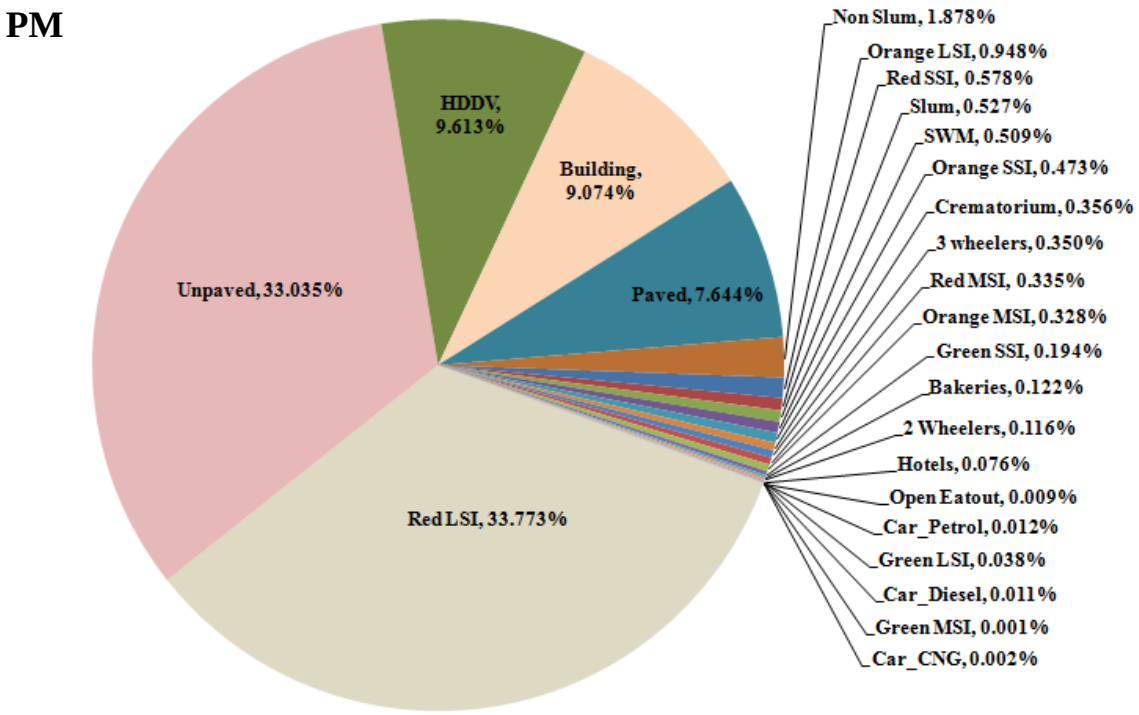


Figure 2 : Percent Contribution of PM from Different Sector in Nashik

NOx

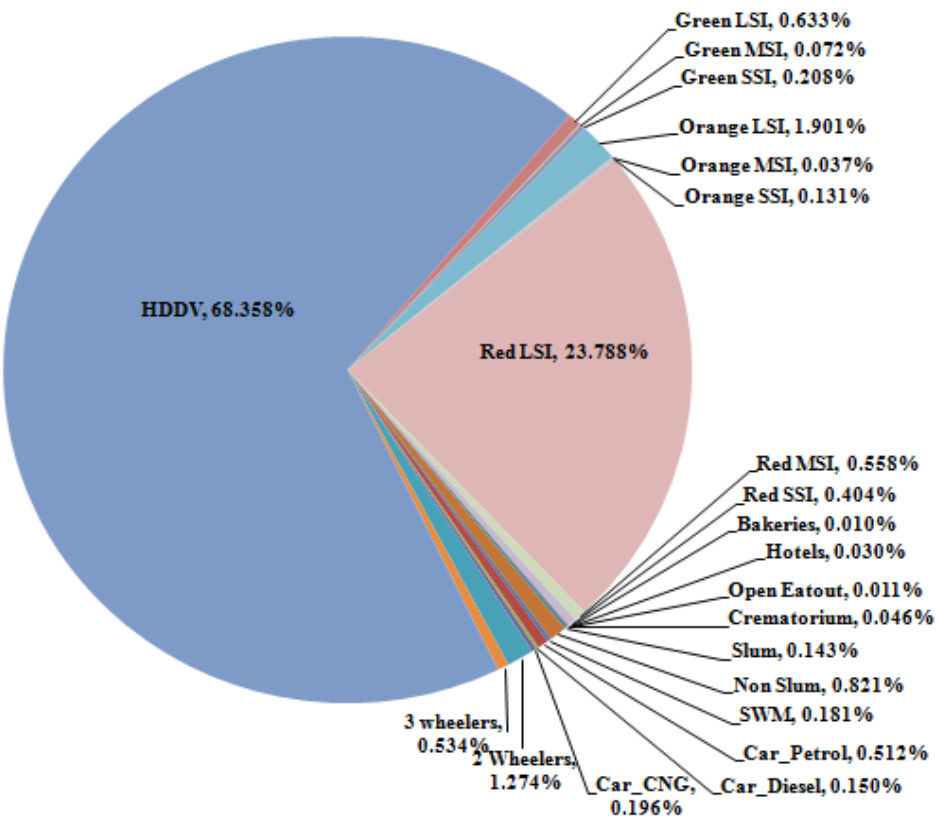


Figure 2b : Percent Contribution of NOx from Different Sector in Nashik

Chapter 4

4.1. Action Plan for Control of Air Pollution

The action plan presented 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

Area sources are mainly domestic sources of fuel (coal, wood, kerosene, LPG) burning, trash/MSW combustion, bakeries, hotels/restaurants etc. and resuspension of dust. Based on the survey and assessment, following recommendations emerge to curb area source emissions:

- From the data provided by Mahangar gas, Nashik region had been supplied with around 62.5 TMT of packed LPG. Consumption of solid fuel is high in Nashik, which contribute to the emission on a large extent. Fuel Gas Organizations and ULB should take initiative to sensitize people from the slum and non-slum to make the shift from conventional domestic fuel (LPG, Kerosene, wood). Provision of PNG should also be explored. HPCL is enhancing its storage capacity of Existing LPG bottling Plant from 1390 MT to 2000 MT at Nashik LPG Plant, Malegaon MIDC Industrial area Sinnar. The distance between project site and Nashik city is 25 KM which will be helpful for domestic fuel supply.
- The data for the usage of domestic fuel in slum and non-slum area is not readily available. Inventorization of LPG quantity from supply agencies should be maintained.
- Nashik being a tourist attraction place, there is increase in number of hotels and dhabas along the highways. On survey it was found that there were 392 registered hotels in Nashik region with consumption of LPG of 2140 kg/day and coal around 1.4 Ton/day. These hotels and dhabas should be regulated to use LPG for its cooking purposes. Traditional wood/coal based tandoors of restaurants as fuel should be replaced by LPG/electrically operated tandoors.
- Similarly usage of LPG by small hotels/ restaurants and roadside tea /snack stalls should also be encouraged. Subsequent concession should be provided. 620 eat out found in survey had fuel consumption of 1698 Kg/day of LPG and 40 kg/day of coal, respectively.
- No license is issued to the hawkers on prominent roads. Instead the licenses are given to them where there is low traffic. The strict vigilance from time to time is necessary to observer whether rules are followed or not.
- Permission must be granted in the vacant places in residential areas, so that they do not cause disturbance on the road.

- With 53 bakeries in the region, the emissions from the stacks of bakeries should be regulated and emission control devices such as bag filter, scrubbers etc should be installed. These bakeries can be made to operate on electric or LPG.
- There are around 25 wood operated crematorium under NMC jurisdiction. For increasing population, existing facilities of cremation and burial ground is not sufficient. All crematoria should be installed with efficient pyres and chimneys for release of emissions. Bodies related emissions from the pyre can be reduced by installing efficient PM control measures such as bag filters or cyclones. Further, a study involving usage of LPG burners in closed furnace like electrical crematoria may be explored as substitute to existing practices.
- Building construction / demolition codes need to be formulated with specific reference to PM control. There were around 214 new building constructions and alteration activities being carried out all over the region in 2017, which emitted PM load of 3.3 ton/day in the region.
- Operational measures to be made compulsory and building permissions should be revoked if the norms are not met by the organization.
- There is Poor pedestrian infrastructure in Nashik. RUBs / ROBs / Footpaths, Pedestrian crossing etc. are necessary for proper transport system. Provision should be made from Corporation with appropriate fiscal measures.
- In all there are existing 144 gardens, having area 98.87 hectares. Out of which 22 are of bigger size. This works out to be 0.58 sq.m. per person which is less. There are 32 playgrounds having 64.21 hectares area out of which 17 are of bigger size. This works out to be 0.38 sq.m. per person which is less. Green Belt Development can be done along the banks of river with provision of cycle track and recreational spots. For the population of 2026 year, total 49 sites for park are necessary.
- Open Trash Burning is common in Nashik, especially in the season of winter. NMC should take required regulatory measures to abolish the practice of open burning of waste within the city.

The Nashik Municipal Corporation is collecting about 501 MT of municipal solid waste per day. All the waste from different areas are collected and transported to MSW facility at Pathardi which is 15 km from core area. The bio hazardous waste generated by hospitals in the city is treated at 1000°C in an incinerating plant located near Kannamwar Bridge (near core area). With better collection and transportation measures, the collection efficiency should increase. It is estimated that the projected quantity of municipal solid waste will be 1200 TPD by the year 2031. The present emission load from area source is around 4606.9 kg/day which contribute 12.5% of the total emission load for Nashik city. With the implementation of the short and long term scenarios, the total reduction in particulate matter from area sources would be more than 37%.

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	50% of slums to use LPG/ PNG 75% abolishment of solid fuel use	100% of slum to use LPG/ PNG 100% abolishment of solid fuel use	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 Nashik region. Ensure proper ventilation reforms to be implemented in kitchens through periodic information dissemination of indoor air quality via seminars street plays and workshops.
Hotel & Restaurants	50% of coal/wood to be replaced by LPG	75% of coal/wood to be replaced by LPG	Around 1.5 tons of coal is being used daily by hotel and restaurants in Nashik. 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. 75% replacement of coal/wood consumption would bring down emission load of PM to7 kg/day and NOx to 2.9 kg/day.
Open Eat outs	Since these operations are illegal, they are difficult to quantify. An effective redressal system towards their total number and fuel consumption should be made.		If we restrict the activities with proper rehabilitation or their conversion from traditional fuels to clean fuels, then per unit /day reduction of PM- 1.62, and NOx – 3.22 kg/day can be achieved, considering emissions from 620 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	100% immediate and stringent redressal of open burning cases 100% control of Landfill burning events	Feasibility study for establishment of Waste to energy plant facility	It has been observed that the unaccounted or mismanaged waste from SWM system, often are reported into road side open burning cases. Nashik City region has a daily average SW generation of 501 MT, out of which 52.88% is bio-degradable and remaining is non-biodegradable. The maximum solid waste generation is from Panchavati division. The APMC accounts considerable amount of the total solid waste generated in the city. Assessing the demography, an efficient and strategic SWM plan should be implanted for the region. Also at the landfill site, surveillance facility and response team should be brought in place
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			

(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
Bldg. & Road Construction	50% control on dust emission	75% 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.
Paved & Unpaved Road Dust	Paving : 75% control on dust Unpaving: 15% of remaining road if any	Paving : 100% control on dust Unpaved : 100% of remaining road if any	85% 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. NMC should implement usage of mechanical sweepers for resuspension control activities such as frequent sweeping, sprinkling of roads and collection of dust. A strategic plan should be devised so as to cover larger area of region. This will help in effective management of manual sweeping labors in other activities and to cover areas which are inaccessible with vehicles. Feasibility study for road construction material that can be used in the region so as to control resuspension should be initiated. Local resources should be considered as priority.

4.3. Line Source

Presently, most public transport in Nashik comprises bus services operated by the Maharashtra State Road Transportation Corporation (MSRTC). The remaining trips are made via privately owned and operated shared autorickshaws. The public transport in the city is of substandard quality. Buses are overcrowded during peak hours and their speed is dropping by the day due to traffic congestion. As a result, the number of personal motor vehicles is growing at 7 per cent per annum. If this growth continues, The Institute for Transportation and Development Policy (ITDP) estimates that the number of trips made by personal motorized modes will double over the next 10 years. Accommodating this increase in personal motor vehicle use will be difficult. Even if all of Nashik's main roads are transformed to include elevated corridors on top, there won't be enough capacity to meet 2023 demand. Recently, Nashik Municipal Corporation has taken over the City Bus Service to control the increasing traffic problems.

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 Nashik 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 in below.

Looking into scenario the Regional Transport officer in collaboration with ULB and private and PPP entity should be directed to give information about the time bound strategy to control the vehicular pollution and traffic management for:

- Banning out-dated vehicles of age more than 15 years.
- P.U.C. check of auto-rickshaws to be done periodically and ensure that adulterated fuel is not being used. Remote Sensing technology can be utilized for PUC monitoring.
- The district has 319 petrol pumps, including 74 in the city. Oil companies such as HPCL, BPCL and IOC supply fuel, both petrol and diesel, through 200 tankers daily to pumps across the district. A single tanker includes fuel worth Rs 8 lakh on an average. Accordingly, the total fuel supply in the district is estimated at Rs 16 crore per day. Better quality fuel by adopting stricter fuel supply & dispensing system along with Chemical marker system to keep check on adulterations in fuel.
- Concession/ rebates by NMC for erection of CNG fuel. Conversion of existing public transport buses/tempos/mini buses to CNG fuel operation.
- The electrical countdown mechanism has to be implemented at major traffic intersections, which will help in switching on and off vehicles. Proper routing of the vehicles to avoid congestion.
- Adoption of standard emission regulation BS-V and BS-VI in line with EURO-V & EURO-VI for all categories. The benefit of BS-V and BS-VI in PM are 1% and 2.5% of total PM respectively. Similarly the NOx benefits with BSV and BSVI are 7.5 & 14.6%, respectively.
- Need to frame legislation for the Retro-fitment of new engine/Emission Control Devices (Diesel Particulate Filter (DPF) /Diesel Oxidation Catalyst (DOC) particularly to heavy duty vehicles that could help in major reduction of PM. Cost sharing and subsidy by the agencies will help in immediate provision.
- Hybrid buses can be introduced in fleet of Public buses. Biodiesel (B5/B10:5–10% blends) should be considered as a fuel option for public transport. Promotion of electric public transport. Battery Operated transport vehicles providing point to point service can also be initiated.
- I&M (Inspection and Maintenance) of old vehicles: Promotion of proper maintenance of vehicles. Use of 2T oil in excess is to be avoided. All private vehicles should be subjected to proper assessment and fitness tests through I&M centres. All autos and buses shall also be subjected to I&M tests Implementation of penalties should be laid on vehicles if found exceeding the emission limits. Set up a mechanism of Inspection and Maintenance programme for all vehicles in the district through RTO with automated system assessment. The I &M center should also test all vehicles for their in-built emission tests.

- In 2013, the total numbers of buses were 241 which used to ply on 508 different routes, covering route of 7728.4 Kms. The number of passengers handled by the bus system at that time was near-about 145000 per day out of which 45000 are students. But these bus numbers are brought down to 110 in 2018. Apart from state transport, there is huge dependence on 3 wheelers and private vehicle aggregators for intermediate point transport within the city.
- Management of Intermediate Public Transport - IPT (auto rickshaws / shared auto rickshaws / taxis) can be done considering the travel demand management. Widening of roads approaching towards mass transit stations.
- Prepare a traffic dispersal model for efficient mobility and Mass Rapid Transit connectivity. Facilitate safe and convenient movement for pedestrian (Subways/ FOBs/ Footpaths including Skywalks).
- As per the provisions of 73 (3), Central Govt. can restrict and limit number of contract carriers in the cities / towns were heavy population is not less than 5 lakhs. Accordingly, Maharashtra Govt. has issued notification restricting number of contract carriers in the city of Mumbai, Thane, Pune, Nagpur, Solapur, Nashik, Aurangabad etc., the provision of Act & Rules need to be reviewed and amended suitably in the light of increasing population & urbanization of these cities. Traffic of heavy goods vehicles may be routed outside city area by creating by-passes & ring roads before entry and exit of the city.
- NMC, RTO, MSRDC & MIDC should collaborate to formulate time bound design and construction of under passes, flyovers and widening of roads to control the traffic jams and congestion along Highway and pre-determined junctions passing through core of the city. All buses (STC/PVT/PPP/School/Airport) in the city should be regulated to run only on clean fuels (LPG or CNG) or clean diesel of 10 ppm sulphur with particulate trap for exhaust.
- Promotion of non-motorized transport (NMT). Bicycle sharing schemes should be introduced in the city. Provision of cycle parking facilities at mass transit (BRT/Metro) stations should be made. Provision of City E rickshaw can be initiated. Allocation of designated space for idling/ parking of cycle rickshaws will curb traffic congestion.
- Promotion of use of pool car system, sharing of vehicles, utilization of public transport and use of bicycles for short distances.
- Sweeping of the roads should be done regularly. Vacuum suction pumps for sucking of road dust can be utilized.
- Finally, awareness programme should be undertaken with no vehicle day and assessment for air pollution to share the benefits among the general population. Mass awareness should be done at

local level by the way of advertisements on local TV channels, theatres and at public stations like bus stops, libraries etc.

Parking : Free on-street parking is the norm in Nashik. Double parking is common, especially in busy commercial areas such. Parked vehicles often occupy one or more lanes of the carriageway. This reduction in effective width often results in congestion and traffic jams. Congestion from poorly managed parked vehicles not only reduces carriageway widths, but it also hampers the mobility of all vehicles (especially public transport), increasing travel times and emissions secondary to vehicle idling. It has been observed that the traffic police do not have sufficient vehicles or personnel to enforce parking restrictions. Provision of public parking is required at the places like C.B.S., M.G.Road, Main Road, Canada Corner, College Road, Gangapur Road, Bytco point, Dwarka junction etc.

On street parking Measures :

- The safety and efficiency of the road shall be maintained through effective on street parking restrictions and management options. On street parking spaces shall be designed as per IRC:SP:12:2015.
- Carrying capacity of the road shall be taken into consideration while allotting on street parking spaces. Options such as restricting parking at all times on all mobility corridors shall be explored.
- Areas up to 50 m from intersections on all arms and other critical locations shall be kept free from parking and other encroachments.
- Parking shall be prohibited up to 3 metres on both sides of pedestrian crossings with appropriate road markings showing boundary of parking lots and 'No parking zone'.
- Opinion of traffic police and local stakeholders shall be necessary while designating parking spaces. Parking and halting (including auto rickshaws) shall be prohibited up to 20 metres prior to the bus stop and 15 metres after the bus stop.
- Lots for bicycle parking shall be provided in the on street parking lots at suitable locations as recommended in Bicycle plan for Nashik.
- Any type of commercial activity (goods vehicles) or vehicles indulging in commercial activity shall not be permitted in designated parking lots.
- Parallel parking configuration shall be adopted for all three-wheeled and four-wheeler vehicles including motor cars, light commercial vehicles (LCV), buses and trucks.

- Perpendicular parking configuration shall be adopted for motorized two wheelers as well as bicycles. Only single lane parking shall be allowed for any on street parking lots

Off street parking structures

- Private sector's investment shall be encouraged for creating multi story parking structures.
- Cost of land, construction of built space, operation and maintenance shall be recovered from the users using such facility.
- The capacity of off street parking block shall be dependent on the carrying capacity of the adjoining street and not on FSI permissibility or availability of built up space.
- Design of multi storey parking spaces and standards. Off street parking spaces shall be designed to comply with design standards, including dimensional and circulation requirements. IRC:SP:12:2015, NBCC,BSI standards shall be adopted.
- Multi Storey parking structure shall have proper access road and separate entry and exit ramps for vehicle movement to all floors.

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)

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

Line Sources	Short Term	Mid Term	Long Term	Action required
Reduction Emission per Unit of Fuel				
Fuel Adulteration	Strict Banning of Fuel Adulteration-50%	Strict Banning of Fuel Adulteration-80%	Strict Banning of Fuel Adulteration-100%	There is significant contribution from adulterated fuel as compared to clean fuel. There seem to be a loop hole in distribution system of pure fuel to the end customers. Ministry of petroleum has constituted anti adulteration cell for preventing the malpractices of fuel adulteration. A local level body should be developed for the periodic vigilance and fair distribution in the region. At petrol pumps, facility should be provided for identification of fuel adulteration by way of marker. Oil companies should use colour codes on the tanker transporting the fuel, regular testing of the fuel before it is filled in the bunks and after. Promotion of 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 some of the stringent tools.
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 transport should be converted - 50%	Privately operated Vehicles viz. OLA, Uber and other contract buses, public transport should be converted - 75%	In 2013, the total numbers of buses were 241 which used ply on 508 different routes, covering route of 7728.4 Kms. But these bus numbers are brought down to 110 in 2018. Apart from state transport, there is huge dependence on 3 wheelers and private vehicle aggregators for intermediate point transport within the city. Buses run either on Diesel or CNG. All can be converted to CNG phase wise. Private aggregator vehicles from institution, schools and services should be regulated to convert to CNG/LPG. Incentives for fast paced successful implementation. Incentive for new owners to buy CNG/LPG vehicles. Developed infrastructure for easy availability of fuel station for CNG/LPG refueling and availability of subsidiary kits for such conversion to the older vehicles.

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

Line Sources	Short Term	Mid Term	Long Term	Action required
Reduction Emission per Unit of Fuel				
New Vehicle Standards Sulphur Reduction	Currently BS-IV standards are in operation	Implement BS- VI from 2020 -50% (adopt progressive increment)	Implement BS- VI from 2025 -75% (adopt progressive increment)	Sulphur specification for petrol and diesel will be reduced 50 times from a level of 50 ppm for BS-IV fuel to 10 ppm in BS-VI. Cities in the national capital region like Noida, Ghaziabad, Gurugram and Faridabad as well as 13 major cities, including Mumbai, Chennai, Bengaluru, Hyderabad and Pune, will switch over to Euro-VI grade fuel from January 1 next year. Rest of the country will follow suit from April 2020. The cleaner fuel should cost around 50 paise a litre more. There presently exists no better fuel than this anywhere in the world. Oil refineries will need to invest Rs.30,000 crore in upgrading petrol and diesel quality to meet cleaner fuel specifications by 2020. A strategic plan should be devised for its successful implantation across all levels. Vehicle manufacture should be taken in confidence for the respective modification of engines.
Reduction Emission per Unit of Vehicle/Congestion				
Banning of 15 year Old Commercial Vehicle	50% banning	70% banning	100% banning	Encouragement by provision of incentives in form of scrap value, tax rebate, and transferrable discount rewards for new vehicles and registrations. All the existing and newly vehicles should go through inspection and certification every two years. Corporation and metropolitan authority should demark designated places and system facility for scrapping vehicles, as such there is no provision in the city. According to reports, the government has set up a central depository called 'VAHAN' to store data relating to all vehicles. A city level depository of all the vehicles should be made by the administrative bodies in collaboration with traffic and RTO bodies, which can be linked to the central depository with appropriate information technology structure. This can help the city administration for the monitoring and management for future perusal.
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)	There are significant emissions at signals and congestion zones, especially because of hot and cold start due to unsynchronized and delayed traffic signals. Pre-feasibility study should be undertaken 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.

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

Line 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: 15%, 3 wheeler: 15% Public transport buses -20%	Two wheeler: 30%, 3 wheeler: 30% Public transport buses -40%	Two wheeler: 60%, 3 wheeler: 60% Public transport buses -80%	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. 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. (presently only two wheeler models appear to be taking advantage of the scheme) 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. For example, 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. Nashik city 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. Improvement of efficiencies in the power generation sector and its distribution should also be recognized as a priority. There are 24 two-wheeler models, all battery-operated electric, registered to receive demand incentives under the FAME scheme.

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

Line Sources	Short Term	Mid Term	Long Term	Action required
Reducing Fuel Consumption Per Unit Distance				
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%	Hybrids with efficient internal-combustion engines and other non-polluting power trains will contribute to a cleaner environment. The flagship program to boost hybrid technologies in India is the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME) scheme from the Central Government, launched in April 2015. 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 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. For example, the Central Government of India levies an excise duty of up to 30% on conventional car technologies while hybrid vehicles are subjected to flat duties of 12.5%. 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.

Here are some of the subsidiary benefits from government and emission reduction study conducted at Delhi explained with examples for various hybrid/electric models available in the market.

Passenger Cars Currently Eligible for Demand Incentives Under FAME Scheme

Vehicle	Technology	Segment[25]	Curb Weight (kg)	Length (mm)	Displacement (cc)	Price Range (INR Lakhs)[26]	Gasoline Equivalent Fuel Consumption (liter/100Km)	Life-Cycle CO2 e Emissions (Tonnes /5 Yrs.)
Maruti Ciaz SHVS	Mild Hybrid (Diesel)	Midsize	1,115	4,490	1,248	8 to 10.5	3.98	6.73
Maruti Ertiga SHVS	Mild Hybrid (Diesel)	Utility Vehicle (UV1)	1,235	4,265	1,248	7.5 to 9.5	4.55	7.71
Toyota Camry Hybrid	Strong Hybrid (Gasoline)	Premium	1,635	4,850	2,494	28 to 32	5.22	8.12
Mahindra E2O	Battery Operated Electric	Mini	830	3,280	NA	4.5 to 7.5	0.86	5.06
Mahindra eVerito	Battery Operated Electric	Midsize	1,140	4,277	NA	9.5 to 10	1.47	9.94

Fuel Consumption Savings of Models Under FAME Scheme Compared with Base Models

Technology	Hybrid/ Electric Model (BEER Fuel Efficiency Star Rating	Non-Hybrid /Non Electric Base Model (BEE Fuel Efficiency Star Rating)	Gasoline Equivalent Fuel Consumption Reduction over Base Model
Diesel –Based Mild Hybrid	Maruti Ciaz, VDI SHVS (5 Star)	Maruti Ciaz, VDI (5 Star)	7%
Diesel –Based Mild Hybrid	Maruti Ertiga, VDI SHVS (5 Star)	Maruti Ertiga, VDI (4 Star)	15%
Gasoline Based Strong Hybrid	Toyota Camry, Hybrid (5 Star)	Toyota Camry, At 2.5 L (2 – Star)	32%
Battery Operated Electric	Mahindra E-Vertio D2 (5 Star)	Mahindra Verito D2 (4 Star)	68%
Battery Operated Electric	Mahindra E2Om (5 Star)	--	--

Fuel Consumption Limits for Two-Wheelers Under FAME Scheme Compared with Non-Electric Benchmark

	Maximum Speed (kmph)	Maximum Power Output (w)	Gasoline Equivalent Fuel Consumption (t/100 Km)	Life Cycle CO2 Emission (tons/5 Yrs.)
Low speed Electric Scooters	25	250	< 0.51	< 3.04
High Speed Electric Scooters	45-55	1,500 – 1,800	< 0.82	< 4.86
Honda Activa 3G	82	5.966	1.5	2.33

Source: International Council on Clean Transportation

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

Line 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 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. The test design should have the basis of engine and overall vehicles fitness (roadworthiness). Set up a mechanism of Inspection and Maintenance programme for all vehicles in the district through RTO with automated system assessment. Implementation of penalties should be laid on vehicles if found exceeding the emission limits. The I &M center should also test all vehicles for their in-built emission tests. All private vehicles should be subjected to proper assessment and fitness tests through I&M centers. All autos and buses shall also be subjected to I&M tests. On-road emission tests for vehicles plying on Indian roads will be mandatory once the Bharat Stage VI norm kicks in from 2020, for which testing agency Automotive Research Association of India (ARAI) is developing a unified test cycle. The European Commission will begin conducting these tests on new models from September 2017 and on new vehicles by 2019. India, however, will begin collecting data through these tests from 2020 and set permissible limits for emissions by 2024.
Ban of odd /even vehicles	It is feasible to take trail for commercial / office areas – 20%	Identified interlinking roads and traffic hotspots and implement for trail road - 20%	Identified interlinking roads and traffic hotspots and implement for trail road - 50%	A trial run should be arranged to study the impact. 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.

Environment Pollution (Prevention and Control) Authority (EPCA) for Delhi NCR for submitted a "Report of assessment of Pollution Under Control (PUC) Programme in Delhi and NCR: Recommendations for improvement to ensure pollution from in-use vehicles is under control" to Supreme court. Some of the measures can be followed as recommendation for existing PUCs of the city:

EPCA states that without a robust system of emissions monitoring and compliance, the investments in emission monitoring of on-road vehicles as well as advanced emissions control systems in new vehicles to meet tighter emissions standards, can go waste and negate air pollution control efforts in our cities. Management of emissions from on-road vehicles will require an integrated approach to ensure all generations of vehicles -old and new remain low emitting for as long as the vehicles are on the road.

This will require strengthening of the PUC systems for all on-road vehicles - Bharat stage (BS) I to IV generations of vehicles combining both physical tests as well as On-board Diagnostic (OBD) tests. This will also require appropriate emissions monitoring system for the new generation of BSVI vehicles to come within three years. PUC will not be the relevant programme for that genre of vehicles. The BSVI standards and regulations have already provided for real driving emissions testing when vehicles move on the road. But the roadmap for its implementation needs to be charted quickly to allow Delhi and NCR to be prepared in time.

Simultaneously, the newly amended Motor Vehicle Act and Rules has given the opportunity to implement emissions recall programme so that the vehicle manufacturers can be held responsible for any manufacturing defect that increase on-road emissions. Both EPCA and Auto Fuel Policy committee had recommended emissions recall programme in 2003. Thus, addressing all the three element of the programme, PUC both physical testing and OBD testing; real driving emissions testing for in-use compliance; and manufacturer responsibility for manufacturing defects, are the critical steps to get a robust system to keep vehicles low emitting on roads. This is needed for both consumers as well as manufacturers' responsibility. In view of this the following recommendations are made:

1. Limit the numbers of PUC centres, upgrade them and bring them under strong supervision and quality control:
   The current practice of allowing mushrooming of small time and numerous PUC centres in refuelling stations across the NCR must be stopped. It is more important to limit their numbers, upgrade their capacity to carry out proper credible and authentic testing and bring them within a strong accountability framework

2. For improving compliance with the PUC programme, MoRTH and state transport departments should do the following:

   2.1 Ensure 100 per cent compliance by linking annual vehicle insurance with PUC certificates. Annual vehicle insurance cannot be obtained without all the requisite PUC certificates. Currently, PUC certificates need to be obtained every quarter in Delhi and every six months in the NCR. This periodicity of PUC certification can be made uniform across Delhi and NCR later only after PUC norms and oversight systems have been adequately upgraded and made stringent. Issue of authentic certificates must be ensured based on authentic and credible tests.

   2.2 Introduce automatic online network for transmission of PUC data to the central server to minimize manual interference and allow proper analysis of data for remote auditing of PUC centres. Adopt uniform and standardized data recording and reporting format and uniform software across Delhi NCR. Mandate periodic analysis of data to refine enforcement and for monitoring and submission of compliance report every six months. Software used in different make of testing equipment across NCR needs to be standardized to prevent fake values. MoRTH needs to develop the standardized protocol for uniform application across Delhi-NCR.

   2.3 Mandate pre-payment of PUC fees before the tests are conducted. No test should be conducted without taking the fee in advance. The software should be modified accordingly.

   2.4 Strengthen inspection of the PUC centres for quality control and strengthen the licensing programme to ensure proper calibration, authentic tests; annual maintenance contact for the maintenance of all testing equipment and accessories; training of operators, calibration of equipment etc are carried out. Make quality audit of centres and calibration quarterly. Introduce annual third party inspection of PUC centres immediately. State Pollution Control Boards with guidance from Central Pollution Control Board should coordinate this.

   2.5 Phase in big centralized emissions testing centres capable of conducting automatic and upgraded tests for commercial vehicles on a priority basis. Delhi already has Burari vehicle inspection and fitness centre in Delhi for commercial vehicles. The commercial vehicles visit it for annual vehicle fitness and roadworthiness tests. This needs to be upgraded for high level of automatic emissions testing so that operators and vehicle drivers do not come in contact to influence the test results and credible and upgraded tests are conducted. MoRTH is also setting up centralized inspection centres in NCR as in Rohtak. These should be aligned to firm up the roadmap. Add more such centres as needed.

2.6 Introduce well equipped mobile test centres and a programme to check visibly polluting vehicles:

- In addition to stationery testing centres, mobile units are also needed for surprise checks as well as to catch the visibly polluting vehicles on road. There should be appropriate penalty for visibly polluting vehicles.
- Enforce stringent penalty for PUC centres for non-compliance and malpractices.

3. For improving the effectiveness of the PUC tests and inspection, MoRTH should do the following:

3.1 Tighten the PUC emissions norms for pre-Bharat Stage IV vehicles: Analysis of large data set on actual emissions concentration tested in large number of PUC centres in Delhi and UP has also brought out that the actual observed emissions values of pre-Bharat Stage IV vehicles are significantly lower than their prescribed norms. In most cases 80 per cent lower than the limits. These norms cannot identify at least 15 to 20 per cent grossly polluting vehicles in the on-road fleet. Nearly all vehicles pass the tests. Due to poor recording of failed tests and due to very lax norms the overall failure rate in Delhi is 4.69 per cent. For the diesel vehicles tested, the failure rate stands at 1.68 per cent, compared to 5.18 per cent for petrol vehicles and 4.65 per cent for all other fuel categories requires urgent attention and action. In UP NCR cities, the overall failure rate is abysmally low, at 0.49 per cent – 0.39 per cent in two-wheelers and 0.59 per cent in four wheelers. The MoRTH needs to tighten the PUC standards for the pre-Bharat Stage IV emissions standards. This will also help to weed out very old non-compliant vehicles and speed up fleet renewal based on improved standards.

3.2 Overhaul emissions tests and tighten norms for diesel vehicles: The review of available data shows that the smoke density tests – the only test that is carried out in diesel vehicles is very lax for the pre Bharat Stage IV diesel vehicles. More than 80 per cent of vehicles tested show smoke density levels that are below the norm prescribed for the Bharat Stage IV vehicles. Therefore, the current norms for Bharat Stage IV norms should be made uniform for the pre-Bharat Stage IV vehicles as well. This can be further weed out the very old and polluting vehicles and speed up fleet renewal.

Moreover, as explained earlier globally smoke tests are being upgraded with more advanced test procedures to make these tests more rigorous and effective. MoRTH may review those advanced testing procedures and provide a roadmap for the introduction of these tests in the large centralized testing centres for commercial vehicles quickly.

3.3 Make lambda test for petrol cars mandatory across NCR: Lambda testing for petrol cars equipped with three way catalytic converters – introduced in BSII-III level is already mandatory in Delhi as per the MORTH 2004 notification, but not in NCR. Lambda value

represents the air to fuel ratio. It is important to maintain the optimum ratio for proper functioning of the catalytic converters that play a crucial role in cleaning up the exhaust gases from petrol cars. It is not possible to directly test the efficacy of the catalytic converters. That is why it is important to ensure that the operative systems in the vehicles needed for its optimum performance are maintained. Lambda is an indicator of that. Such tests will require upgradation of the test equipment from two gas analysers to four gas analyzers capable of doing lambda testing. Petrol cars are already tested for carbon monoxide, hydrocarbon based on two speeds. If done along with lambda measurement, the test procedures for petrol cars can become more robust and effective. As the MoRTH has already provided for lambda tests in its 2004 notification, the concerned state governments need to issue orders for implementation in the NCR.

3.4 Integrate OBD with inspection and maintenance programme: The MoRTH needs to develop the protocol for implementation of OBD for vehicle inspection programme that will be implemented by the state governments. This will complement the physical testing.10 It is also important to detail out how this will be operationalized at the ground level and how the transport department will implement this programme.

3.5 Detail out the strategy for advanced real driving emissions monitoring of new generation vehicles to come with BSVI emissions standards in 2020: Any roadmap for improving vehicle inspection programme at this juncture will have to keep in view the dramatic transition in emissions control technologies within a short span of three years when BSVI emissions standards will be enforced. The current PUC is not designed to address those vehicle technologies. The notification of MoRTH on BSVI standards has already provided for the introduction of Real Driving Emissions Test Procedures and Standards based on portable emissions monitoring system to monitor emissions as vehicles move on the road. This is needed to ensure that all the advanced emissions control devices that to be fitted in the new vehicles will continue to perform effectively in real world conditions.

This has become necessary in view of the rapid deterioration in emissions noted in new Euro VI vehicles in Europe and the US and also to prevent use of defeat devices to cheat emissions standards. The data available from Europe shows that the actual NOx emissions from Euro VI diesel cars can be as bad or worse than a Euro I diesel car as on-road emissions can be as higher as upto 16 times higher than their certification level EPCA strongly believes that as India is now making this crucial transition to a very advanced genre of vehicles proactive and preventive policies and systems should be put in place to these advanced systems continue to perform efficiently on road and for emissions to all generation of vehicles remain low emitting during their useful lifetime. MoRTH along with the state governments of the NCR-Delhi need to put in place the systems for introduction of Real Driving Emissions testing for BSVI vehicles.

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

Line Sources	Short Term	Mid Term	Long Term	Action required
Reducing Fuel Consumption Per Unit Distance				
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 contract buses and 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. On August 16, 2017, the government of India, in consultation with the Bureau of Energy Efficiency (BEE), published final fuel efficiency standards for commercial heavy-duty vehicles (HDVs). The regulations are aimed at reducing fuel consumption and greenhouse gas (GHG) emissions from diesel-powered trucks and buses with a gross vehicle weight (GVW) of 12 tonnes or greater.

On August 16, 2017, the government of India, in consultation with the Bureau of Energy Efficiency (BEE), published final fuel efficiency standards for commercial heavy-duty vehicles (HDVs). The regulations are aimed at reducing fuel consumption and greenhouse gas (GHG) emissions from diesel-powered trucks and buses with a gross vehicle weight (GVW) of 12 tonnes or greater. The new standards include two phases of regulatory compliance. Phase 1 goes into effect April 1, 2018, while Phase 2 is effective beginning April 1, 2021. The regulatory classes affected by this rule are as follows (Vahan Sewa, 2017) :

- Category M3: motor vehicles for the carriage of passengers, comprising nine or more seats in addition to the driver's seat with GVW exceeding 5 tonnes
- Category N3: motor vehicles for the carriage of goods with GVW exceeding 12 tonnes

Although, the M3 regulatory subclass includes vehicles 5 tonnes and above, the rule applies only to vehicles greater than 12 tonnes GVW. Tables 1 and 2 summarize the limit value equations for all of the subcategories within the M3 and N3 vehicle classifications.

Table 1 : Stringency Equations for Phase 1 (Effective April 1, 2018)

Vehicle Category	Gross Vehicle Weight (tones)	Axle Configuration	Equation	Fuel Consumption (l/100 Km)	
				Value at lower weight limit	Value at upper weight limit
40 Kilometer per hour					
N3 Rigid Vehicles	12.0- 16.2	4 x 2	Y=0.362X + 10.327	14.7	16.2
	16.2- 25.0	6 x 2	Y=0.603X + 6.415	16.2	21.5
	16.2- 25.0	6 x 4	Y=0.723X + 4.482	16.2	22.6
	25.0- 31.0	8 x 2	Y=0.527X + 8.333	21.5	24.7
	25.0- 31.0	8 x 4	Y=0.928X – 0.658	22.5	28.1
	31.0- 37.0	10 x 2	Y=0.960X – 5.100	24.7	30.4
N3 Tractor Trailers	35.2- 40.2	4 x 2	Y=0.986X – 7.727	27.0	31.9
	40.2- 49.0	6 x 2	Y=0.628X – 6.648	31.9	37.4
	40.2- 49.0	6 x 4	Y=1.255X – 18.523	31.9	43.0
M3 Vehicles	12.0 and above	4 x 2 & 6 x 2	Y=0.509X – 11.062	17.2	
60 Kilometer per hour					
N3 Rigid Vehicles	12.0- 16.2	4 x 2	Y=0.788X + 9.003	18.5	21.8
	16.2- 25.0	6 x 2	Y=0.755X + 9.546	21.8	28.4
	16.2- 25.0	6 x 4	Y=1.151X + 3.122	21.8	31.9
	25.0- 31.0	8 x 2	Y=0.650X + 12.160	28.4	32.3
	25.0- 31.0	8 x 4	Y=0.968X + 7.692	31.9	37.7
	31.0- 37.0	10 x 2	Y=0.960X + 5.100	24.7	30.4
N3 Tractor Trailers	35.2- 40.2	4 x 2	Y=0.208X + 32.198	39.5	40.6
	40.2- 49.0	6 x 2	Y=0.628X + 15.298	40.5	46.1
	40.2- 49.0	6 x 4	Y=1.342X + 13.390	40.6	52.4
M3 Vehicles	12.0 and above	4 x 2 & 6 x 2	Y=0.199X + 19.342	21.7	

** Source: International Council On Clean Transportation*

The standards are represented in an equation based on GVW and axle configuration, providing normalized values of fuel consumption in liters per hundred kilometers (l/100 km). The regulations are a minimum performance requirement, similar to the existing Bharat Stage (BS) emission norms.

Table 2. Stringency Equations for Phase 2 (Effective April 1, 2021)

Vehicle Category	Gross Vehicle Weight (tones)	Axle Configuration	Equation	Fuel Consumption (l/100 Km)	
				Value at lower weight limit	Value at upper weight limit
40 Kilometer per hour					
N3 Rigid Vehicles	12.0- 16.2	4 x 2	Y=0.329X + 9.607	13.6	14.9
	16.2- 25.0	6 x 2	Y=0.523X + 6.462	14.9	19.5
	16.2- 25.0	6 x 4	Y=0.673X + 4.032	14.9	20.9
	25.0- 31.0	8 x 2	Y=0.430X + 8.780	19.5	22.1
	25.0- 31.0	8 x 4	Y=0.732X + 2.558	15.7	20.1
	31.0- 37.0	10 x 2	Y=0.963X – 7.753	22.1	27.9
N3 Tractor Trailers	35.2- 40.2	4 x 2	Y=0.826X – 3.165	25.9	30.0
	40.2- 49.0	6 x 2	Y=0.630X + 4.732	20.6	26.1
	40.2- 49.0	6 x 4	Y=1.008X – 10.480	30.0	38.9
M3 Vehicles	12.0 and above	4 x 2 & 6 x 2	Y=0.659X + 6.582	17.2	
60 Kilometer per hour					
N3 Rigid Vehicles	12.0- 16.2	4 x 2	Y=0.600X + 9.890	17.1	19.6
	16.2- 25.0	6 x 2	Y=0.515X + 11.271	19.6	24.6
	16.2- 25.0	6 x 4	Y=0.932X + 4.515	19.6	27.8
	25.0- 31.0	8 x 2	Y=0.382X + 14.598	24.2	26.4
	25.0- 31.0	8 x 4	Y=1.318X – 5.148	27.8	35.7
	31.0- 37.0	10 x 2	Y=1.043X – 5.913	26.4	32.7
N3 Tractor Trailers	35.2- 40.2	4 x 2	Y=0.260X + 27.888	37.0	38.3
	40.2- 49.0	6 x 2	Y=0.236X + 28.838	38.3	40.4
	40.2- 49.0	6 x 4	Y=0.563X + 15.728	38.4	43.3
M3 Vehicles	12.0 and above	4 x 2 & 6 x 2	Y=0.340X + 14.300	18.4	

** Source: International Council On Clean Transportation*

To demonstrate compliance, each vehicle model and configuration is required to meet the fuel consumption levels shown in Tables 1 and 2. This stands in contrast to the fuel consumption and greenhouse gas standards in the United States and Canada, which are based on sales-weighted averaging.

For evaluating the performance of the vehicles, manufacturers are required to use a Constant Speed Fuel Consumption (CSFC) driving cycle. This means that the fuel consumption is measured over a set speed without any transient behavior. In this particular regulation, the CSFC test is run at two separate speeds one at 40 km/h, and the other at 60 km/h. The CSFC testing has been used in India as part of the vehicle certification process for several years *(Sharpe & Delgado, 2015)*. The CSFC cycle is different from the regulatory cycles adopted in HDV standards for other countries.

The efficiency standards are required for both vehicle manufacturers and importers. The conformity-of-production test will be undertaken by MoRTH once every two years. The CSFC testing and reporting also needs to be done at least once before April 1, 2020. There is no such requirement before Phase 1 goes into effect April 1, 2018, because the standards reflect averages found in HDV baseline testing between 2014 and 2015.

As per internal government records, the Phase 1 stringency for each vehicle subcategory represents the average fuel consumption from CSFC testing. Thus, starting April 1, 2018, for every segment of the market, the maximum allowable fuel consumption is equal to the average fuel consumption from the baseline testing campaign. The Phase 2 stringency represents the 20th percentile of the baseline testing data, meaning that 20% of the baseline vehicles had fuel consumption levels lower than the limit curve.

Fuel Consumption Stringency : Phase 1 to Phase 2

Assuming equal weighting for the two test cycles, an estimated fuel-consumption reduction from Phase 1 to Phase 2 can be calculated as shown in Table 3. The average stringency is calculated using sales weighting, which comes from data that was acquired from Segment Y Automotive Intelligence for the year 2013-2014.

Table 3: Required reduction in fuel consumption from Phase 1 to Phase 2 and market shares by vehicle category in fiscal year 2013-14

	GVW Bin (tones)	Axle Configuration	Required Fuel- Consumption Reduction Between Phase1 and Phase 2	Market Share
Rigid Truck	12.0- 16.2	4 x 2	8.2 %	23.3 %
	16.2- 25.0	6 x 2	10.7 %	13.9 %
	16.2- 25.0	6 x 4	9.6 %	16.8 %
	25.0- 31.0	8 x 2	13.3 %	12.9 %
	25.0- 31.0	8 x 4	8.9 %	6.5 %
	31.0- 37.0	10 x 2	11.5 %	0.5 %
Tractor-Trailers	35.2- 40.2	4 x 2	5.4 %	8.9 %
	40.2- 49.0	6 x 2	7.2 %	0.0 %
	40.2- 49.0	6 x 4	10.0 %	2.6 %
Bus	12.0 and above	All Configuration	15.5 %	14.5 %
Sales weighted average stringency			10.4 %	

** Source: International Council On Clean Transportation*

The Phase 1 to Phase 2 stringency analysis shows that transit buses face the largest reduction in fuel consumption from 2018 to 2021 at 15.5%. The fleet-wide fuel-consumption reduction from Phase 1 to Phase 2 is estimated at 10.4%. This is calculated on a vehicle-population weighted average and therefore is not necessarily representative of the overall fuel savings that will be achieved as a result of the regulation. This is due to the difference in fuel consumption that the different vehicle configuration may have. For example, changing the stringency of for a tractor-trailer by 1% will not have the same result as changing the value for a rigid truck. Because the regulation applies only to trucks and buses greater than 12 tonnes GVW, a significant percentage of the HDV market in India is not subject to these standards. Sales data from Segment Y provides evidence that nearly half of the HDV market is less than 12 tonnes and thus is not covered by this regulatory program.

Truck Terminal : Terminal facility in the form of Truck Terminus for heavy vehicles is in existence at Adgaon. Truck Terminus is partly developed on Mumbai-Agra National Highway and is functioning. At Pune-Nashik National Highway such type of truck terminus is presently absent and need to be provided. The C.B.S. in Nashik city and the existing Nashik Road Bus Station outside the Railway Station are very heavily loaded and their location in the heart of developed locality offers no scope for making more space available for bus parking.

The growing traffic needs in the city would also call for proper traffic management measures along with traffic signal with area co-ordination traffic signals etc. Due to rapid growth of auto-rickshaws and two-wheelers and lack of proper traffic control, the road accidents are prevalent in the city.

- The inner city roads are congested particularly during the morning and evening peak hours. The comprehensive area traffic control plans need to be prepared for the congested area.
- The wholesale market like Gole Colony and Main road may need to be suitably relocated by making reservation in the land use plan.
- The national and state highways passing through the city function as major arterial roads. In the absence of an effective by pass, intermixing of regional traffic and city traffic takes place, especially on the national highway. This adds to the traffic congestion on the highway in the city area. Thus, there is a need to segregate inter-city and intra-city traffic, may be by providing service roads or by constructing effective by pass links.
- There should be planned and designated bus stops that reduce traffic congestion and accidents.
- Footpath should be built on every road of the city. The widening and maintenance of the roads should be undertaken in an effective manner.
- The road marking such as Zebra Crossings would be essential, particularly, at the intersection where there is significant pedestrian- vehicle conflict.
- Inadequate street lighting also undermines the safety and convenience on the city road. This situation needs to improve.
- Efficiency, energy, environment and equity should be taken into account while solving traffic and transportation problem.

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

Line Sources	Short Term	Mid Term	Long Term	Action required
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%	Currently, parking in city is either free or priced very low. Increased parking cost, if coupled with the parking locations, so that they are as far as the bus and the rail stops, will make public transportation an attractive option Parking on roads should be regulated along with a rule to allow purchase of vehicles only if parking place is available. Municipal corporation should define designated space in the localities and develop elevated pay and park zones. Higher parking fee for longer period of time. Diversion of non-destined traffic especially the trucks trough by-pass roads. Major haul trucks with heavy loads should not be left to pass through the main city; instead a Truck Terminal can be established at outskirt of city. Construction of multi storied parking complexes. Pay and Park Schemes on major roads and mass transit stations. Road side parking should be regulated on internal roads.
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	Efficient public transport 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 Nashik city at one or two road stretches Management of Intermediate Public Transport - IPT (auto rickshaws / shared auto rickshaws / taxis) can be done considering the travel demand management. One way traffic movement on few roads. Widening of roads approaching towards mass transit stations.

Buses are critical as spine of city mobility- 40-60% of daily trips. These allow greater flexibility to allow more efficient geographical coverage and score high on space efficiency. Buses move people in most cost-effective way and emit a lot less per person.

Yet city have Inadequate and unreliable services, poor fleet utilization, under-utilization of passenger carrying capacity, no route rationalization and poor geographical and population coverage, operated kilometer are much less than scheduled kilometer and no dedicated right of way for buses.

Bus numbers of the state transport corporations are extremely inadequate and dwindling over time. According to the bus transport guidelines of the Ministry of Urban Development framed with support from Asian Development Bank states that a city should ideally have at least 60 buses per lakh of population. Estimating this number for cities is extremely difficult as in most cities public transport buses are operated by both state owned city transport corporations and private agencies.

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 wheelers are 11.8 and 6.8 times respectively for the same distance. Besides, the major issues are that a car occupies 38 times more road space compared to a bus for a kilometer of 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 term of fuel savings, emission and safety.

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

Promotion of NMT

The vehicle ownership in India is low as compared to foreign countries and also traditional mixed-use design of the cities makes the majority share of trips by walk or cycle. In big cities with higher population density, in the absence of dedicated Non-Motorized Transport infrastructure (NMT), people owning two-wheelers and cars are encouraged to use their vehicles, even for walk-able distances. In the context of growing cities, the measures to improve air quality should include NMT policies as an integral part.

4.3.1 Non Motorized Sectors

Cycle Track : To contribute to the sustainable development of the city, provision of dedicated 3 m. wide cycle track along all nallas having width more than 6 m, can be developed. Municipal Corporation should look after the procurement of required lands and its construction. In addition to this, 6 m. wide cycle track can be developed in the Nashik bank canal land. The development of this cycle track can be done by public-private participation or from the funds of Municipal Corporation. In addition to this, provision of cycle track shall be made in green belt proposed along river sides.

Green Belt Development : The Green Belt along the banks of Godavari, Nasardi, Valdevi and Darna Rivers can be developed. This belt shall be a use for plantation, cycle track, recreation, etc. which will protect the erosion of the river banks and also enhance the environment.

- Conservation and development of green belts on the road side in order to increase beauty
- Improvements of Footpaths
- Periodic manicure of tree planted on roads.
- Improvement of Traffic island & junctions.
- Awareness to citizens to keep city clean through slogans, messages, media etc.
- Maintenance of public utility buildings and Monuments.
- Total use of open land for green belt development
- Arranging the seminar/awareness programme at school & college levels.

Congestion Pricing

Some economic measures should also be designed to force the use of public transport. One such measure is the congestion pricing where the motorists are charged to use a network of roads during periods of the peak hours. Its purpose is to reduce automobile (mostly car) use during peak congestion periods, thereby easing traffic and encouraging commuters to walk, bike, or take mass transit rail/bus as an alternative.

Congestion pricing programs were successfully implemented in Singapore, London, and Stockholmb *(Eliasson, 2009; Menon and Guttikunda, 2010; Litman, 2011)*. On average, in London, congestion pricing is estimated to have reduced 20-30% of the downtown passenger car traffic and promote the non-motorized transport, whereas Stockholm experienced an immediate reduction of at least 20% in the daily car use. In Singapore, the average traffic speeds increased by at least 15 km/h. In all three cities, 10-20% reduction in eCO2 emissions was estimated, along with health benefits of reducing air pollution

Increased Parking Cost

With increasing costs for private vehicles linked with their usage (fuel and other operational expenses), it is possible to achieve a shift to public transport, if combined with the provision of an adequate, reliable, and safe public transportation. One such measure is the increased parking cost. Currently, parking in most cities is either free or priced very low. Increased parking cost, if coupled with the parking locations, so that they are as far as the bus and the rail stops, will make public transportation an attractive option *(Barter, 2012; CSE, 2012).*

Car Specific Taxes

According to International Energy Agency IEA's World Energy Outlook (WEO) report, in the new policies scenario, passenger car ownership will grow from less than 20 vehicles per 1,000 inhabitants today to 175 cars per 1,000 people in 2040, and overall road passenger vehicle activity will increase more than six-times. While the congestion pricing and parking policies target reduced vehicle usage, some countries have used regulatory measures to reduce the growth of private vehicles. For instance, a Chinese national regulation enacted in September, 2008, raised taxes on big cars and reduced on smaller ones. Car owners with engines above 4-L capacity have to pay a 40% tax; 15%-25% for cars with engines above 3-L capacity; and 1%-3% for cars with engines below 1-L capacity. China also introduced a policy to limit the number of licenses issued every year, where the license plates are auctioned in the cities of Beijing, Shanghai, and Guangzhou. Similar to congestion pricing, for the time being, such measures are difficult to implement under democratic political context of India.

Action on Vehicle Technology and Fuels

In urban landscape clean air action on vehicles and mobility is the weakest. Even though vehicles are one of the most rapidly growing sources of pollution local action has remained the minimal. Emissions standards for vehicles and fuel quality are common across cities. 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. For the first time monitoring of real world emissions with portable monitoring system along with in-service compliance regulations will be implemented to keep an eye on real world emissions. Real driving emissions (RDE) testing will be included as an additional requirement for vehicle certification. Emissions measurements will be carried out with the help of Portable Emission Measurement System (PEMS) and onwards in-service conformity factor will be applied to ensure that emissions from vehicles remain within the stated margin. This can prevent emissions cheating and use of sub standards emissions control or defeat devices as was done by Volkswagen. However, adoption of more advanced on-board diagnostic system has been delayed until 2023. Cities will have to develop a compliance programme to integrate these emissions control approaches within this time frame for successful implementation.

Since 01 September 2017, Real Driving Emissions (RDE) has become mandatory with specific pollutant limits for new light duty vehicle approvals in Europe. This year, European Commission will finalize the RDE 4th package, with which, Europe will consolidate the most stringent approach worldwide for light duty vehicles emissions regulation. The new approach of RDE in measuring vehicle emissions during on-road driving is rapidly being adopted by many other countries. There is already a substantial diversity arising in the local applications of RDE, some examples are given below this is not a complete list of those intending to apply RDE in future, nor does it contain a comprehensive list of all the differences in comparison to the European application:

India is developing its own RDE -currently investigations are running regarding driving speeds, conditions and potential limits as well as on the robustness of the measurement equipment under Indian driving conditions.

4.3.2 Clean Air Fund

Prioritization of Public Transport on Roads: 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. The efficiency of the public transport can be maintained only if priority is given to the public transport vehicles. Some of the suggestions are:

In Nashik City Bus lane, there is need to find out gaps and exclusive bus lanes should be introducing base on point to point service. 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 auto 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. Modalities and options which can be adopted for no increase in bus fares are presented below:

- 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 shopping centres (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 PMT 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 :**

Vehicle Km Travel in a Day for Nashik City (2017)

	2 Wheelers	3 Wheelers	Car CNG	Car Petrol	Car Diesel	HDDV
VKT	3288367	1088602	129463	2200879	258927	2845787
Cost (Rs.)	1644183	544300.9	64732	2200879	258927	2845787
Rate Rs./Km	0.5	0.5	0.5	1	1	1

Total Collection about Rs. 75,58,810 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 NMC, 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 transport 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.

4.4. Point Sources

Nashik had been growing very fast industrially, during the last few decades. There are some major industrial activities on the out skirt of Nashik city, such as Hindustan Aeronautics Ltd. at Ozar, Thermal power station at Eklahare, Sinnar M.I.D.C., Five Star Industrial Estate at Sinnar, which can directly or indirectly influence the working population as well as trade and commerce activities of the city. Industrial development within city limit is also noteworthy which has directly or indirectly increased the working population, as well as Trade and Commerce. Some of them are Currency and Security Press, Govt. of India, Crompton Greaves, M.I.C.O., V.I.P., CEAT, Mahindra and Mahindra, Railway Traction Factory. Besides this, there is sporadic Industrial development comprising of sawmills, small scale industries, work-shops etc. spread all over the Corporation Area. M.I.D.C has developed an Industrial Area in Satpur over an area of 635.76 hectares, Ambad over an area of 515.50 hectares and Sinner over an area of 51.067 hectares. In addition to above, there is Nashik Industrial Co-op Estate having an area of 135 hectares, established in 1962. There are about 6990 small scale, 27 medium scale and 131 large scale industrial units registered. Majority of the Industries which came up in the city or Industrial areas are Automobiles, Engineering, Electrical, Electronics, Stationary manufacturing, Printing press components, Metal Arts, Steel and wooden Furniture, Fiber and plastic moldings, Pharmaceutical and medical equipment, Data processing etc. All the above units, more or less, have contributed directly or indirectly in pushing up the trade and commerce activity in the city.

Thermal Power Plant : Eklahare Thermal Power Plant located in village Eklahare, near Nashik Road, caters to the power demand. From there, power is fed into the western division grid and subsequently distributed to substations and finally to households. In line with the guide lines issued by Central Electricity Authority (CEA), MAHAGENCO plans to install energy efficient 1 x 660 MW coal based super-critical thermal unit at Nashik as replacement project.

- The data for fuel consumption pattern in the industries of Nashik is not updated. There are large numbers of medium scale industries established within the city limit as well as in MIDCs. Inventorisation of fuel consumption of prominent industries should be maintained with inclusion of technological gaps.
- Nashik district and circumferential area earmarked for development and industrialization should be grouped under a Nashik Metropolitan Development Authority and MIDC for better planning and administration. The fuel (vehicular and industry) of corresponding quality in this area should be ensured. Similarly, national level decision of controlling sulfur content of these industrial fuels will yield good results (present sulfur content: FO 4%, LDO 1.8%)

- Majority of the industries of Nashik are of engineering or manufacturing nature. There is dire need for the identification of low cost and advanced cleaner technology for these industries. Use of air pollution monitoring devices (Continuous Environment Monitoring System) and other in-situ emission reduction devices should be made mandatory in their premises. Some units having coal fired boilers are proposed to improve efficiency of the wet scrubber and to stick for eco-friendly fuels.
- Use of fossil based fuel is high in Nashik's Industrial area. Industries should adopt natural gas or renewable resources as fuel for their operations. Use of FO, LSHS, LDO, and Bagasse should be regulated. Provision for supply of LPG or PNG should be explored.
- Industries should adopt stack emission norms beyond those prescribed by CPCB Industries/power plants, which should be followed by regular QA/QC & performance audit.
- Power Shedding is a common phenomenon in Nashik MIDC area, which gave rise to number of D.G sets in the vicinity. To control the emission from the D.G set, their stack should be regulated according to the standards prescribed. Control equipment installation should be made mandatory. Provision of continuous supply should be made.
- All the bulk drug and pesticides manufacturing units should be proposed to improve efficiency of their VOC scrubbers. Some units having coal fired boilers are proposed to improve efficiency of the wet scrubber and to stick for eco-friendly fuels. Solvent distillation Units should be directed to establish waste solvent recovery unit. The chemical and dyes units should improve their scrubbers and dust collectors.
- Energy Conservation Scheme should be encouraged in the industries that are not economically capable towards shifting cleaner fuel use or advanced cleaner technologies. Air polluting industries can improve their ECS by increasing efficiency of their scrubbers and changing to eco-friendly fuels.
- NMC, MIDC & MPCB should survey for the identification of illegal SSI and their levels of operation and their contribution in each of the grids in the city. Need for regulations for such units.

With the implementation of the short and long term scenarios, the total reduction in particulate matter from point sources would be 54% and 98% respectively.

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

Point Sources	Short Term	Long Term	Action Plan
RED CATEGORY FO – 14.5 tpd LDO – 3.6 tpd Coal – 1154.8 tpd Wood – 111.2 tpd Diesel – 22.4 tpd Briquette -74.8 tpd Bagasse – 2831.3 tpd **ORANGE CATEGORY** HSD –29.5 tpd Coal –77.9 tpd Wood –15.5 tpd Diesel & Briquette – 9.4 tpd Bagasse - 34.4 tpd **GREEN CATEGORY** LDO -2.5 tpd HSD- 8.1 tpd Wood – 3.6 tpd Briquette – 48 tpd Diesel -35.3 tpd Consumption are major contributors towards PM and NOx emission loads from this category	Shift to cleaner fuels in both the category of industries– 50% of FO, LSHS, HSD to LDO, Coal & Others to NG	Shift to cleaner fuels – 100% All types of fuel to Natural gas	There are around 1000 Air Polluting industries in area/cluster. The emission load of PM is highest from burning of biomass, coal and wood as power source in different industrial process of Nashik region. The highest PM emission load was calculated from Bagasse (48.1%), followed by Coal (33.9%) and Wood (17.4%), whereas highest NOx emission load is from Coal (83.8%). While Indian coal has a low sulfur content in comparison with other coals, ash levels are reported to be quite high and can contribute to coarse PM emissions. A requisition should be made to Mahanagar Gas Co. for commissioning of pipeline for the supply across the region. The civic regulatory bodies should intervene to make sure it is facilitated at all levels of demography, management and organizational scale. Identification of low cost and advanced cleaner technology for air pollution control with policy intervention at specific zones. Feasibility of changing combustion technology to facilitate usage of gaseous fuels may be undertaken with financial incentives. All the bulk drug and pesticides manufacturing units are being proposed to improve efficiency of their VOC scrubbers. All the Hazardous Air Polluting Units should be directed to install Leak detection & repair system (LDAR) as safety as well control measure. Fuel consumption in DG set operation in industrial should be regulated with stringent surveillance and made to follow stack emission standards with installation of efficient air control equipment. The dependency on DG set on power cut should be replaced by conventional source of energy. Industries should adopt stringent stack emission norms beyond those prescribed by CPCB Industries with periodic audits like QA/QC of units from both the parties.

(Contd..) : Emission Reduction Action Plan for Point Source

Point Sources	Short Term	Long Term	Action Plan
Red, Orange & Green fuel consumption from industries at Nashik City	Shift to cleaner fuels in both the category of industries– 50% of FO, LSHS, HSD to LDO, Coal & Others to NG	Shift to cleaner fuels – 100% All types of fuel to Natural gas	Inventorisation of prominent industries with technological gaps and detailed feasibility study is required as dispersion of pollution with modeling and formulate land can be used to devise regulatory policy. 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. The number of illegal MSI and SSI are left unaccountable. Their identification and consent to operation should be provided with proper regulations. Stringent regular monitoring should be initiated by the authority. Industries should be regulated to install air monitoring devices within their premises and same data should be regularly submitted to MPCB. Inter organizational stakeholder meetings and workshop should be held industry wise, so as to collaboratively devise measures that can be adopted within their operation and process. Fiscal measures can be shared on mutual understanding. NMC should make arrangements for provision of land to Industrial Authorities for the development of green zone in and around industrial region of Nashik MIDC areas
One tree will offset an average about 10 kg of CO_2 each year. According to this we will need 500 million additional trees in 2020 and 1200 million trees in 2051.			

4.5. Management

There are five AAQM locations covered under SAMP at SRO Office, KTHM College, MIDC Satpur, RTC Colony and NMC Nashik office. The Air Quality Index (AQI) of period January to February 2018 shows AQI is satisfactory (51-100) to moderate (101-200). The average concentration of SO_2, NOx and RSPM during this period was 7.04 µg/m^3, 22.47 µg/m^3 and 106.72 µg/m^3, respectively. The dominant parameter are Particulate matter & CO, attributed to growing vehicular traffic and construction projects as well as commercial and infrastructure development including road construction etc. A strategic approach towards Hierarchical and structured managerial system for efficient implementation should be initiated with information exchange to SPCB/CPCB (of monitoring devices).

There is a lack of collaborative policy initiative among the administrations and organization with regard to air quality improvement. These sources could be State Pollution Control Board, Regional Transport Office, Nashik Municipal Corporation, CIDCO, MIDC, Oil Companies, Anti-Adulteration Cell, and representative from ULB and NGOs, school and colleges. As and when, it is felt by the apex body that particular information desired is either site specific or city specific it can commission studies/ investigate on its own. Monitoring and regulatory agencies will provide all the information on monitoring to this body for data assimilation and dissemination. Regulatory framework, if needs can be communicated to the apex body for starting the initiative for policy formation.

Nashik stands at a crossroad in its history and development. With suitable urban interventions at this stage, it can avoid the pitfalls of cities of similar characteristics and can set high standards for other cities to follow. The city has the potential to become a global commercial and cultural centre that affords its citizens immense benefits in the form of jobs, opportunities, and improved quality of life. For this opportunity to become a reality, the city will have to develop adequate infrastructure and services to facilitate development and improve the quality of life of all its citizens, both rich and poor.

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-benefit 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. Nashik as a big metro city will provide the impetus of overall mitigation of GHG.

Chapter 5

5.1 Air Quality Dispersion Modeling

Air quality dispersion modelling exercise was also undertaken with a view to delineate the immediate sources and their impact on measurement locations. Dispersion modelling 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 24 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 61 stacks (1 m height) and 32 stacks (15 m height). 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, Nashik. 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 6 Nashik 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 94 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 Nashik city. The comparison of concentrations for the scenario has been carried out by considering the highest ten concentrations. **Figure 3** shows the Annual predicted concentrations of PM and NOx due to all sources.

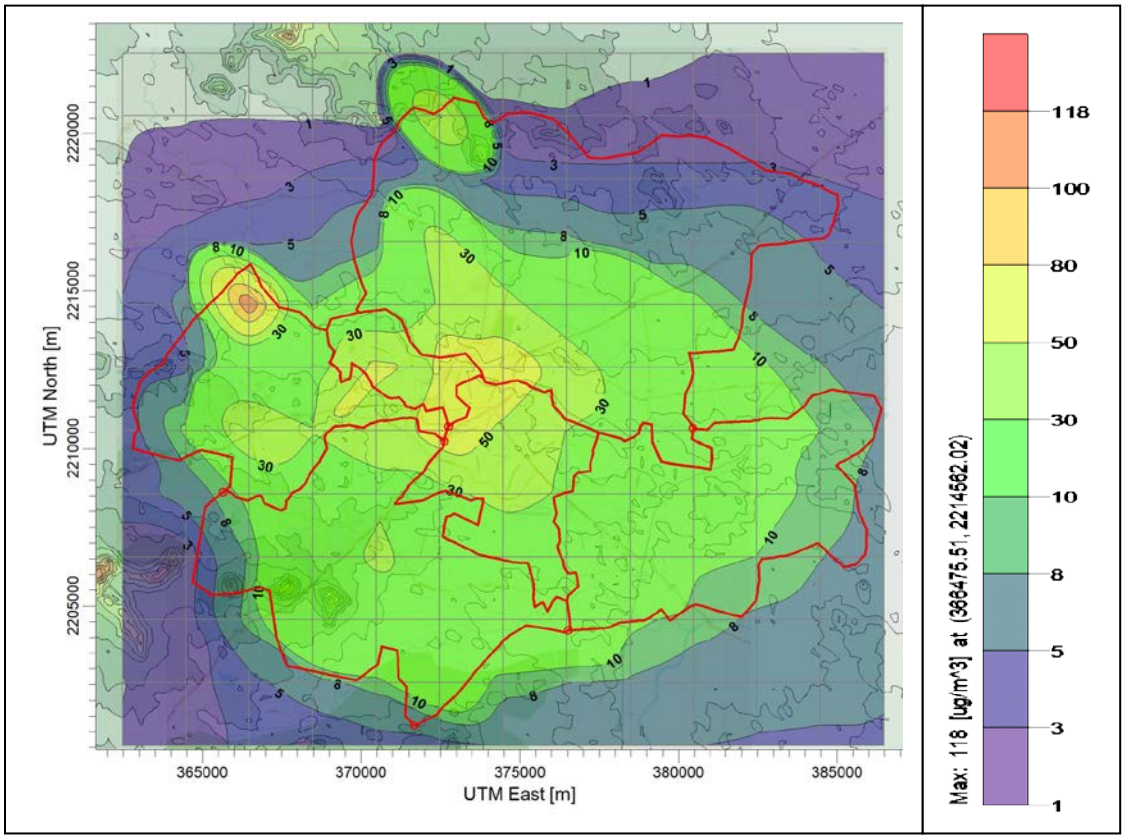


Figure 3a: AERMOD Predicted Concentrations of PM Due to All Sources – Annual (Nashik City)

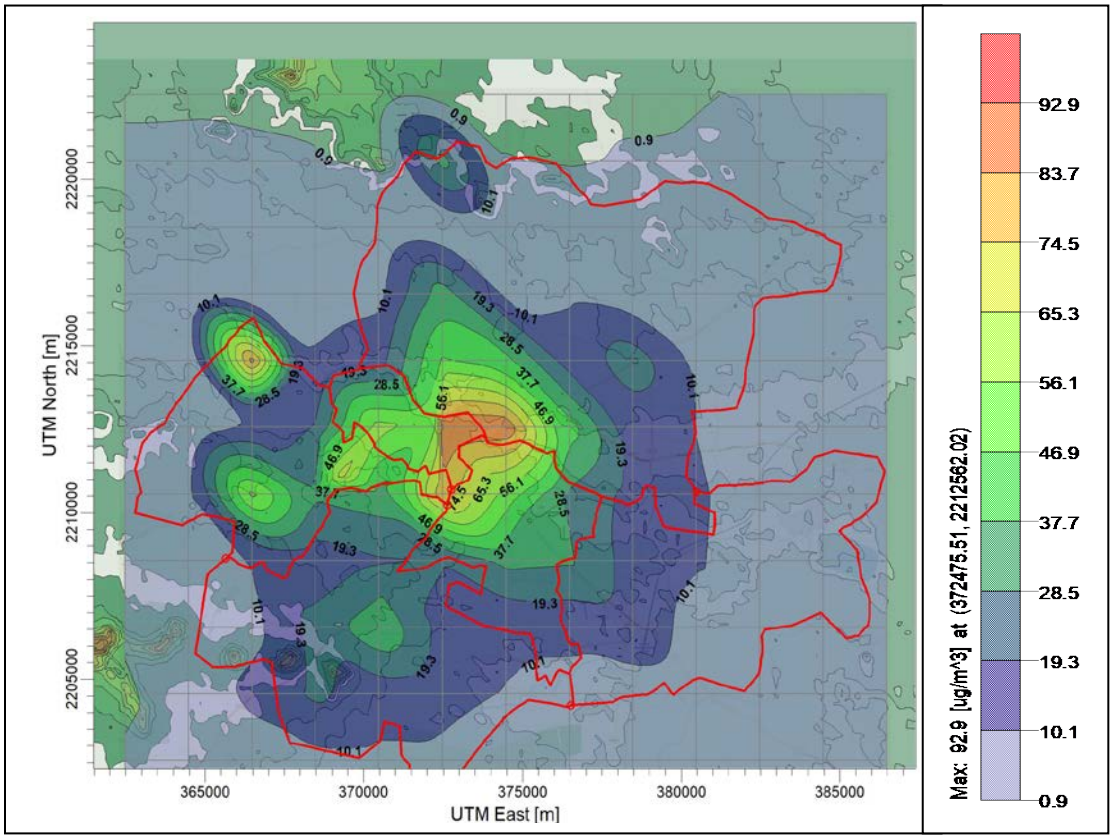


Figure 3b: AERMOD Predicted Concentrations of NOx Due to All Sources – Annual (Nashik City)

Draft Interim Submission

Annexure – I

Design of a Clean Tandoor Community Kitchen System (CTCKS)

Design of a Clean Tandoor Community Kitchen System (CTCKS)

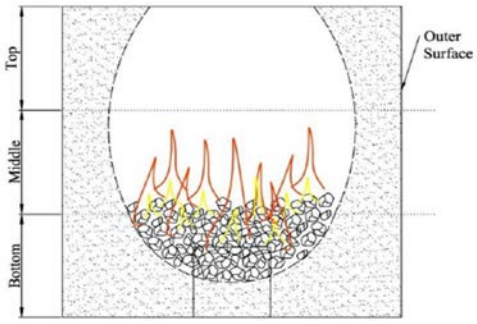
The objective of the experiment is to design a clean tandoor community kitchen system to reduce air pollution. There are no standards or guidelines to evaluate the performance of the tandoors w.r.t. its thermal efficiency, emissions and safety. While such standards are developed for the cook stoves however, 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.

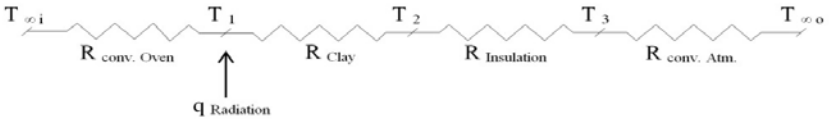
Advantages of pellet based tandoor also leads to reduced ash generation. Pellets based tandoor will also generate market for pellet industry and enable the use of agro-waste residues for development of an alternative fuel, promote employment generation in rural areas and would partly contribute to emission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

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):

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

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

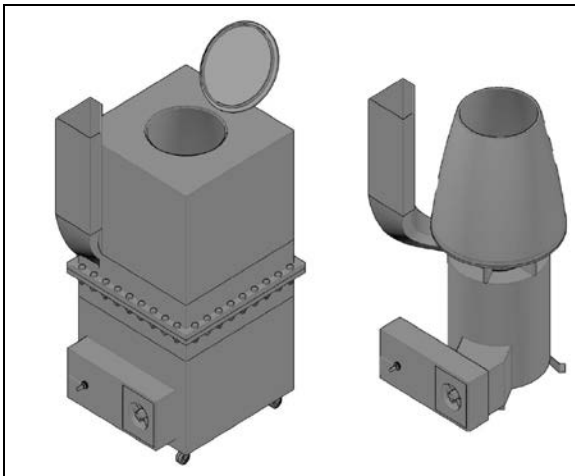


Fig.1 Pellet based Forced Draft Clean Tandoor Community Kitchen System (CTCKS) (a) With outer casing (b) Without outer casing

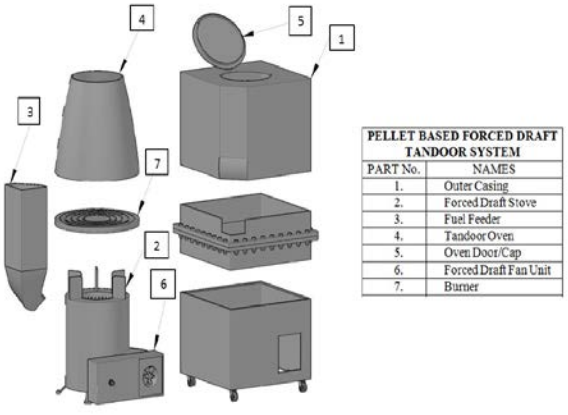


Fig. 2 Exploded view CTCKS: Inner Assembly & Outer Casing

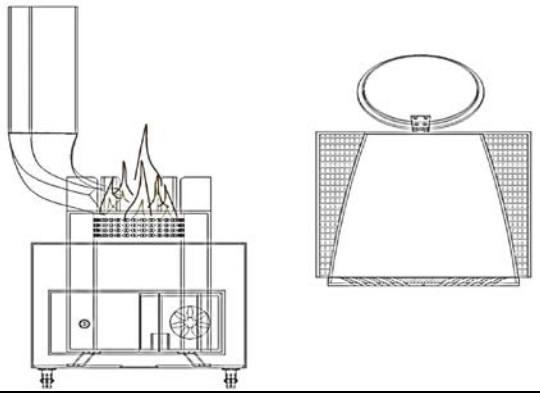
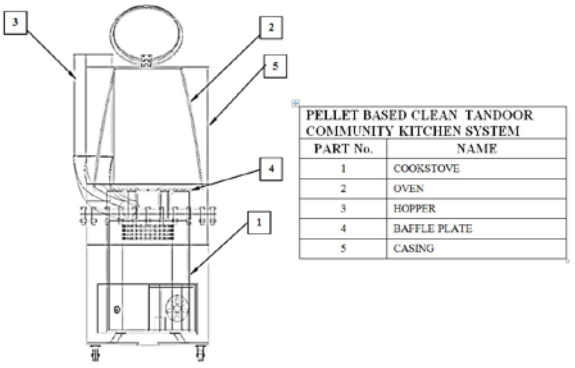
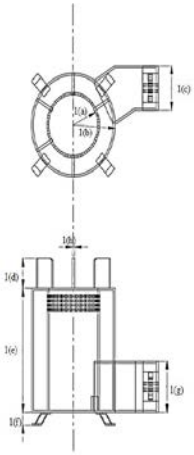


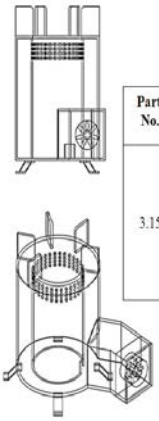
Fig. 3 Line diagram of CTCKS showing Combustion unit and Oven section (Dimensions not to scale)



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

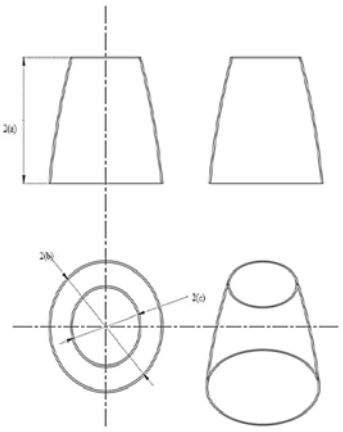
Fig. 4 Line diagram of CTCKS





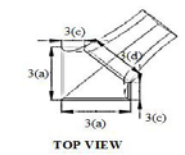
Part. No.	Dimensions (mm)	
3.15	a	170
	b	250
	c	80
	d	50
	e	400
	f	40
	g	80
	h	4

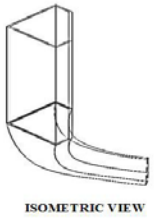
Fig. 5 Child Parts of CTCKS: Cookstove

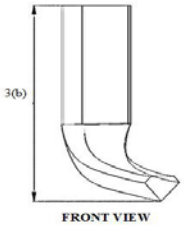


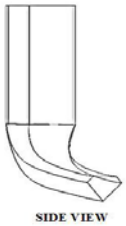
Part. No.	Dimensional Range (mm)	
3.16	a	450 – 500
	b	680 – 700
	c	300 – 350

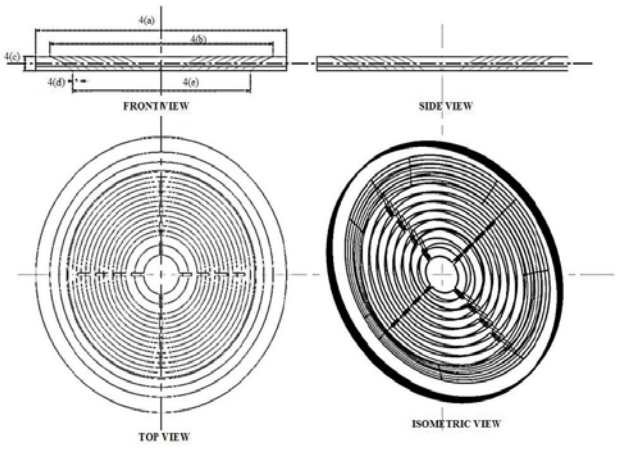
Fig. 6 Child Parts of CTCKS: Oven









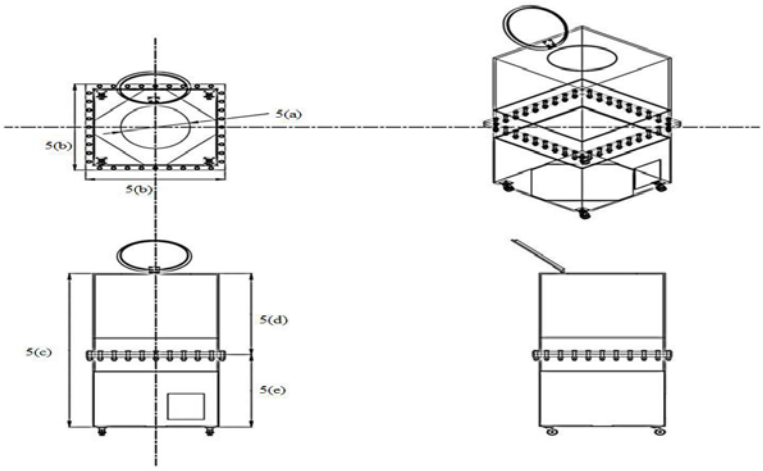


Part. No.	Dimensional Range (mm)	
3.17	a	160 – 180
	b	600 – 700
	c	80 – 100
	d	170 – 200

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	

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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.

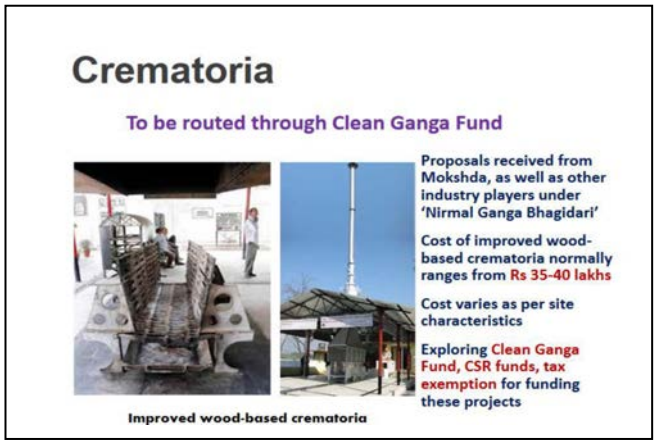
There has always been a controversy on the use of the electric crematoriums due to rituals as most persons follow the traditional burning of the bodies. In metropolitan cities it is promoted by the Government, private NGOs and environmentalists, but not to a great extent and most of these have failed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

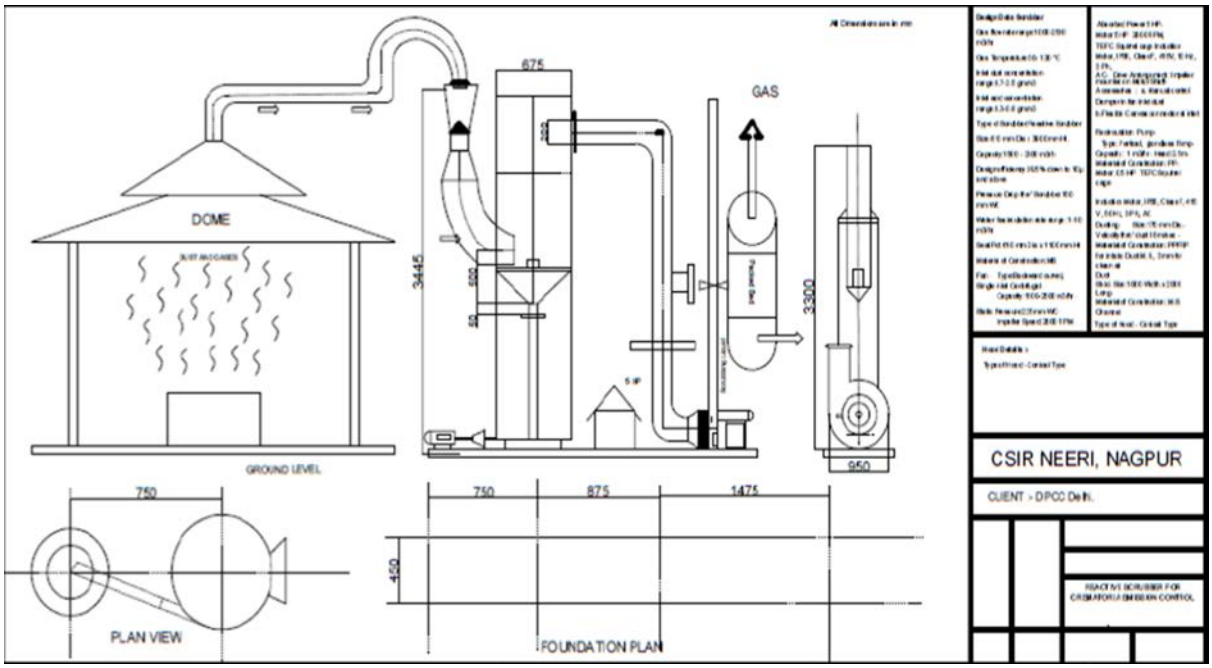


Figure 1 : Detailed diagram of emission control system for open type with side enclosed crematoria

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**.

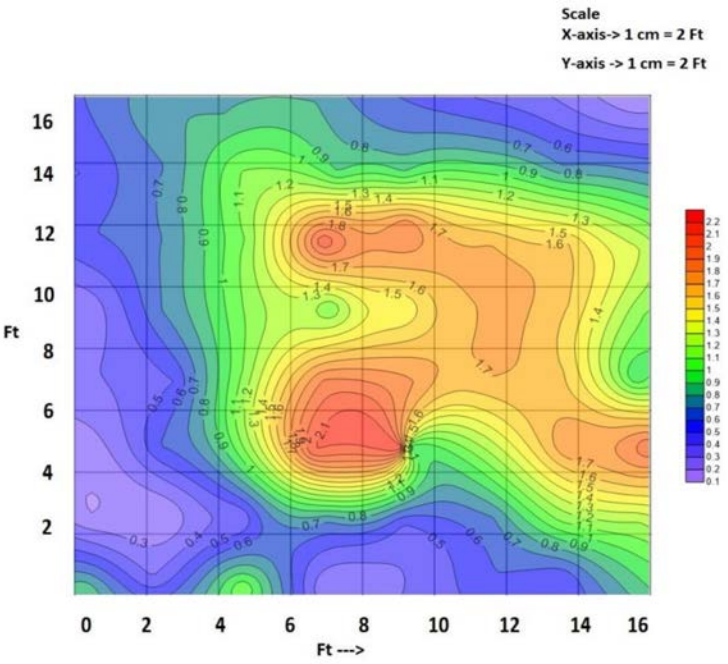


Figure 2 : Velocity profile of fumes during cremation

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.

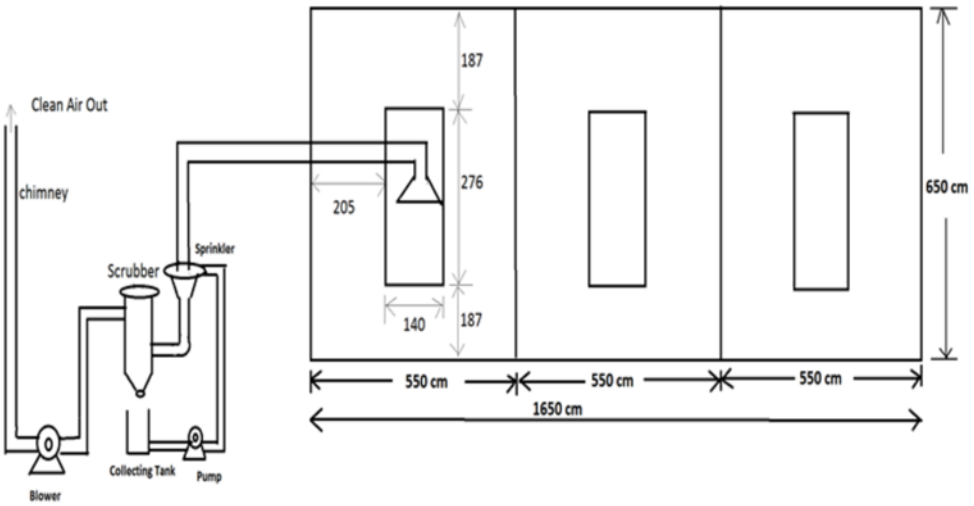


Figure 3 : Schematic view of Air Pollution Control System installed at Mokshadham Crematoria, Nagpur

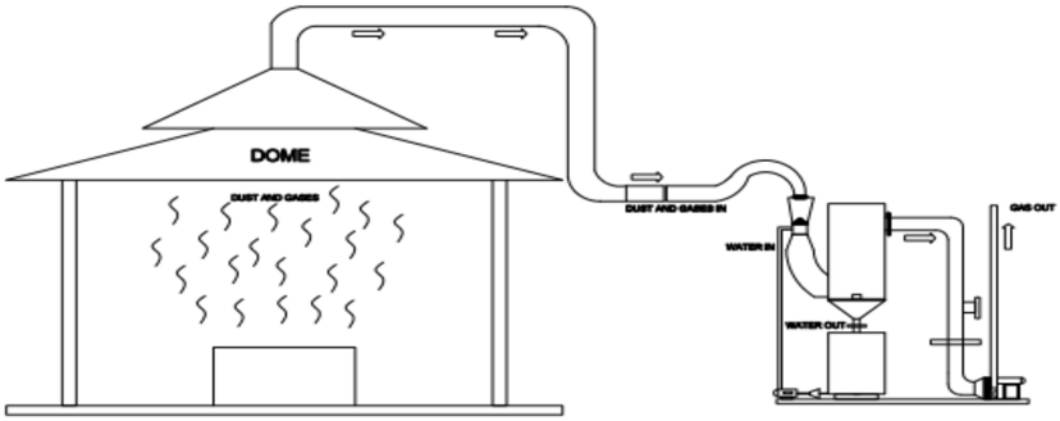


Figure 4 : Schematic view of Air Pollution Control System

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.

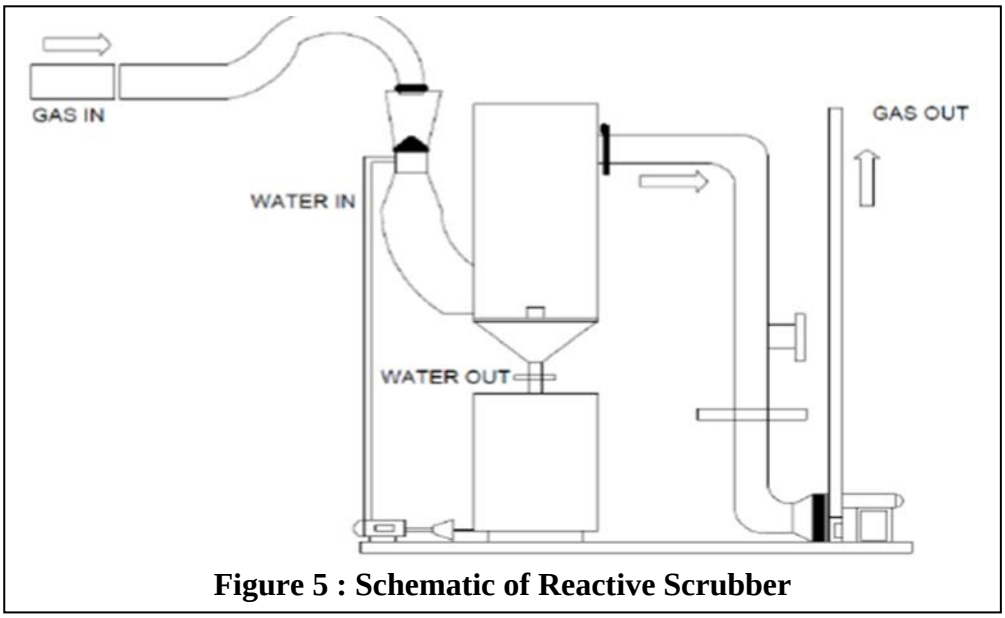


Figure 5 : Schematic of Reactive Scrubber

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.

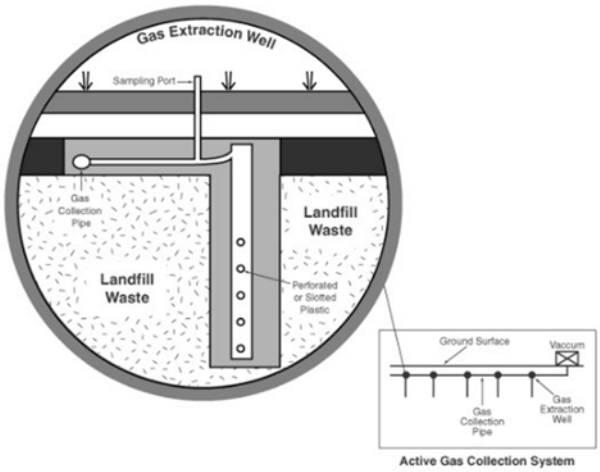
Most of the MSW generated is disposed of non-scientifically in open dumps, which causes a serious threat of landfill gas (LFG) emissions. The present note will focus on the landfill sites for the LFG emissions and designing the appropriate gas venting for the landfill sites.

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

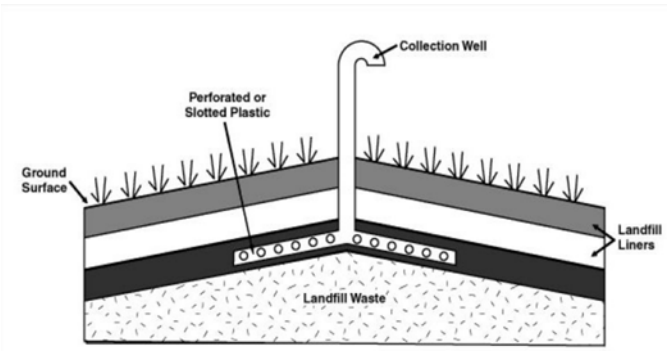
Well-designed active collection systems are considered the most effective means of landfill gas collection (EPA 1991). Active gas collection systems include vertical and horizontal gas collection wells similar to passive collection systems. Unlike the gas collection wells in a passive system, however, 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

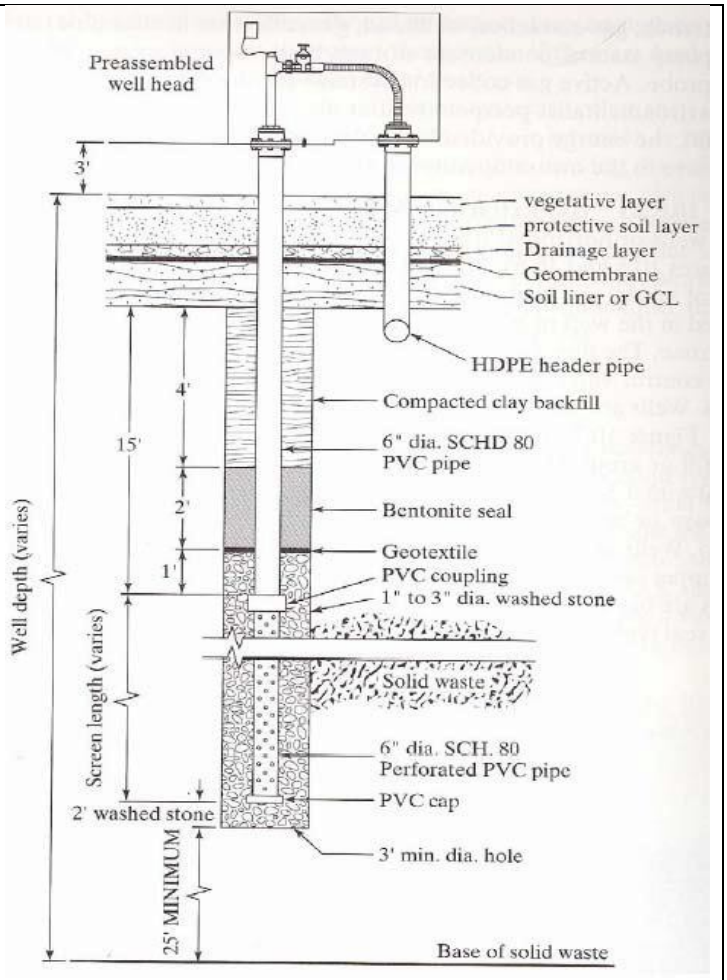
groundwater table. Vertical wells are typically installed after the landfill, or a portion of a landfill, has been closed. A passive collection system may also include horizontal wells located below the ground surface to serve as conduits for gas movement within the landfill as shown below. Horizontal 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).

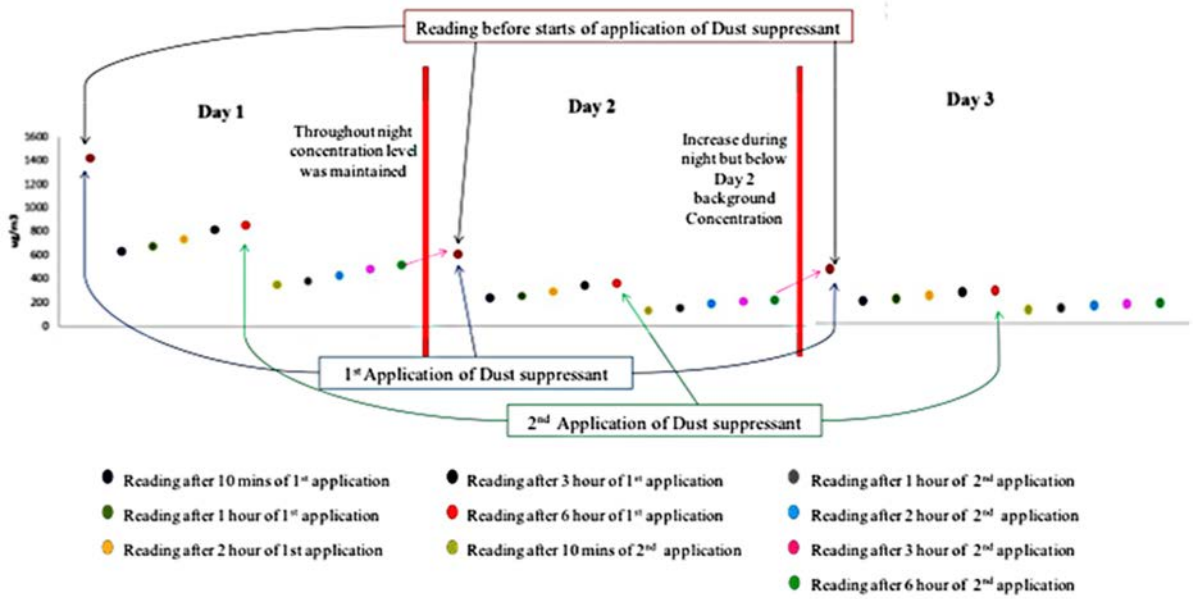
Advantages

- 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.



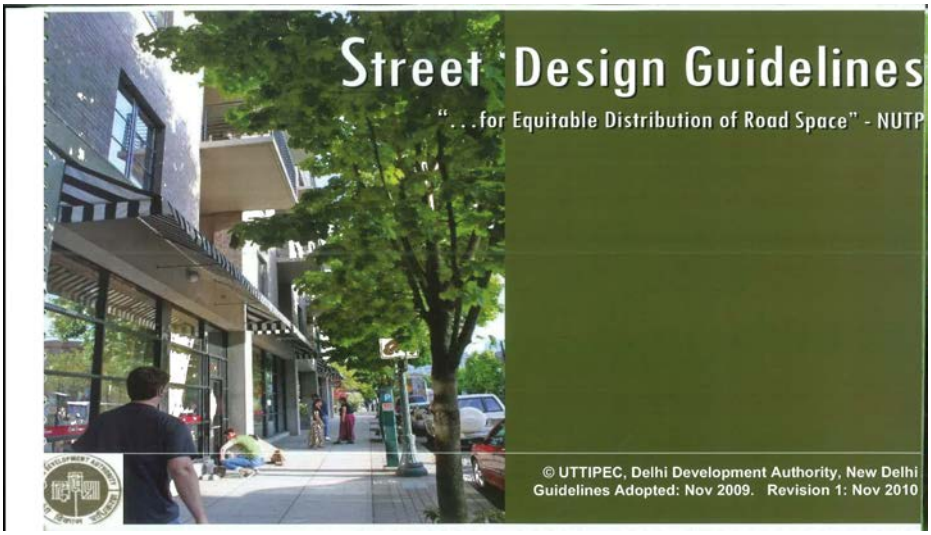
Bioswale : System for Storm Water and Dust Suppression Road Side

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.

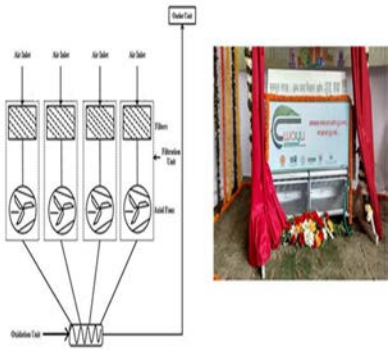
The device uses low speed wind generators, appropriate size filters for long operation cycle with reasonable efficiency. It also has an oxidizer unit for removal of Carbon-monoxide and Hydrocarbons including VOCs. The air is passed through the filters where the particulates are removed. The air generators 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.



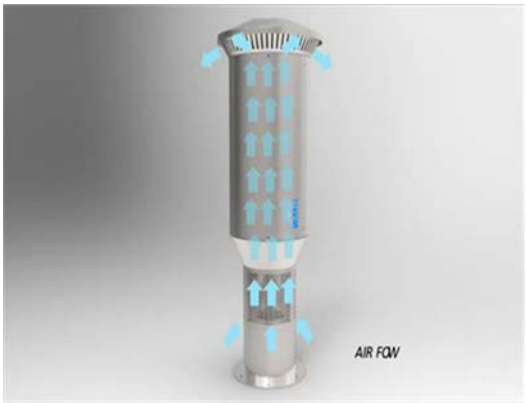
UV- TiO2 adsorption-photocatalytic oxidation has a lot of advantages. They are very efficient in removal of VOCs. Pichat et al. (2000) have shown that ozone can be directly eliminated by TiO_2 nanoparticles in a process that is promoted by both heat (in the ambient temperature range of 0° to 50°C) and 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.

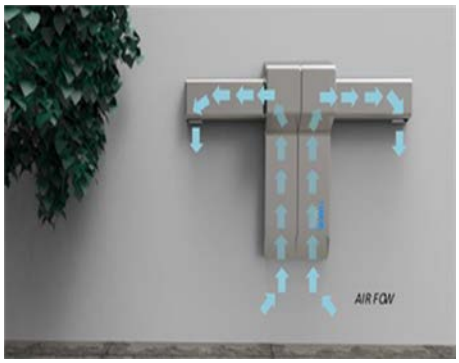
WAYU is a device jointly developed by IIT-CSIR-NEERI focused on controlling pollution in ambient air. WAYU has been successfully tested in a pilot project of 25 devices in Mumbai in collaboration with Maharashtra Pollution Control Board (MPCB). With an aim to solve the ever rising menace of air pollution 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



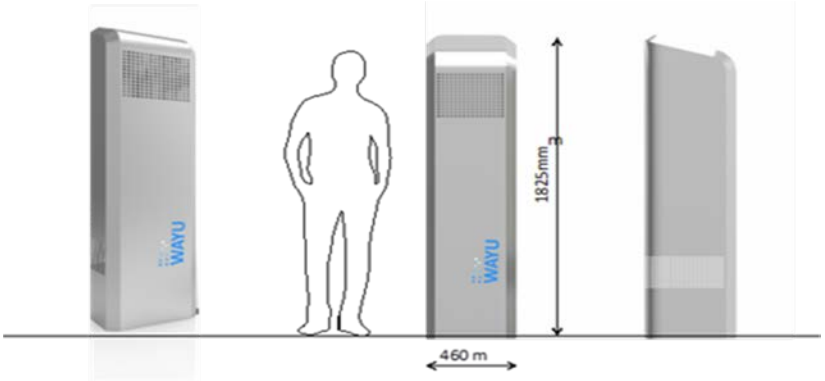
WAYU device improved design



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.