Draft Interim Report

Air Quality and Emission Source Apportionment Studies for

Ten Cities of Maharashtra

AURANGABAD CITY

Sponsor

Maharashtra Pollution Control Board, Mumbai

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Contents

List of Tables

List of Figures

List of Annexure

Chapter 1

1. Introduction

1.1 Background of the City

Aurangabad District is located mainly in the Godavari River Basin and partly in the Tapi River Basin. The district is from 19 to 20 degrees north longitude and 74 to 76 degrees east latitude. Aurangabad city is situated on the bank of river Kham a tributary of the Godavari River. The entire city is situated at the latitude of 19°53'50" N and longitude of 75° 22'46" E. It is located 512 meters above Sea Level. The city is surrounded by hills of the Vindhya Ranges and the river Kham passes through it.

The city is a tourism hub which is surrounded by many historical monuments including the Ajanta Caves and Ellora Caves which are UNESCO World Heritage Sites. Bibi Ka Maqbara and Panchakki are also tourist's places in Aurangabad. Aurangabad is the administrative headquarter of the Aurangabad Division or Marathwada region and is entitled as "The City of Gates" and the strong presence of these can be felt as one drives through 52 gates in the city.

According to the evaluation of 2011, the city had a population of 1.1 Million. In order to check out the population of Aurangabad in 2020, we need to have a look at the population of the past 5 years. It has been seen that every year (2012-17) the population increases by 0.22 Million. So the population of Aurangabad is forecasted to reach 4.4 Million by 2020.

1.2 Demographic Structure of the City

According to the 2011 Indian Census, Aurangabad has a population of 11,75,116, of which 6,09,206 are males and 5,65,910 are females. Population in the age range of 0 to 6 years is 1,58,779. The total number of literates in Aurangabad was 8,89,224 which constituted 75.67% of the population with male literacy of 79.34% and female literacy of 71.72%. The effective literacy rate of Aurangabad was 87.5%, of which male literacy rate was 92.2% and female literacy rate was 82.5%. There were 2,36,659 households in Aurangabad in 2011.

Aurangabad has central MSRTC bus stand for public transport centre. Buses are available to every major bus depots of Maharashtra. The city has one more additional bus stand name as CIDCO bus stand. This is constructed for serving load of old bus stand. Ola Cabs service is available in city. Aurangabad railway station is the major railway station under Nanded railway division of the South Central Railway zone. It is located on the Secundarabad-Manmad section. The city has rail connectivity with major cities such as Hyderabad, Delhi, Nizamabad, Nagpur, Nasik, Pune, Nanded and Latur Road. This railway line runs on diesel locomotive engines. Aurangabad Airport (Chikhalthana Airport) is an airport serving the city and has connecting flights to all major cities of the country.

Aurangabad Municipal Corporation (AMC) is the local civic body. It is divided into six zones. The Municipal Council was established in 1936, the Municipal Council area was about 54.5 km^2. It was elevated to the status of Municipal Corporation including eighteen peripheral villages, making the total area under its jurisdiction to 138.5 km^2 extended its limits. The city is divided in 115 electoral wards called as Prabhag.

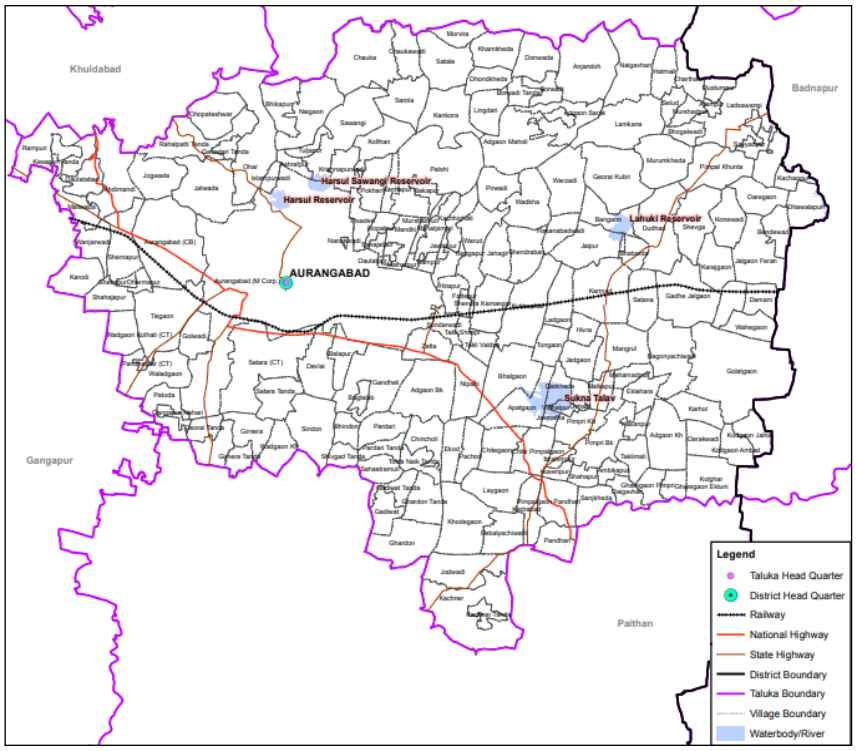

Fig. 1.1: Map of Aurangabad Tehsil

Fig. 1.2: Municipal boundary of Aurangabad city

Table 1.1: Summary of Demographic Structure in Study Area

S. No.	Demographic Parameters	Aurangabad Municipal Corporation
1	State/District	Maharashtra/Aurangabad
2	No. of Wards/Prabhags	115
3	Total No. of Households	236659
4	Total Population	1309106
6	Sex Ratio (Females/100 males)	923

According to 2011 Census, the sex ratio in the District is recorded as 923. This is lower compared to the State average 929 (Source: Primary Census of Aurangabad District, Maharashtra state, 2011).

1.3 Climate and Meteorology

The climate of the District is characterised by a hot summer and general dryness throughout the year except during the south-west monsoon season. The year may be divided into four seasons. The cold season is from December to February and is followed by the summer

season from March to May. The south west monsoon season is from June to September while October and November constitute the post-monsoon season.

The average annual rainfall of Aurangabad is 731.0 mm. In general, the amount of rainfall increases as one proceeds from west to east. About 83 per cent of the total annual rainfall is received during the south-west monsoon season. July is the rainiest month of the year. Some rainfall occurs during May, October and November and is mainly in the form of thunder showers. The variation in the annual rainfall from year to year is large.

The summer season from March to May is a period of rapid and continuous increase in both day and night temperatures.

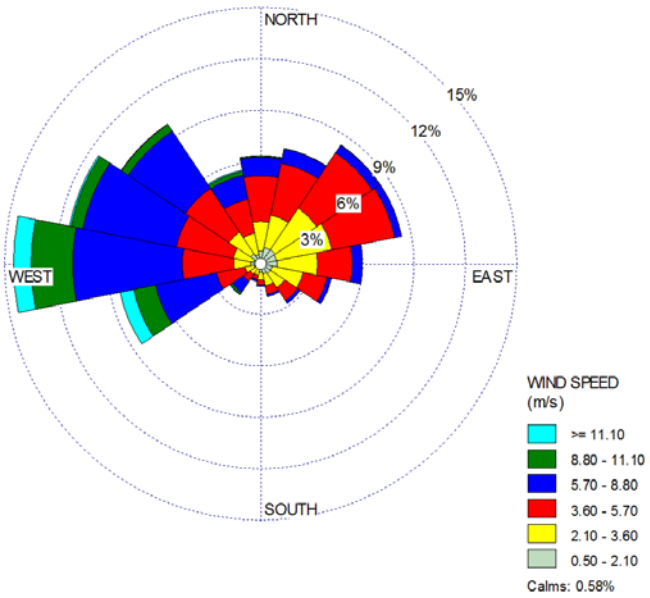

Fig.1.3: Windrose pattern

1.4 Industry

Industrially Maharashtra is one of the advanced States in the country and Aurangabad is one of the developing Districts of the State. Now a day's Aurangabad attracts many industrialists and many large scale industries have been started in the since past like two-wheelers, Videocon, Colgate, Garware Plastics, Crompton and Pharmaceutical companies are functioning in the District. Other small scale industries are also in Aurangabad District such as oil mill, ginning, dairy products, leather goods, wool weaving etc. Aurangabad District is famous for Himroo mashroo weaving industries. Paithan has been associated with fine silk

Paithani sarees. Agriculture is the main economic activity of the District. The raw materials available in the District are mostly agricultural products like cotton, groundnut, sugarcane etc. These materials have encouraged the establishment of number of ginning factories and sugar factories in the District.

1.5 Trade and Commerce

The District is famous for Himroo cloth and Paithani sarees. The chief manufactured articles are two wheelers, industrial goods, chemicals, wine, tyres, animal skin, sugar cane, wheat, cotton, tobacco, food grain, wooden furniture, agricultural instruments, medicines, plastics, sugar, Jowar, groundnut, bidi etc. and chief exported commodities are medicines, polyester films, tyre, milk, animal skin, sugar, cotton bales, Jowar, auto parts, industrial goods, maize, Paithani sarees etc., are exported to all over India and overseas also. The chief imported commodities are wheat, rice, cloth, cotton and sugar cane etc. Most of these goods are imported from surrounding places. Apart from the weekly markets and fairs Aurangabad, Paithan, Vaijapur and Sillod are important trade centres also.

Chapter 2

2. Status of Air Environment

2.1 Ambient Air Quality – Secondary Data

The Annual average concentration of ambient air quality data for Aurangabad city is analysed from MPCB data and it is observed that the levels of pollutants are increasing annually. The table represents the values of RSPM & SPM for the last five years (2009-2016). Based on last 5 year NAMP (national Ambient Monitoring Plan) data obtained from the MPCB website, PM_{10}, SO_2 and NO_2 concentration is plotted. Since MPCB provides the AAQ data on SPM, RSPM.

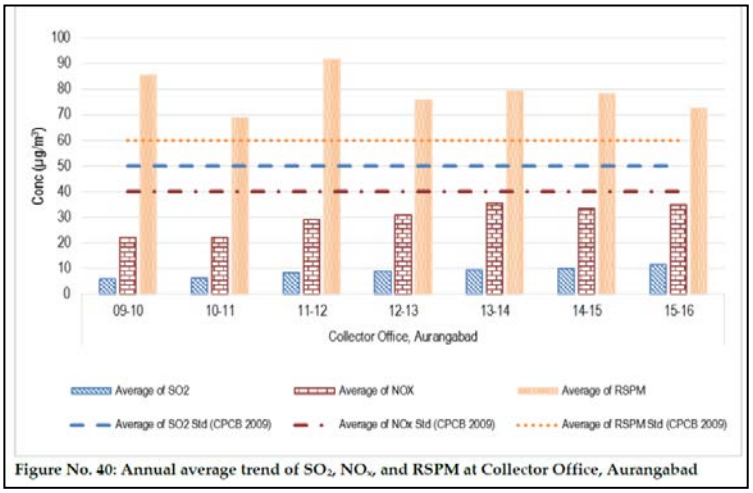

Figure No. 40: Annual average trend of SO_2, NO_x, and RSPM at Collector Office, Aurangabad

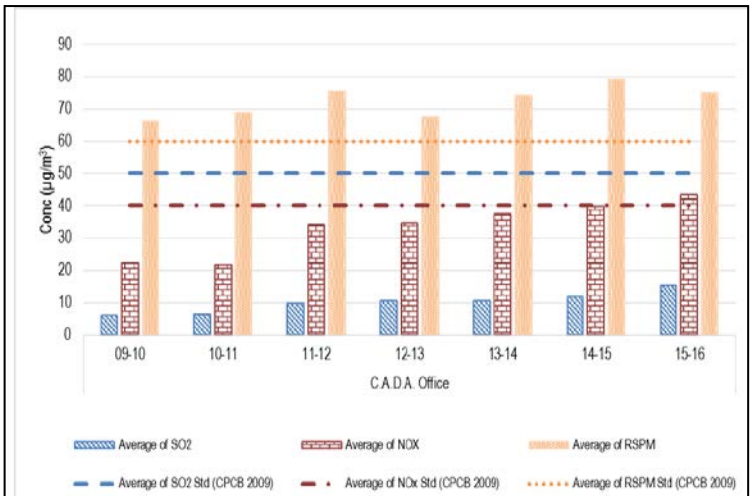

Figure No. 42: Annual average trend of SO_2, NO_x, and RSPM at C.A.D.A. Office - Aurangabad

Fig. 2.1: Average AAQ for Aurangabad city

2.2 Current Ambient Air Quality

Ambient air quality monitoring exercise was carried out keeping in view the protocol for source apportionment (SA) study. CPCB guidelines document for source apportionment through receptor modeling was followed**.** Monitoring for particulate Matter of diameter 10 micron and 2.5 micron (PM_{10} and $PM_{2.5}$, respectively) was carried out following the standard operating procedures prescribed in CPCB guidelines document on SA studies. The sampling was carried out at 4 sites selected based on the land-use activity and dispersion modeling results. The location of the sites is given in **Fig. 2.2.a**. The description of the sampling sites is given in **Table 2.1**. The results are shown in **Fig.2.2.b.**

Table 2.1: Description of Sampling Sites

Sampling Location	Type	Geographic Location	Characteristics
University Campus	Reference	19°53'45.30"N 75°18'43.61"E	1 km away from Main road of the city, near BAMU staff quarters. Internal road 0.5 km away from the site.
MPCB Office	Industrial	19°52'26.07"N 75°23'10.64"E	1km away from Nagpur-Mumbai Highway, unpaved roads nearby
Padampura	Commercial	19°51'57.58"N 75°19'7.27"E	Hotels, Shops, continuous flow of vehicles (autorickshaws), near to railway station
Garkheda	Residential	19°51'40.23"N 75°20'42.35"E	2 kms away from highway, cement road construction going nearby

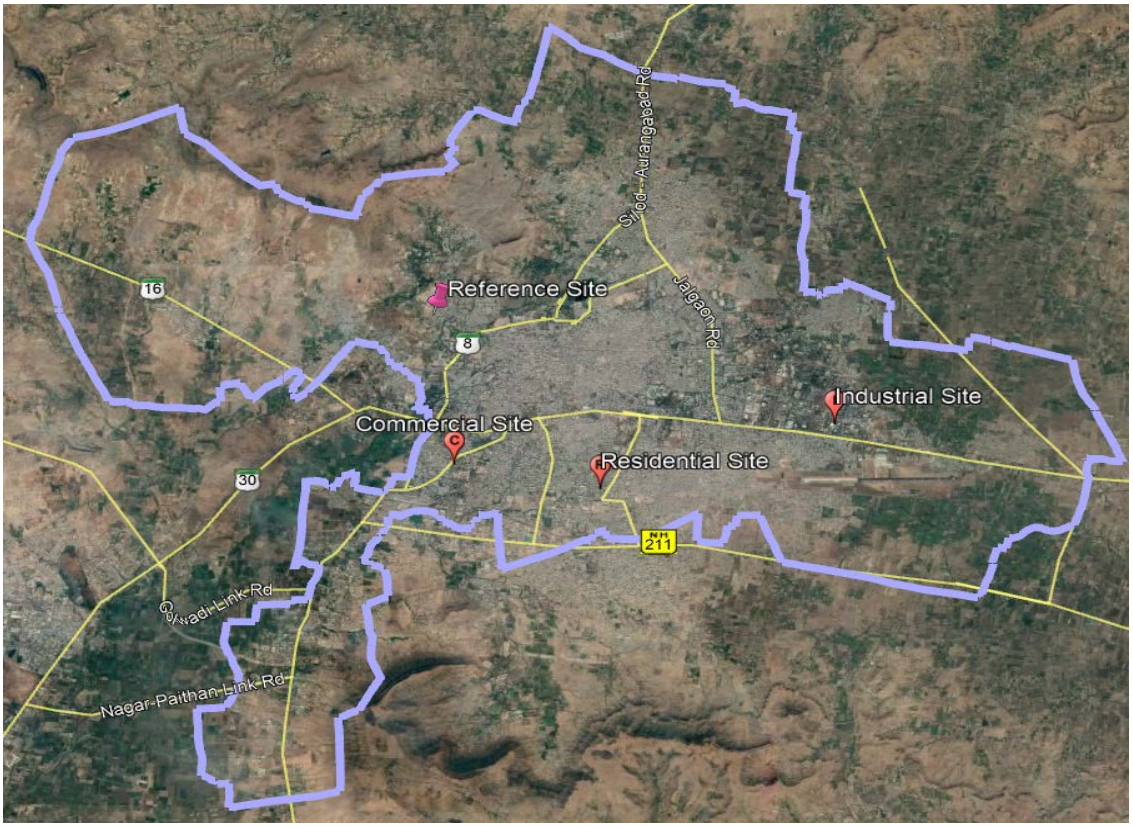

Fig. 2.2.a: **Location of sampling sites**

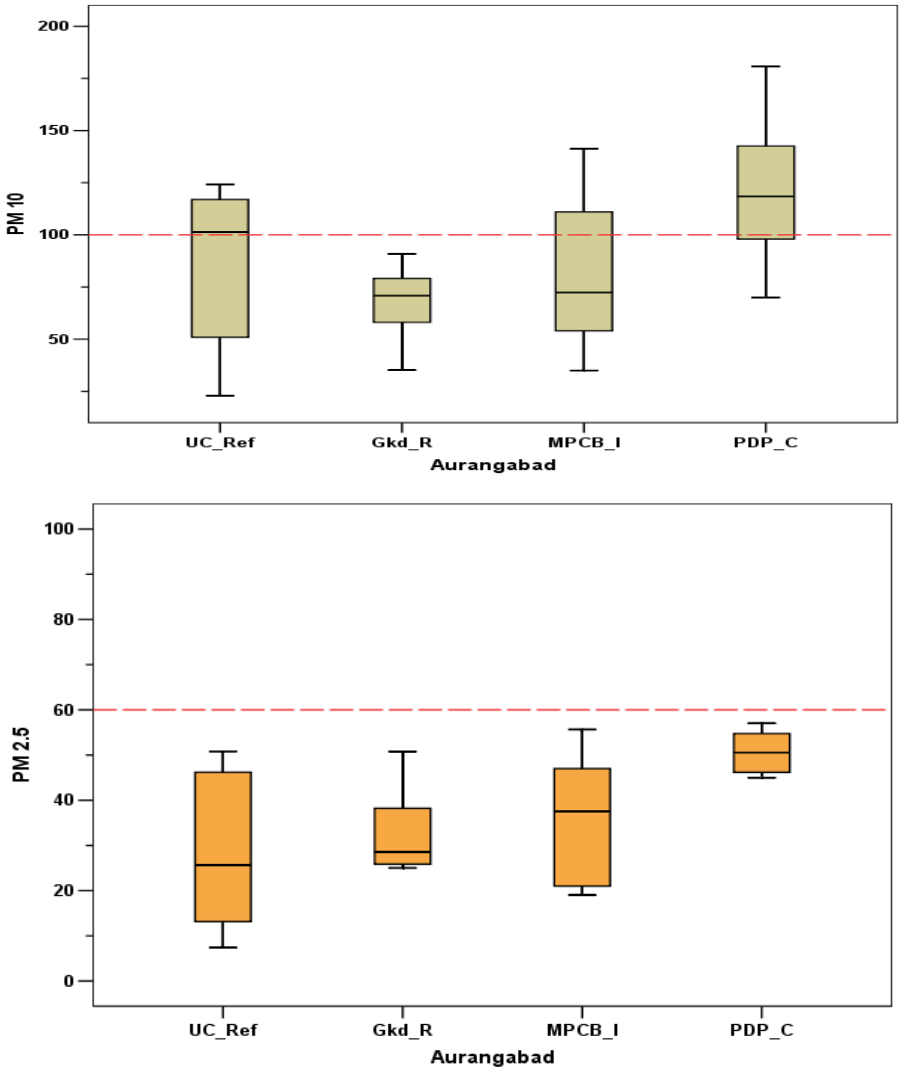

Fig.2.2.b: PM_{10} and $PM_{2.5}$ monitored values

Air quality status at four sites in terms of PM_{10} and $PM_{2.5}$ is given in **Fig. 2.2.b**. It can be seen that PM_{10} concentration violated the CPCB threshold (100 $\mu g/m^3$) during the entire study period at commercial/traffic site (Padampura) and slightly high concentrations were seen at reference site (University campus). It was due to heavy traffic load on roads and the open burning activities in commercial area. At university campus site, open burning was seen daily and a stone crusher was seen in operation 2 kms away from the site. At residential site (Garkheda Parisar), PM_{10} was below standard limit. At industrial site (MPCB office), PM_{10} is observed to be slightly higher than the standard concentration. This may be due to poor roads condition in industrial areas and due to industrial activities. The $PM_{2.5}$ on the other hand is observed to be below the CPCB threshold of 60 $\mu g/m^3$ at all the sites except at commercial area (Padampura).

Chapter 3

3. Emission Inventory

3.1 Introduction

The general sources based on Point, Area and Line source category are considered to facilitate the preparation of emission inventory. Data requirement for preparation of emission inventory along with its probable sources is presented in **Table 3.1.** For area sources, the emissions from domestic fuel consumption, bakeries, hotels, dhabas and open eat outs are considered. The details of the respective sources are given in the appropriate sections. For the emission load estimation from area source and point source, emission factors derived by CPCB and USEPA are used, for vehicular source ARAI/CPCB has provided the emission.

Table 3.1: Data Requirement and Probable Sources for Preparation of Emission Inventory

No.	Task	Data Required	Probable Source
1.	Mapping of road network and other details for delineation of zones / sector	Base maps, road network details, population density, industrial activities	Traffic Commissioner, RTO, Municipal ward office
2.	Emission inventory for vehicular sources	• Secondary data on vehicle counts and locations, in-use vehicle population • Registered data on vehicles (year-wise) and growth rate for past 15 years • Vehicle usage characteristics • Number of garages/service centers.	• Transport commissioner's office, RTOs, Reports, SIAM etc. • Primary data through questionnaire • Petrol pumps/Local Agencies/Marketing Terminal/PUC centers/Parking lot/ • Vehicle service centers/Individual vehicle owner

		• Number of PUC centers • Planned technological interventions • Sale of Petrol/Diesel/ LPG per month • Emission factors for emission load estimation	
3.	Emission Inventory for Industrial Sector	Major types of air polluting industries - Fuel usage (quantity), fuel type (quality) and pollutant load from various industries	PCB, CPCB, Industrial Development Corporation, Industries Association, Fuel supply agencies
4.	Emission Inventory for Area Sources (residential and commercial sector)	• Population and demography • Data on domestic fuel • Number of registered hotels, Restaurants, bakeries etc., • Number of Crematoria • Data on refuse burning • Data on Incinerators • Sale of LPG/kerosene/coal/ wood	Census office, Municipal Corporation. District Collector's office, District fuel supply office, Rationing office, Fuel supply dealers, Development Authority, Associations of Hotels, Restaurants, Bakeries, Health department of Municipal Corporation. Primary data through questionnaire Residential/Hotels and restaurant owners/bakery owners /commercial establishments/ crematoria

3.2 Area Sources

The individual sources that cannot be considered as point and mobile / line sources are categorized as area sources, which includes; bakeries, open eat outs, hotels/restaurants, crematories, construction, domestic cooking, paved/unpaved road dust, solid waste burning. The details of the major area sources in short are given below. The details on the solid waste generation and construction activities are given in the respective sections.

3.2.1 Domestic and Commercial Combustion

3.2.1.1 Bakery

There are total 147 bakeries registered in the city. Major fuel used in bakeries is coal, wood and LPG. Out of 147 bakeries, 78 bakeries uses coal, 57 bakeries as wood and 12 bakeries uses LPG as fuel for the production of bakery products.

Emission Estimates:

Emissions (Kg/d) = No. of Bakeries x Fuel Consumption (Kg/d) x Emission Factor

The PM emission load from bakeries is given in **Table 3.2**.

Table 3.2: Emission Load from Area Sources – Bakery

Source	Fuel/Type	PM_{10} (TPD)	$PM_{2.5}$ (TPD)
Bakery	Wood	0.006	0.0045
	Coal	0.001	0.0005
	LPG	0.008	0.0005

TPD-tons/day

3.2.1.2 Open Eat-outs

Based on the survey, it was observed that 131 open eat out units are operating in the city. All the units were operated on LPG. Maximum open eat outs contains tea stall. Average operating hours of street vendors is 12 hours. The actual number of tea stalls/snack bars/fast food centres could be more than the observed number, however the data collected by survey is considered for the emission estimates.

Emission Estimates:

Per capita consumption for each type of fuel is taken as

Total emissions = LPG burning

Emission from fuel burning (PM) per day

= Number of street vendors operating on particular fuel x fuel consumption per day x emission factor

The PM emission load from open eat-outs is given in **Table 3.3**.

Table 3.3: Emission Load from Area Sources – Open Eat-outs

Source	Fuel/Type	PM_{10} (TPD)	$PM_{2.5}$ (TPD)
Open eat out	LPG	0.00306	0.00204

3.2.1.3 Hotels and Restaurants

There 344 hotels in the city. Hotels and restaurants are mostly LPG based (99%).

Emission Estimates:

Emission Load from LPG

Only $PM_{2.5}$ emissions are present in the LPG

Total emissions ($PM_{2.5}$) due to LPG burning in Hotels

= Number of Hotels x LPG consumption (TPD) x Emission Factor (Kg/MT)

Emission Load from Coal

= No. of Hotels x Coal consumption (TPD) x Emission Factor (Kg/MT)

The PM emission load from hotels is given in **Table 3.4.**

Table 3.4: Emission Load from Area Sources – Hotels & Restaurants

Source	Fuel/Type	PM_{10} (TPD)	$PM_{2.5}$ (TPD)
Hotel	LPG	--	0.005
	Wood	0.002	0.0013
	Coal	0.003	0.002

3.2.1.4 Crematoria

There are 22 crematories in the city. About 3338 number of bodies/year are burnt. Crematoria are operating as wood and kerosene based units. Based on the survey, it was observed that the wood consumed per body is 300 Kgs and kerosene consumed per body is 5 litres.

Emission Estimations:

Emission (TSP) =No. of Hindu Death /yr * wood required per body (Kg) * emission factor + Number of Hindu Death /yr * kerosene required (litres) * emission factor

The PM emission load from crematories is given in **Table 3.5.**

Table 3.5: Emission Load from Area Sources – Crematories

Source	Fuel/Type	PM_{10} (TPD)	$PM_{2.5}$ (TPD)
Crematoria	Wood	0.0183	0.0122
	Kerosene	0.000039	0.000026
	Cowdung	0.00025	0.00017

3.2.1.5 House Hold Fuel Consumption

There are 115 Prabhags in the city. The emission load is however calculated based on the data from the report of Census of India (2011). As per the Prime Minister Ujjawala Yojana, 2017, report the consumers for LPG use are increasing day by day. The distribution of the fuel consumption pattern of the households is given below (**Table 3.6**);

Table 3.6: Distribution of Domestic Fuel Consumption Pattern

No. of households	Firewood	Crop residue	Cow dung	Coal	Kerosene	LPG
315530	1578	63	631	1262	6571	3944

For emission calculations, the quantity of fuel required per house is assumed as given in table 3.7. (NEERI Mumbai SA study report)

Table 3.7: Assumptions of Per Capita Fuel Consumption Pattern

Fuel	**Per capita consumption**	**Unit**
LPG	12	Cylinder/y
Kerosene	0.833	L/d
Wood	4	kg/d
Coal	5	Kg/d
Cow dung	3	Kg/d
Crop residue	3	Kg/d

3.2.1.6 Recommendations

- The fuel used in hotels, bakeries, open eat outs can be reduce or shifted to alternate fuel pattern.

- Bakeries must use electric ovens for the production of bakery products.
- Crematories need installation with efficient pyres and chimneys for release of emissions.
- Crematories must be shifted from wood to biomass briquettes to reduce PM emissions.

3.2.1.7 Solid Waste Emissions

Aurangabad is grappling with the issue of garbage disposal. Aurangabad generates about 500 Metric ton (MT) of municipal solid waste. Villagers said no to dump the municipal garbage in Naregaon. The AMC is under identifying new site for solid waste dumping and is working for new methods to reduce the solid waste generation along with local NGOs. New dumping site is yet to finalize by Aurangabad Municipal Corporation. Still the problem was MSW dumping is not solved. There are in all 120 vehicles which comprise of tractors & hydraulic loader Autos and tipper trucks for lifting and transportation of MSW. Vehicles collect garbage and transport to Naregaon landfill site. Overall 10% of the solid waste generated is disposed off. The AMC is under identifying new site for solid waste dumping and is working for new methods to reduce the solid waste generation along with local NGOs. New dumping site is yet to finalize by Aurangabad Municipal Corporation. Still the problem was MSW dumping is not solved. A notice inviting expression of interest dated Feb 05, 2018 is available at AMC website to make available necessary land for segregation of dry and wet waste generated in Aurangabad Municipal Corporation area.

The PM emission load from open burning of MSW is given in **Table 3.8**.

Table 3.8: Emission Load from Area Sources – Solid Waste Burning

Source	**PM_{10} (TPD)**	**$PM_{2.5}$ (TPD)**
Open burning	0.002	0.0015

3.2.1.8 Recommendations

1. Urgent need to identify the landfill site for MSW treatment and processing.
2. Collection and transportation facilities required in evening hours at commercial areas.

3.2.2 Other Area Sources

3.2.2.1 Construction

There are total 209 numbers of building construction sites in Aurangabad city. The total construction is spread over a land of 202 acres. Out of 209, 50 projects construction is yet to start (data from RERA website). The year of completion for all construction sites is December 2020.

Emission Estimation:

PM_{10} Tons /years = 1.2 x total number of acre – months (AP42, Section 13.2.3.3)

Acre-months: construction area (acres) x months of activity (18 for new and 6 for old/on-going construction)

The PM emission load from construction activity is given in **Table 3.9**.

Table 3.9: Emission Load from Area Sources – Construction

Source	Type	PM_{10} (TPD)	$PM_{2.5}$(TPD)
Construction	Building	0.072	0.0321
	Road	0.081	0.052

3.2.2.2 Road dust

Due to poor roads and no wall to wall pavements, dust is seen deposited all over the corner of roads. This leads to resuspension of dust. The roads need urgent repairment with a layer of bitumen.

Table 3.10: Road Length in the City

Road Type	Length (Km)
Bitumen	560
Concrete Road/Paver block	213
WBM	562
Un surface Road	316
Total	1651

Table 3.11: Vehicle Weight

Vehicle	2w	3w	4w	Bus/Truck
Weight (Kg)	175	450	1425	7500

(Source: NEERI Report-Mumbai, 2010)

Emission Estimates:

Paved Road dust

Emission factor, $E\_Pvd = \{k \times (sL/2)^{0.65} (W/3)^{1.5} - C\} (1-P/4N)$

E = particulate emission factor (having units matching the units of k)

k = particle size multiplier for particle size range and units of interest (k (g/vkt) = $PM_{2.5}$ -1.1, PM_{10}-4.6)

sL = road surface silt loading (grams per square meter) (g/m^2) – 0.531(Source: NEERI Report-Mumbai, 2010)

W = average weight (tons) of the vehicles traveling on the road (as per above table)

P=No. of wet days with at least 0.254 mm of precipitation during avg. period (assumed 120 days)

C= Break and tire wear correction ($PM_{2.5}$=0.1005, PM_{10}=0.1317)

N = No. of days in averaging period (365 /year, 30/monthly, 91/seasonal);

Emission from Paved Road (g/d)= E_Pvd (g/VKT) x VKT (km/d)

Emission Estimation for Unpaved Dust

Emission factor, $E\_unpvd = \{([k (s/12)^a (S/30)^d] /(m/0.5)^c - C)\} *(365-P)/ 365$

E = size specific emission factor, (lb/vmt),

s= surface material silt content (%), m= surface material moisture content (%),

S=mean vehicle speed (mph);

k =particle size multiplier (lb/vmt) (PM2.5= 0.21, PM10=1.386)

P=No. of wet days with at least 0.254 mm of precipitation during avg. period

C= Break and tire wear correction (PM2.5=0.00036, PM10=0.00047) - lb/VMT

a for $PM_{2.5}$=1, PM_{10}=1;

c for $PM_{2.5}$=0.2, PM_{10}=0.2;

d for $PM_{2.5}$=0.5, PM_{10}=0.5.

Emission from Unpaved Road (g/d)= E_Unpvd (g/VKT) x VKT (km/d)

The emission factors for area sources are given in **Table 3.13**. The PM_{10} emission load of different area sources is given in **Table 3.12**.

Table 3.12: Emission Load from Area Sources – Road Dust

Source	Type	PM_{10} (TPD)	$PM_{2.5}$(TPD)
Road dust	Paved	0.017	0.010
	Unpaved	0.04	0.02

Table 3.13: Emission factors for PM_{10} from area sources

Fuel	EF	Unit	Source
LPG	1.95	g/lit	NEERI Report-Mumbai, 2010
Wood	15.3	Kg/mg	
Kerosene	1.95	g/kg	
Cow dung	5.04	g/kg	
Coal	20	Kg/mg	
Crop	11	Kg/ton	
Diesel	0.25	Kg/KL	
Construction	1.2	T/Acres-months	AP42, 13.2.3.3

3.3 Point Source

As per emission inventory, the percent emission contribution to PM_{10} is around 32% from industrial sector (coal, pet coke, furnace oil, Bagasse and wood).

Table 3.14: Industrial Scenario of Aurangabad

S. No.	Head	Unit
1	Registered Industrial Unit	9659 nos.
2	Registered Medium & Large Unit	32 nos.
3	No. of Industrial areas in Municipal limit (Chikhalthana and Railway Station MIDC)	02
4	No. of Industrial Area	04
5	Turnover of Small Scale Ind. in Lacs	148645
6	Turnover of Medium & Large Scale Industries in Lacs	22948

Source: MSME, 2016-17

Based on the consent data collected from the MPCB website, it is observed that there are total 117 air polluting industries in Aurangabad Industrial Clusters, out of which 24 air polluting industries in Chikhalthana MIDC, 18 in Shendra MIDC, 68 in Waluj MIDC and 7 in other areas. Chikhalthana MIDC area falls in Municipal corporation boundary of Aurangabad city. The emission sources for point sources are given in **Table 3.15**. Fuel based contribution is given in **Table 3.16**. There are no brick kilns and stone crusher inside the municipal corporation boundary limits.

Emission Estimates:

Emission = Fuel consumption x EF

Table 3.15: Emission factors (EF) used for Point Source Emission Load Estimation

Fuel used	EF	Unit	Source
Coal	PM – 5A	kg /Mg	AP-42 (Table 1.1-3-4), A-ash content
Wood	PM – 17.3	Kg/Mg	AP42 (Sec. 1.9, Pp. 1.10.4, Table 1.9.1)
Furnace Oil	TSP – {9.19(S) + 3.22} * 0.120	kg /Mg	EPA-42: Table 1.3 – 1 And Table 1.3 – 3; S – Sulphur Content In Fuel
DG	PM10- 1.33*10^-3	kg/Kw-Hr	AP-42 (Table 3.3-1) EF For Uncontrolled Gasoline & Diesel Industrial Engines
HSD	TSP – 0.24	kg/KL	NEERI Report-Delhi, 2010
LDO	TSP -0.24	kg/KL	NEERI Report-Mumbai, 2010
Bagasse	TSP -7.8	kg/ton	EPA-AP42: Table 1.8-1, Uncontrolled Emission Factors
Biomass Briquettes	PM10 – 11	kg/ton	NEERI Report-Mumbai, 2010
LPG	PM10 – 2.1	Kg/MT	NEERI Report-Mumbai, 2010
Pet coke	PM10 – 0.04	Kg/Mg	

Table 3.16: Point Source Emission Inventory

Emission Sources types	PM10 (TPD)	PM 2.5 (TPD)
Briquettes	0.25	0.10
Furnace Oil	0.15	0.06
Coal	0.02	0.0015
Diesel	0.09	0.06
HSD	0.002	0.00
LDO	0.004	0.002
LPG	--	0.001
Wood	0.18	0.12
Bagasse	0.00	0.00
Propane Gas	0.017	0.011
Pet coke	0.018	0.010

An additional MIDC is sanctioned near Aurangabad named as five star Shendra-Bidkin MIDC. This MIDC is available for large scale industrial setup.

3.3.1 Recommendations

- Change in coal quality with less ash content will reduce the PM emission to a larger extent.
- It is further to note that information on small scale and medium scale industries is fully not available and accounting for those industries contribution is difficult.

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

3.4 Line Source

There are about 1183919 Lakhs registered vehicles in Aurangabad District. The distribution of vehicles based on RTO data is given in **Table 3.17**. The distribution of different vehicles is given in **Table 3.18**. Currently the city buses operated by AMC are running on diesel. At present 15 buses are available for fleet and more are yet to arrive. The city has more number of autorickshaws for local transportation. Apart from the city bus services ST bus service facilities is provided by the MSRTC Aurangabad depot.

Table 3.17: Number of Vehicles in the District

S. No.	Type of vehicles	No of Vehicles
1	2W	932739
2	Cars	63826
3	Jeeps	29322
4	Station Wagons	452
5	Auto Rickshaws	27806
6	Stage Carriages	5959
7	Contract Carriages/Mini-bus/ School van	1544
8	School Buses	1114
9	Pvt. Service Vehicles	1997
10	Ambulance	504
11	Trucks & Lorries	14806
12	Tankers	4727
13	Delivery Van (4W)	26403
14	Delivery Van (3W)	30393
15	Tractors	24852
16	Trailers	14901
17	Others	492
Total		**1183919**

Table 3.18: Vehicle Count in Aurangabad city

Vehicle Type	No. of Vehicles
2W	332180
3W	104047
Car	104122
4W	36195
Total	576544

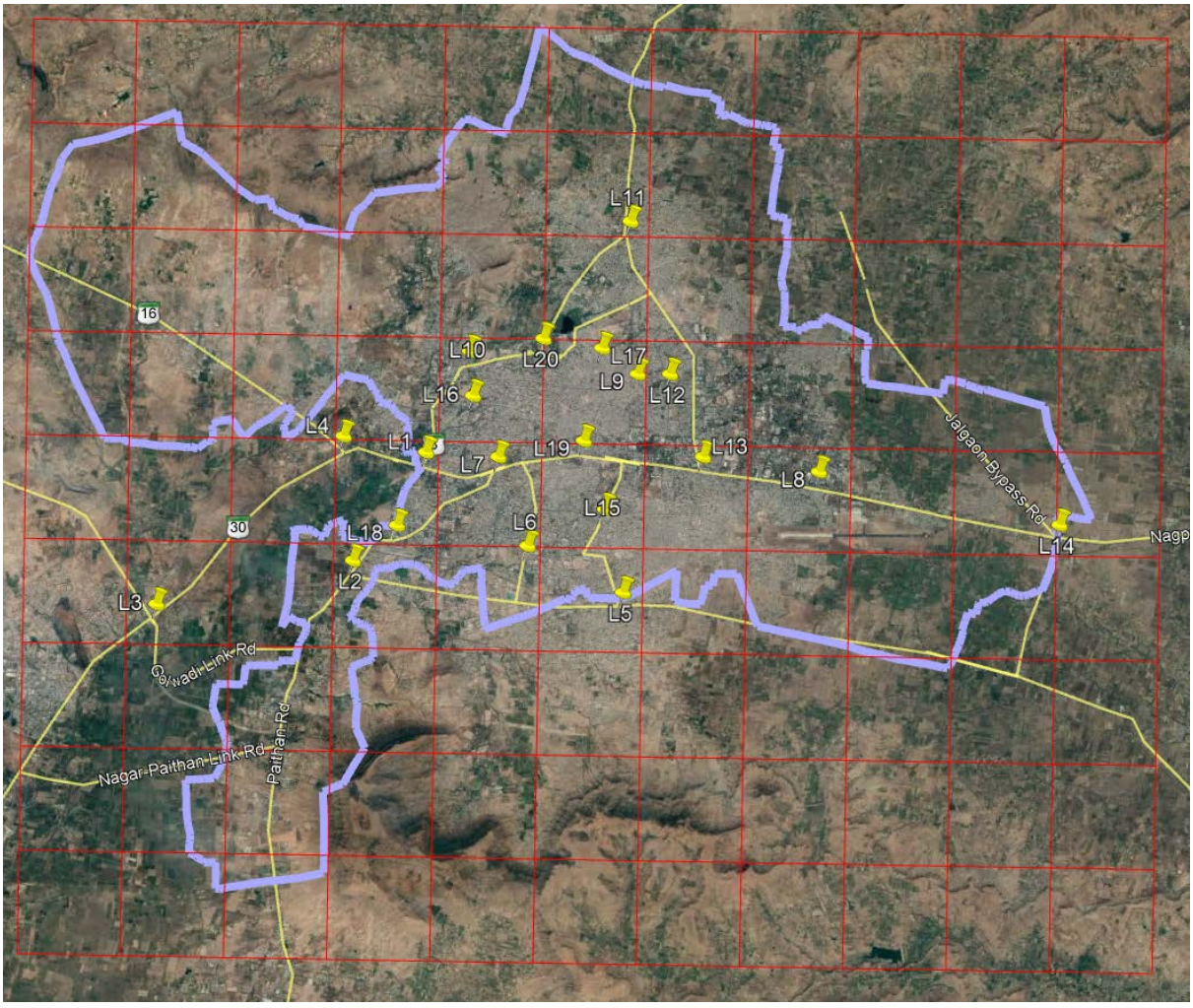

Fig. 3.4: Location of points for traffic counts

Emission Estimates:

For emission calculations, the % of petrol and diesel vehicles is assumed as below:

% of vehicles	Petrol	Diesel
Cars	55%	45%
3W	73%	27%

Source: Press Information Bureau, Min. of Petroleum and Natural gases, Govt. of India, (2014)

2W and 3W BS-III vehicles are assumed to be 80%, and BS-IV vehicles are 20% as it was introduced in mid-2017. Cars are assumed to be of 80% for BS-IV and 20% for BS-III norms.

Estimation of vehicle kilometres (km) travelled by each type of vehicle

VKT = RL * N

Where, VKTI = Vehicle km travelled by vehicle type, RL = Road length, N = Number of vehicles travelling for vehicle type per day

The road network data is given in **Fig. 3.6a**. Road length in each grid is computed using GIS software.

PM= Σ VKT x EF x N

Where, PM= Particulate matter load from vehicle type in tonnes/year, N = Number of activity days in a year (200 days), EF = Emission factor for a vehicle type

The emission factors are given for each vehicle type in **Table 3.19**. The vehicle contribution to total PM load is given in **Table 3.20** and % contribution to PM_{10} by different types of vehicles is given in **Fig. 3.6b**.

Table 3.19: Emission Factors Automotive Research Association of India (ARAI), 2007

Vehicles	**Petrol Vehicles**			**Diesel Vehicles**		
EF (g/km)	BS-III	BS-IV	BS-VI	BS-III	BS-IV	BS-VI
2W	0.035	0.02	0.0010	0	0	0
3W	0.05	0.03	0.0250	0.05	0.035	0.0250
4W	0.050	0.035	0.0045	0.05	0.008	0.0045
Trucks/Trailors	0	0	0	0.42	0.071	0.0045
Mini Buses/Buses	0	0	0	0.3	0.051	0.0045

Source: Air Quality –Indian Clean Air Programme (ICAP), Automotive Research Association of India (ARAI), 2007

Table 3.20: Contribution of line sources to PM10 emission load

Vehicles	**PM_{10} (TPD)**	**$PM_{2.5}$ (TPD)**
2W	0.205	0.087
3W	0.137	0.025
4W	0.252	0.168
HDV	0.533	0.356
Total	**1.127**	**0.636**

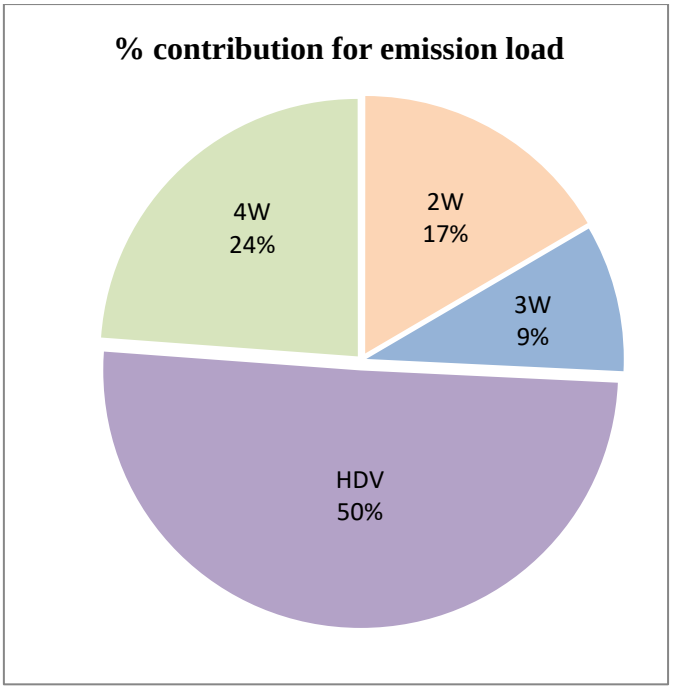

Fig. 3.5: **Percent emission load contribution from line source**

3.5 Gridded Emission Inventory

The gridded emission load grid wise is given in **Table 3.21** below.

Table 3.21: Grid wise (2km x 2km) PM_{10} Emission Load (TPD)

Grid Name	PM 10 (TPD)	Grid Name	PM 10 (TPD)
A6	0.00039	G2	0.00021
A7	0.05858	G3	0.00027
B1	0.0002	G4	0.00033
B5	0.09873	G5	0.22935
B6	0.09293	G6	0.06411
C1	0.05709	G7	0.00023
C3	0.0001	H1	0.00021
C4	0.00002	H2	0.00027
C5	0.00016	H3	0.00027
C6	0.01987	H4	0.01702
C7	0.25562	H5	0.03847
C8	0.00032	H6	0.0456
C9	0.00002	H7	0.00027
D2	0.00021	I1	0.00033
D3	0.00021	I2	0.00735
D4	0.00027	I3	0.00125
D6	0.00678	I4	0.00075
D7	0.00442	I5	0.00113
E2	0.00021	I6	0.00249
E3	0.00023	I7	0.00027
E4	0.00022	J1	0.00021
E6	0.08459	J2	0.00033
E7	0.00409	J3	0.00098
E8	0.0001	J4	0.00541
F3	0.00033	J5	0.00715
F4	0.00046	J6	0.00046
F5	0.00005	K3	0.0005
F6	0.00047	K4	0.00692
F7	0.0016	K5	0.00586
F8	0.00027	K6	0.00046

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

3.6 Overall PM_{10} Contribution by Various Sources

Table 3.13 shows the PM_{10} emission load contribution by various sources. It can be observed that vehicular source is the most predominant source for higher emission load followed by industrial sources. Out of overall vehicular sources, 50% emission load is due to heavy duty vehicles.

Table 3.22: Emission Load Contribution by all Sources

Source	PM_{10} load (TPD)	$PM_{2.5}$ load (TPD)
Area Sources	0.45	0.20
Line Sources	1.21	0.75
Point Sources	0.75	0.40

* Industries located outside Aurangabad City are excluded

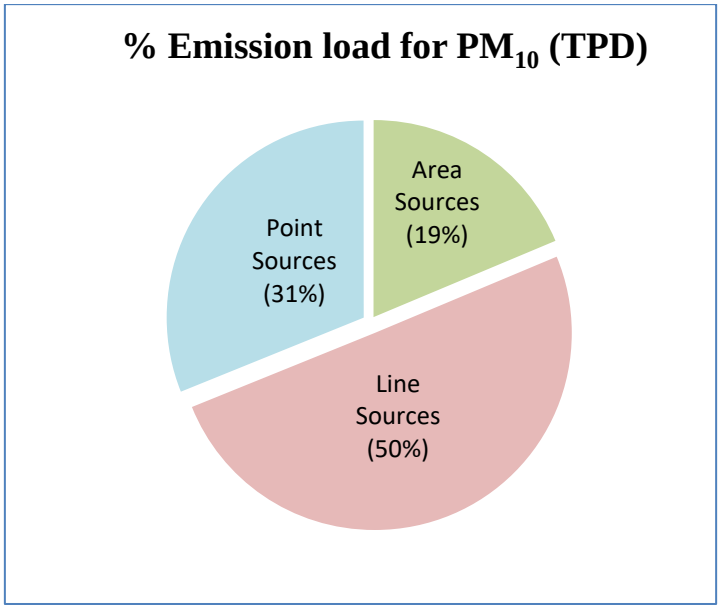

Fig. 3.6: Percent Emission load contribution from all sources

Chapter 4

4.1 Dispersion Modeling

Based on the grid-wise emission inventory, dispersion modeling exercise was carried out for Aurangabad city through AERMOD software. The results are given in **Fig. 4.1**. The maximum GLC is observed at to be 45 μg/m^3 near the main traffic junction (Baba petrol pump Chowk). This may be due to passing of heavy traffic load from the square.

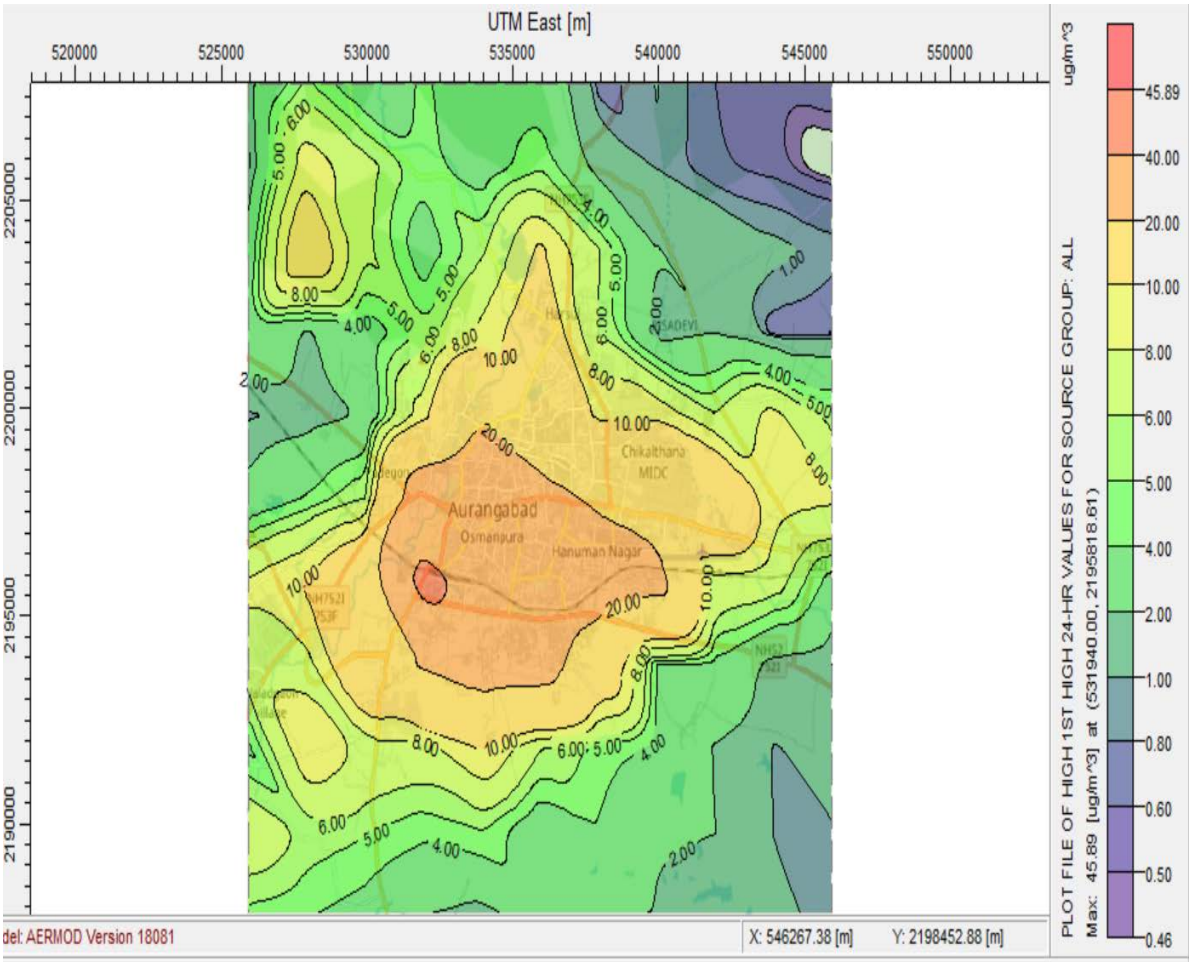

Fig. 4.1: GLC for Aurangabad city

Chapter 5

5.1 Action Plan for Control of Air Pollution

The action plan based on the emission load and its reduction is presented in **Table 5.1**.

Table 5.1: Action Plan for Control of Air Pollution

Sources	**Short Term-2019**	**Long Term-2022**	**Action Required**
Line Sources			
Vehicles	10% reduction in emissions	30% reduction in emissions	• Launch extensive drives against polluting vehicles for ensuring strict compliance. • Increase in public transportation (No public transport buses yet in Aurangabad city. If Biodiesel used as a fuel, reduction will be more). • Prevent parking of Vehicles at non-designated areas. • Widening of roads and wall to wall pavement. • Steps for Promoting Battery operated vehicles. • Synchronize Traffic movements/Introduce Intelligent Traffic systems for Lane Driving . • Provide good public transport system. • Electric / Hybrid Vehicles. • OE-CNG for new public transport buses. • Bio-diesel (B5/B10: 5 – 10% blended). • Restrict commercial vehicles entering city by having ring roads.

The above mitigation measures reduce the line source emissions by 10% in short term and 30% in long term.			
Point Sources			
Industry	To get the 10% reduction in emissions till 2019	To get the 30% reduction in emissions till 2022	• Action against industries doing high air pollution. • Alternate fuel (replacement of wood to Biomass briquettes, Indian coal to Indonesia or SA coal, ash content of briquettes after burning – 0.22%, One cubic meter (or approximately one ton) of briquettes produces as much heat as five cubic meters of air-dried and split firewood while burning, Briquettes produce 10 times less carbon dioxide than natural gas and 50 less carbon dioxide than coal). • Installation of CAAQMS. Installation/ up gradation of air pollution control systems. • Regular audit of stack emissions for QA/QC. • Use of alternate fuel instead of pet coke at tyre manufacturing units

The above mitigation measures reduce the point source emissions by 10% in short term and 30% in long term			
Area Sources			
Fuel burnt Res and commercial Cooking	10% reduction in emissions	50% reduction in emissions	
Domestic combustion			• Household wood and cow-dung burning is to be reduced. Increase in LPG usage through Ujjawala Yojana scheme. • Alternate fuel options e.g. solar needs to be assessed and exercised. • Crop residue burning needs to be completely banned.

Hotels, dhabas and open eat-outs			• Use of LPG in hotels and eateries.
Bakery			• In bakeries, electric ovens and LPG must be used.
Crematoria			• If wood replaced by electricity burners in Crematoria there will be less emissions of particulate matter. • Control equipments must be installed for air pollution control. • 50% Wood in each crematorium if replaced by biomass briquettes. This type of fuel used in crematoria gives 36% less emissions for $PM_{2.5}$ and 86% less SO_2 generation.
Solid waste/open burning	10% reduction in emissions	50% reduction in emissions	• On an urgent basis Aurangabad needs MSW dumping and treatment yard. • Penalty against people burning the MSW. • Policies against burning of MSW. • Implementation and penalty for societies not segregating waste which are generating MSW of 100 Kgs and more. • Awareness among people for segregating waste at source. • Bio-methanization and biogas plant need to be installed.

Road dust and C&D	20% reduction in emissions	40% reduction in emissions	• New bypass for the city • Hand Sweeping / Mechanical sweepers • Cement Concrete roads • Wall to wall road pavement • No entry to heavy vehicles during day time. • Regular water spraying and maintenance of Bus depots, increase in green cover at the periphery of bus depot • Major traffic intersections to have water fountains • Enforcement of construction & demolition rules, implementation of measures for control of emissions during activity. • Control measures for fugitive emissions from material handling, conveying and screening operations through water sprinkling, curtains, barriers and suppression units. • Ensure carriage of construction material in closed/covered Vessels.
Assumptions or required actions to reduce the emissions: The above action plan shall reduce the PM_{10} emissions from construction activity and road dust.			

5.2 Monitoring Mechanism for Implementation

The aforesaid action plan shall be implemented by Maharashtra State Pollution Control Board with co-ordination of Department of Environment and Forest, Govt. of Maharashtra, Urban Development and Housing Department, Govt. of Maharashtra, Transport Department, Aurangabad Municipal Corporation, Traffic police and District administration. Maharashtra State Pollution Control Board shall regularly review the implementation of aforesaid action plan.

5.3 Implementation Status

The Chief Secretary, Govt. of Maharashtra to convene the meetings with different concerned departments and direct for compliance of directions for implementation of air quality of Aurangabad. The Principal Secretary, Environment and Forest, Govt. of Maharashtra to also convene the meeting for follow up of the aforesaid directions. The Hon'ble Deputy Chief Minister to also review the issues subsequently for improvement of ambient air quality of Aurangabad.

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Draft Interim Submission

Annexure – I

Design of a Clean Tandoor Community Kitchen System (CTCKS)

Design of a Clean Tandoor Community Kitchen System (CTCKS)

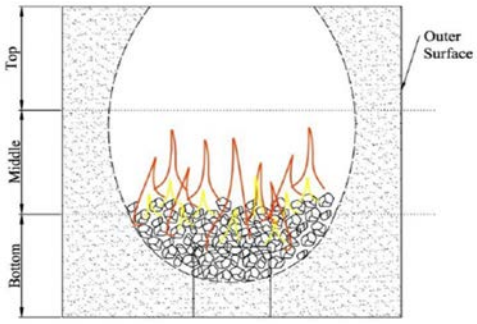
The objective of the experiment is to design a clean tandoor community kitchen system to reduce air pollution. There are no standards or guidelines to evaluate the performance of the tandoors w.r.t. its thermal efficiency, emissions and safety. While such standards are developed for the cook stoves however,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

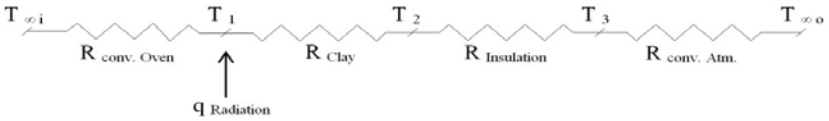
Advantages of pellet based tandoor also leads to reduced ash generation. Pellets based tandoor will also generate market for pellet industry and enable the use of agro-waste residues for development of an alternative fuel, promote employment generation in rural areas and would partly contribute to emission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

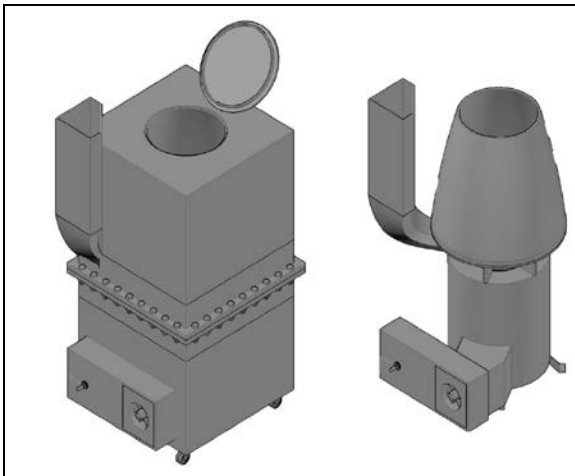


Fig.1 Pellet based Forced Draft Clean Tandoor Community Kitchen System (CTCKS) (a) With outer casing (b) Without outer casing

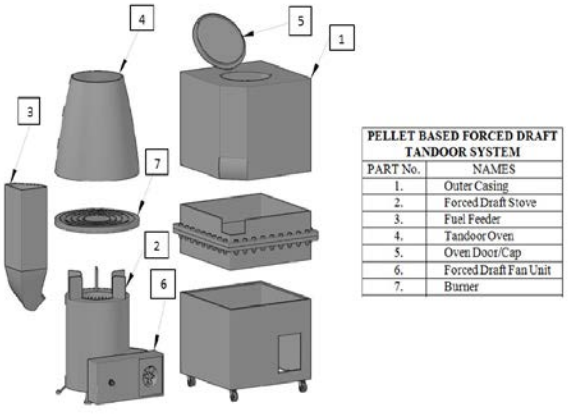


Fig. 2 Exploded view CTCKS: Inner Assembly & Outer Casing

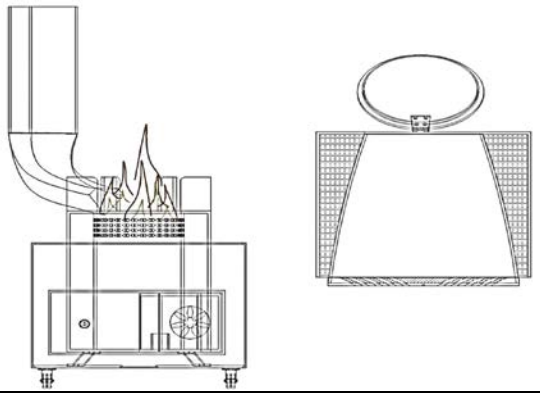
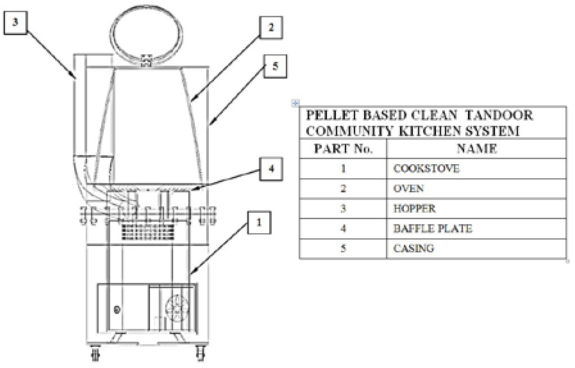
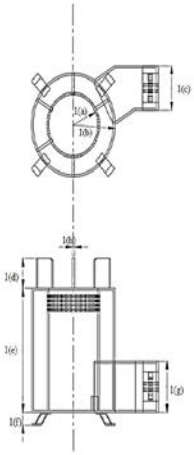


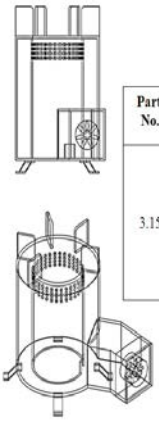
Fig. 3 Line diagram of CTCKS showing Combustion unit and Oven section (Dimensions not to scale)



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

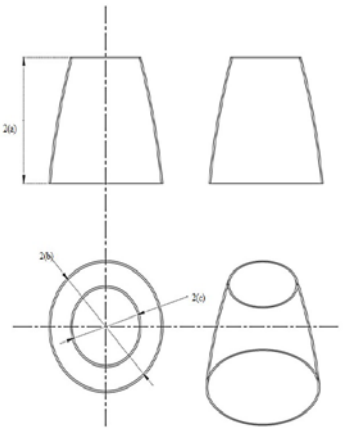
Fig. 4 Line diagram of CTCKS





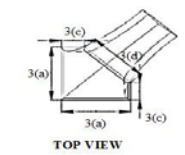
Part. No.	Dimensions (mm)	
3.15	a	170
	b	250
	c	80
	d	50
	e	400
	f	40
	g	80
	h	4

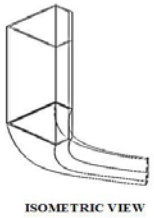
Fig. 5 Child Parts of CTCKS: Cookstove

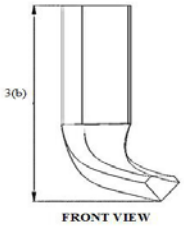


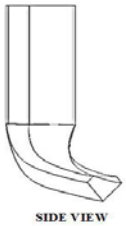
Part. No.	Dimensional Range (mm)	
3.16	a	450 – 500
	b	680 – 700
	c	300 – 350

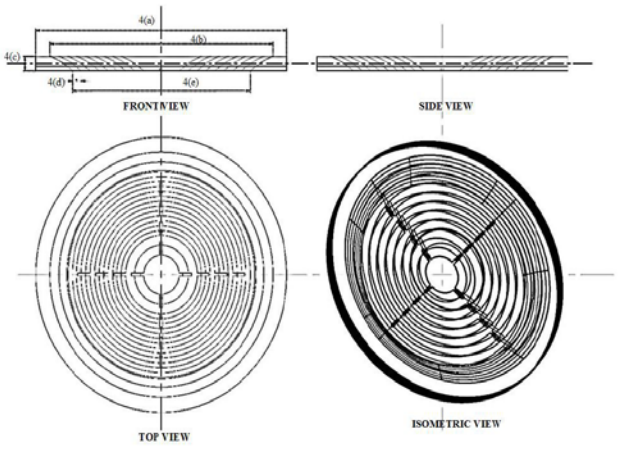
Fig. 6 Child Parts of CTCKS: Oven









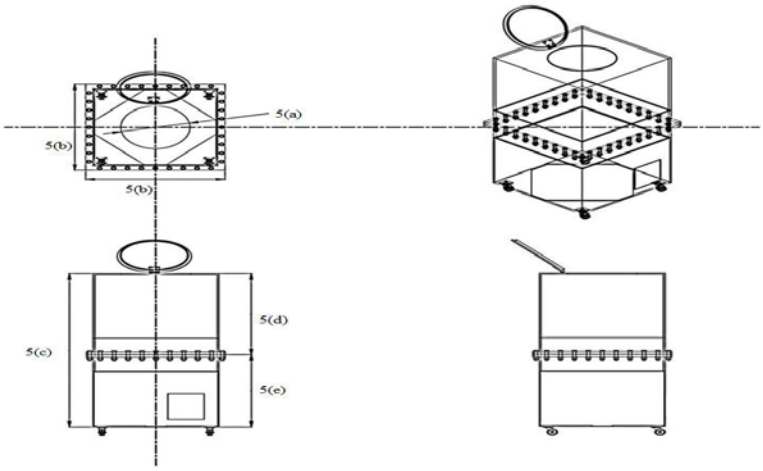


Part. No.	Dimensional Range (mm)	
3.17	a	160 – 180
	b	600 – 700
	c	80 – 100
	d	170 – 200

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	

Draft Interim Submission

Annexure – II

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

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

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

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

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

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

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

Electric Cremation vs The Traditional Funeral Pyre

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

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

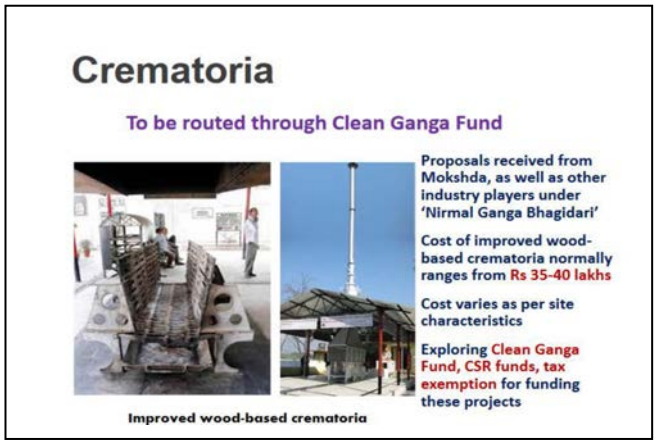
There has always been a controversy on the use of the electric crematoriums due to rituals as most persons follow the traditional burning of the bodies. In metropolitan cities it is promoted by the Government, private NGOs and environmentalists, but not to a great extent and most of these have failed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

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

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

Green Cremation system

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



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

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

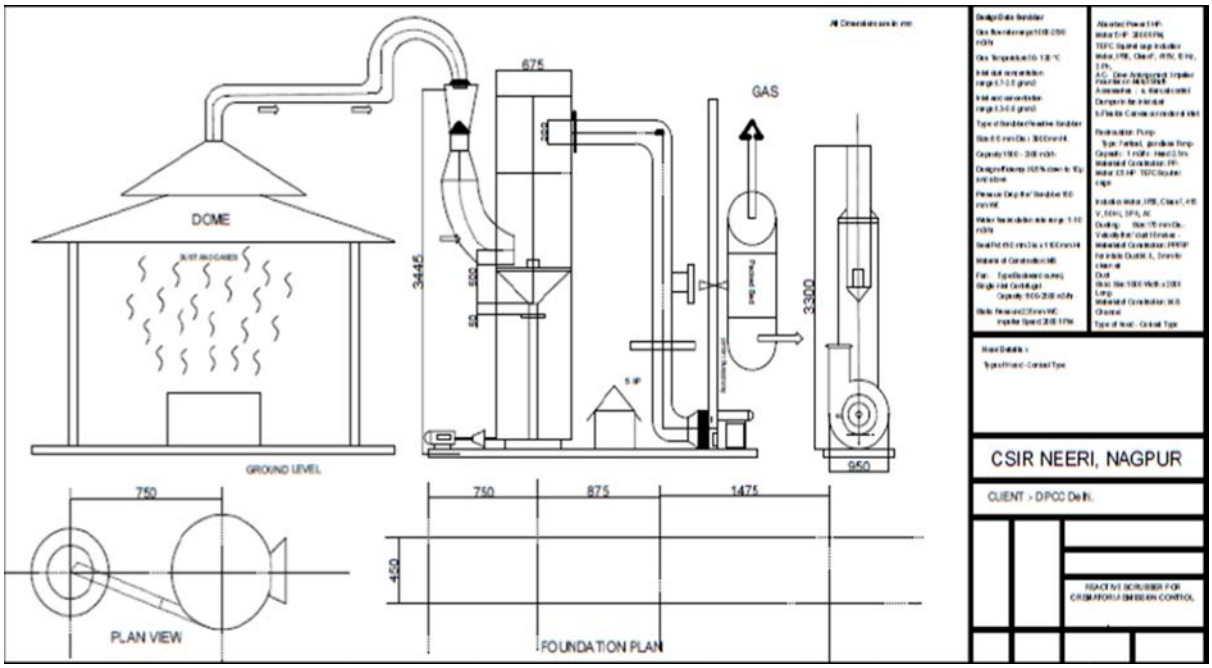


Figure 1 : Detailed diagram of emission control system for open type with side enclosed crematoria

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

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

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

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

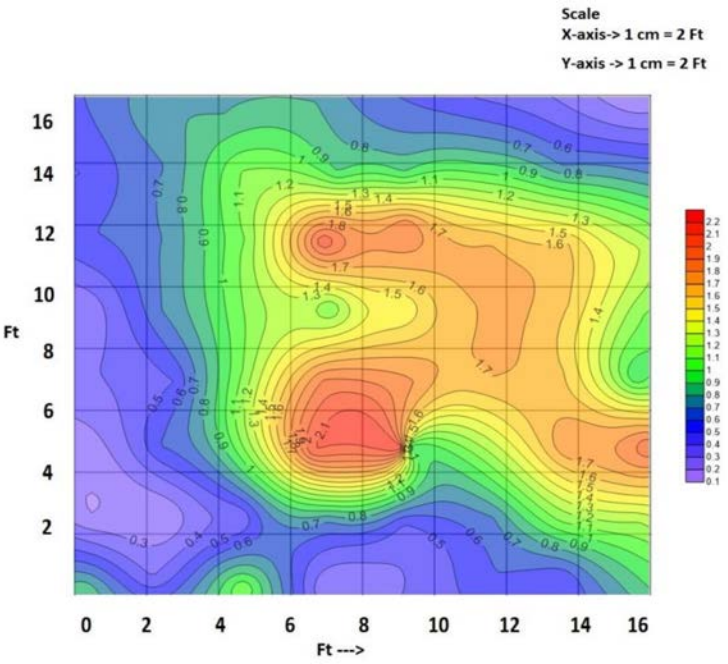


Figure 2 : Velocity profile of fumes during cremation

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

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

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

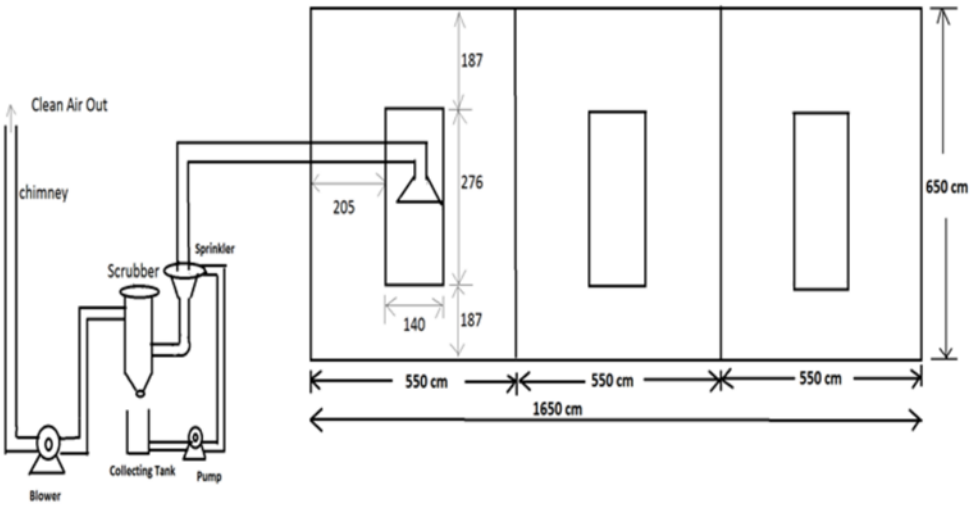


Figure 3 : Schematic view of Air Pollution Control System installed at Mokshadham Crematoria, Nagpur

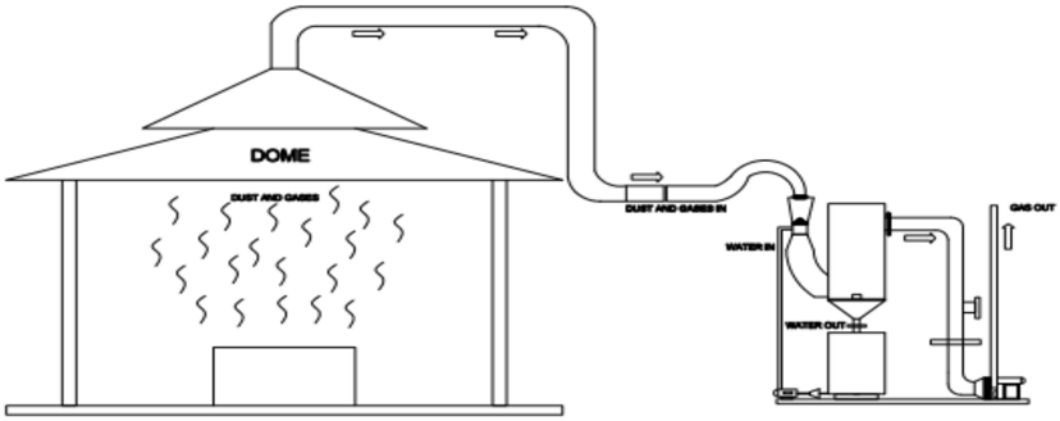


Figure 4 : Schematic view of Air Pollution Control System

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

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

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

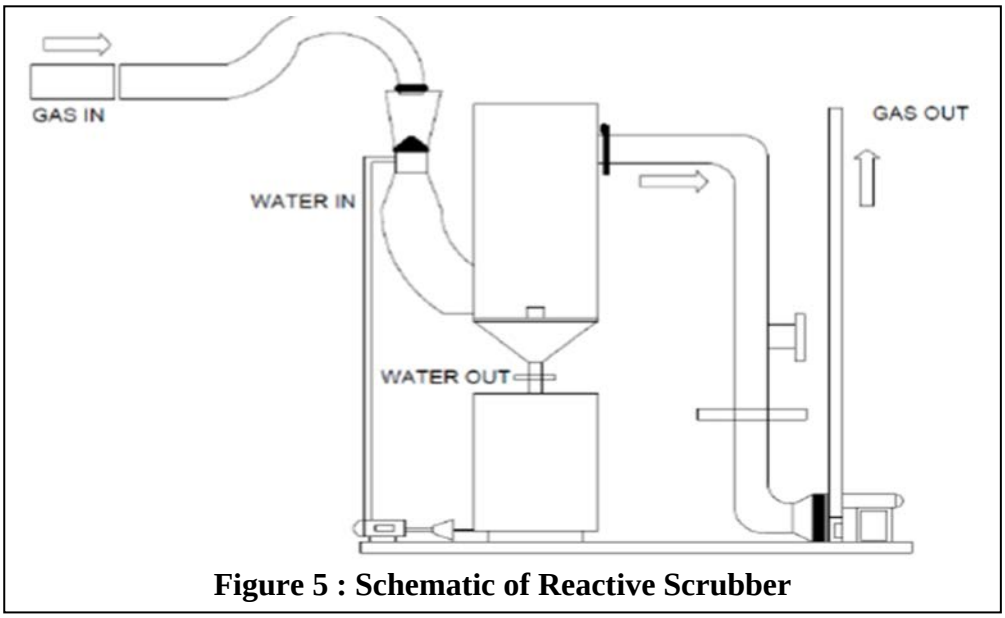


Figure 5 : Schematic of Reactive Scrubber

Gaseous Emission Control System

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

Design of APC System Emission capture system

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

The canopy hood volume is expressed by the following equation:

Hood Volume = T_d (Qp-Qs) Where,

T_d = duration of plume surge (s)

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

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

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

Where:

DC = column diameter at hood face.

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

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

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

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

Where:

DS = diameter of hot source, ft

Emission control system

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

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

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

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

d_d = droplet diameter, m

μg= gas viscosity, ($msec^{-1}$)

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

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

L & G are liquid & gas densities.

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

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

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

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

Draft Interim Submission

Annexure – III

Design of Passive Gas Venting System for Landfill Sites

Design of Passive Gas Venting System for Landfill Sites

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

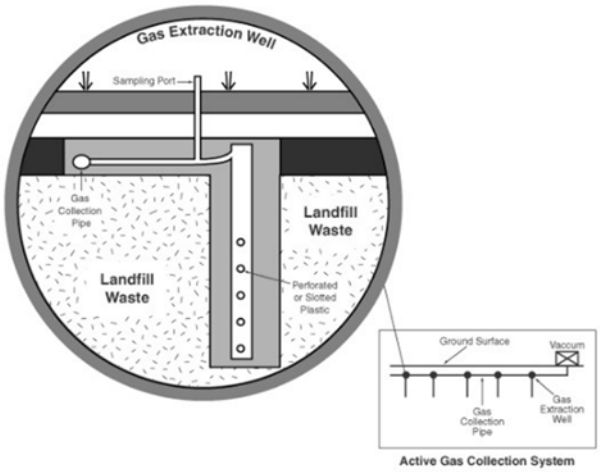
Most of the MSW generated is disposed of non-scientifically in open dumps, which causes a serious threat of landfill gas (LFG) emissions. The present note will focus on the landfill sites for the LFG emissions and designing the appropriate gas venting for the landfill sites.

Landfill Gas Collection System

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

Active Gas Collection System

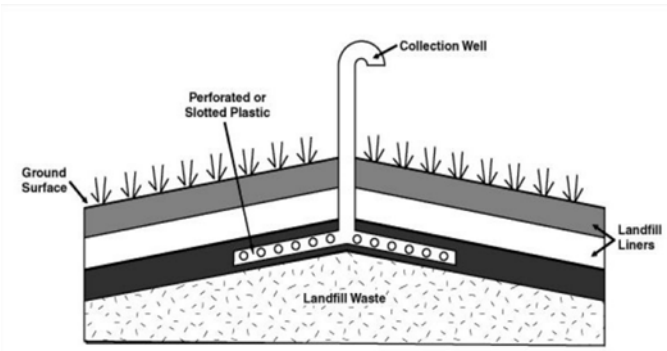
Well-designed active collection systems are considered the most effective means of landfill gas collection (EPA 1991). Active gas collection systems include vertical and horizontal gas collection wells similar to passive collection systems. Unlike the gas collection wells in a passive system, however,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



Active venting systems

Passive Gas Collection System

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



Passive Venting Systems

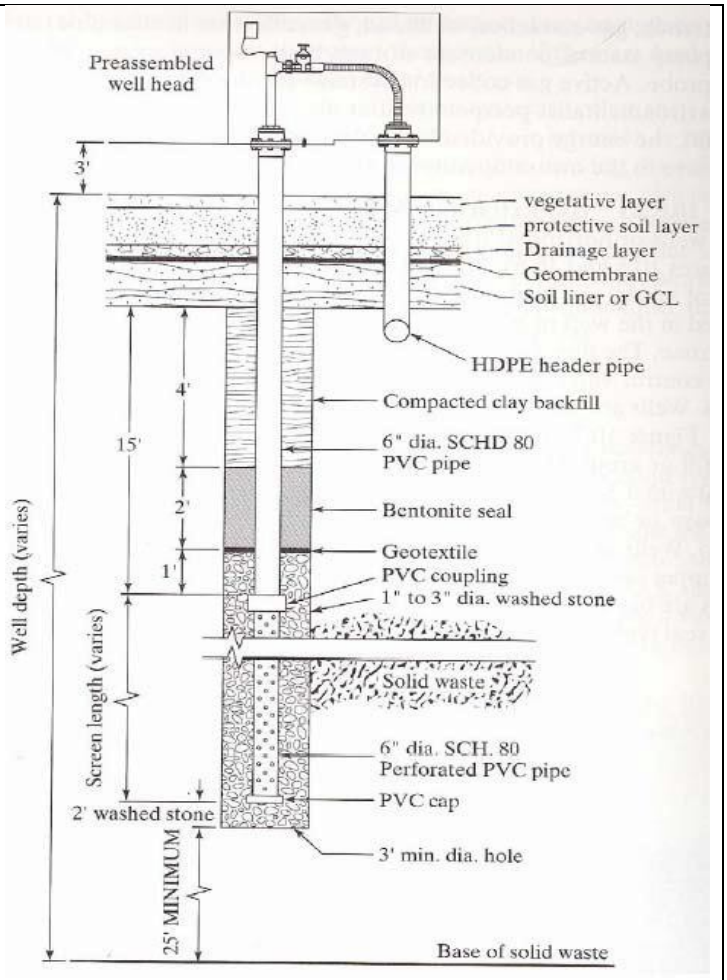
groundwater table. Vertical wells are typically installed after the landfill, or a portion of a landfill, has been closed. A passive collection system may also include horizontal wells located below the ground surface to serve as conduits for gas movement within the landfill as shown below. Horizontal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

Criteria and Process Diagram of Passive Vents

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

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

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



Typical Design of Passive Vent System

Data Requirement and Design of Passive Vent System for Landfill Sites

✓ ***Data Requirement***

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

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

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

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

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

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

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

Methods to Treat Landfill Gas

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

Combustion Methods

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

Non-combustion Methods

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

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

Annexure – IV

Dust Control Measures

Dust Control Measures

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

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

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

Dust Control Agents

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

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

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

Selecting dust control agents

When selecting materials for dust control consider these basic requirements:

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

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

Table 1: Application rates of dust control chemicals

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

Methods of Application

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

Figure 1 : Road side sprinkling of dust control agents

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

Figure 2 : Covered transportation vehicles

Other references

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

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

Specifications/ Application

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

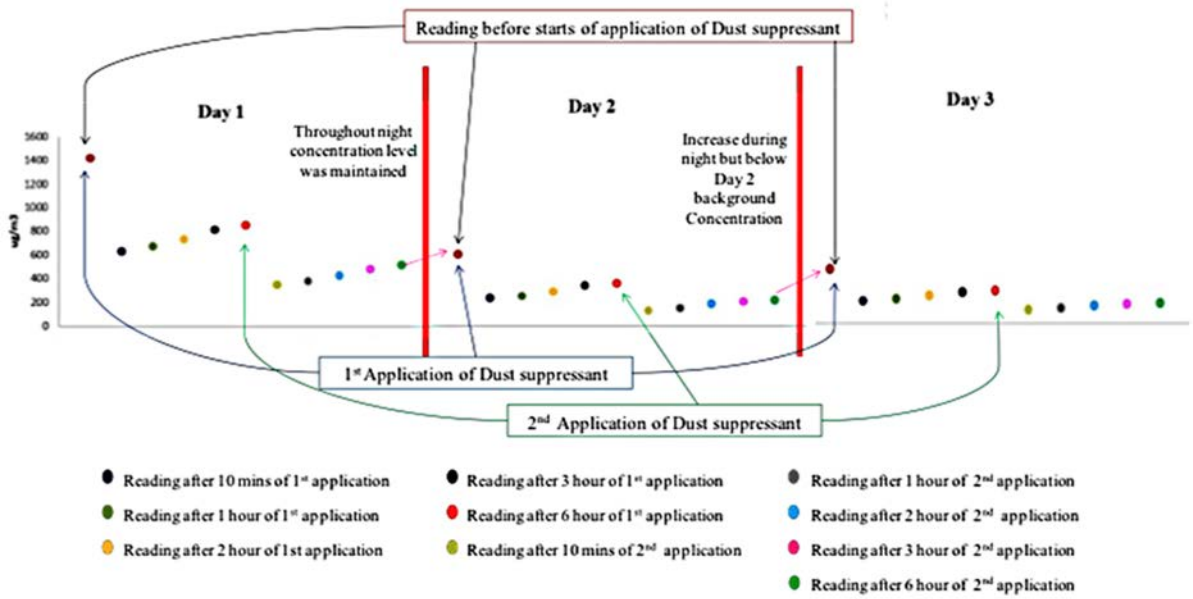
Advantages

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

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

Application of Dust Suppressant using Tanker at Delhi

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



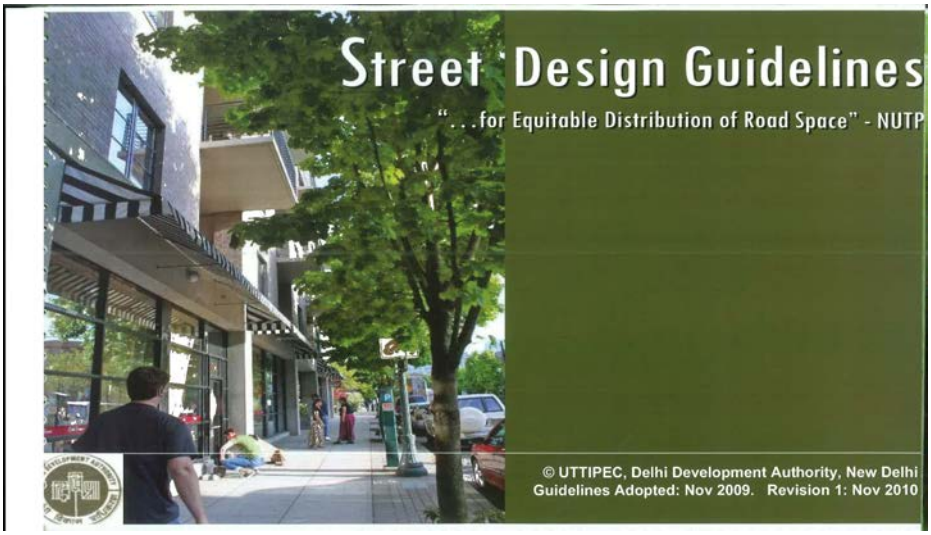
Bioswale : System for Storm Water and Dust Suppression Road Side

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

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

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

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



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

A) National Clean Air Programme (NCAP)

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

Dust management

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

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

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

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

Way Forward

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

B) Dust Mitigation Notification by MoEF-CC

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

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

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

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

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

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

Use of Ready Mix Concrete

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

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

Annexure – V

Wind Augmentation and purifYing Unit (WAYU)

‘Wind Augmentation and purifYing Unit (WAYU)’

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

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

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

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

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

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

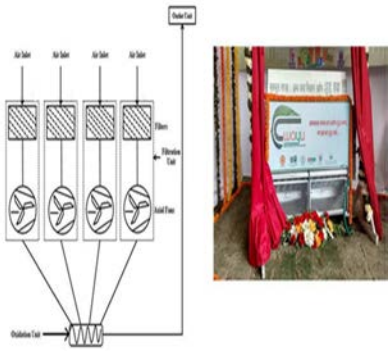
The device uses low speed wind generators, appropriate size filters for long operation cycle with reasonable efficiency. It also has an oxidizer unit for removal of Carbon-monoxide and Hydrocarbons including VOCs. The air is passed through the filters where the particulates are removed. The air generators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

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

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

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

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



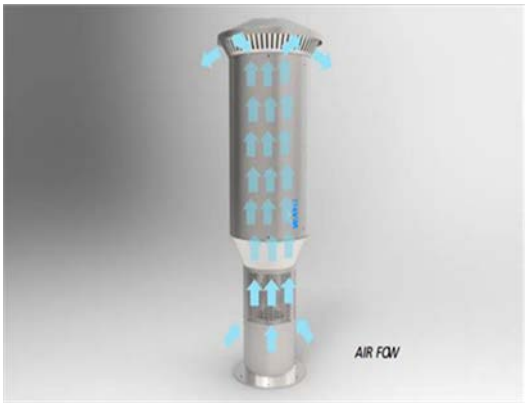
UV- TiO2 adsorption-photocatalytic oxidation has a lot of advantages. They are very efficient in removal of VOCs. Pichat et al. (2000) have shown that ozone can be directly eliminated by TiO_2 nanoparticles in a process that is promoted by both heat (in the ambient temperature range of 0° to 50°C) and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

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

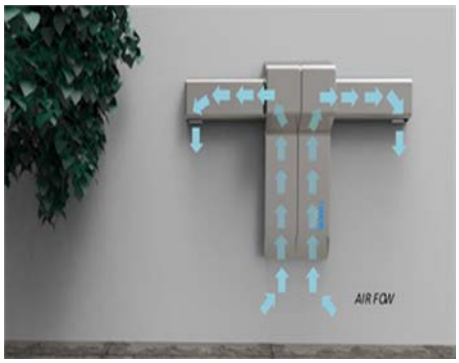
WAYU is a device jointly developed by IIT-CSIR-NEERI focused on controlling pollution in ambient air. WAYU has been successfully tested in a pilot project of 25 devices in Mumbai in collaboration with Maharashtra Pollution Control Board (MPCB). With an aim to solve the ever rising menace of air pollution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

Different Models

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



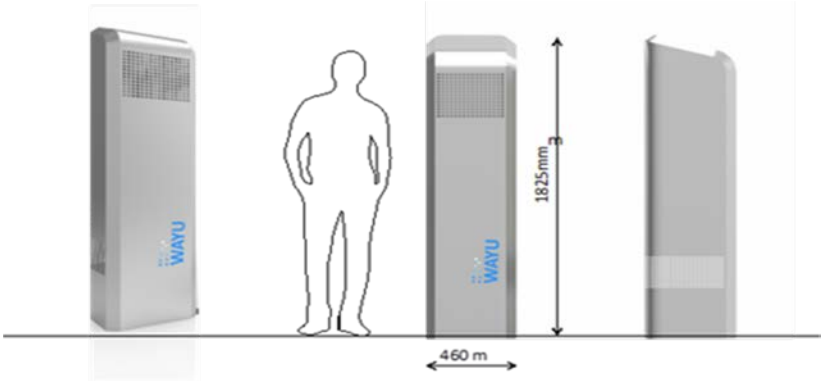
WAYU device improved design



Wall mounted/ Flyover Design

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

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



Bus shelter design

Traffic Roundabouts design

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

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

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

Why WAYU?

WAYU has the following advantages:

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

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