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# Carbonaceous Particle Scavenging and Thermal Comfort Augmentation with an Extended Green Facade Draped with *Vernonia elaeagnifolia*

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## Abstract

Soot or black carbon particles emanating from unregulated vehicular traffic in Chennai city (the Detroit of India) are not only short-lived climate forcers, they also contribute majorly to the problem of $PM_{10}$ pollution. This paper first models the spatial distribution of these particles along a busy thoroughfare with a vehicle density of 45,272 vehicles/km·day, factoring in the vehicle deterioration factor and then suggests a practical amelioration mechanism using a Vertical Green Drape (VGD) using *Vernonia elaeagnifolia*. Apart from its cleansing efficiency, the creeper draped building has shown to enhance the interior thermal comfort of its occupants by bringing down the Predicted Mean Vote (PMV) value from 1.73 (uncomfortably warm) to 0.98 (comfortable) for a multi-storeyed building housing 385 occupants on a single floor. Calculations also yield annual HVAC (Heating Ventilation and Air-Conditioning) savings of 104,999.96 USD (93,333.3 KWh) for a group of three academic buildings, close to a National Highway (NH-32).

***Keywords***: *Vernonia elaeagnifolia*; Carbonaceous Aerosols; Vehicular Emissions; Green Façade; Predicted Mean Vote (PMV); Thermal-Comfort.

## 1. Introduction

Outdoor air pollution is a key reason for premature deaths, and levels of air pollution still outstrip public health standards in many urban regions, chiefly in constricted street canyons formed by tall buildings on either side of the road (Pugh *et al.*, 2012). The air quality of the Indian city Chennai, in particular, has noticeably deteriorated in recent decades because of increased pollutant emissions from traffic and fossil fuel burning.

Chennai is among a list of cities faring poorly in a globally recognized forum that classifies cities based on air quality (Arulprakasajothi *et al.*, 2018). It is unlikely that a 'quick fix' solution can emerge any time soon. Keeping the Kigali and the Paris summits in perspective, sustainable solutions must be explored. India's Central Pollution

Control Board along with the state regulatory authorities has guidelines and mechanisms to impound offending vehicles. However, being a developing Nation, the cost of implementing catalytic converters and customized filters for thousands of auto-rickshaws plying through the city is prohibitively expensive. However, Chennai's saving grace is that it is a tropical metropolis and plants grow in profusion with virtually zero maintenance costs and must form part of a new green drive to restore the city's air to respectable limits. This aspect is still in its infancy and this timely work is likely to alert planners and administrators.

Previous studies on pollution scavenging by green facades in an urban environment have shown high pollution scavenging properties of living green walls (Joshi and Ghosh, 2014; Varghese *et al*., 2015). A Vertical Green Drape (VGD) is proposed here as an extended sink to trap $PM_{10}$ pollution along the city's street canyons.

*1.1 Pollution from Idling vehicles*

The number of vehicles per unit length of road is extremely high in Chennai causing traffic congestion and higher waiting times at certain junctions. At these junctions, vehicles are stacked one after another and are left to idle. Such chaotic pile-ups are confined within artificial canyons bereft of spaces promoting large lateral dispersion. Previous studies on vehicle idling have shown that a buildup of pollution overwhelms actual emissions (Vardoulakis *et al*., 2003; Carrico *et al*., 2009; Riain *et al*., 1998). The resulting particulate pollution pall soils surfaces of buildings and affordable mechanisms must be put in place to intercept them. Vertical green drapes using a time-tested tropical creeper could well be a robust and economical remedial strategy (as we shall show later). Apart from its cleansing properties, extended surfaces draped with this versatile creeper, shall additionally retard inward heat transfer within draped buildings and concomitantly cool the interiors. Further, spray-driven jets can be used to artificially wash down pollutants from these green surfaces (Ghosh *et al*., 1991; Ghosh *et al*., 1993).

In an attempt to understand the fate of these particulates emitted from diesel engine exhausts, after first factoring in their atmospheric life times, it is important also to ascertain the Particle Size Distribution (PSD). An investigation was undertaken to estimate the size and numbers of PM emissions, as and when they are released from a four-stroke diesel engine and diluted in the atmosphere- this is another main objective of this study.

Particles of both sizes- large and small are removed majorly by dry deposition. Compared to hard solid surfaces like concrete, pollutant uptake by plants or green façades is much higher (Pesava *et al*., 1999; Weerakkody *et al*., 2018). Green Facades, particularly in tropical settings, are known to remove air borne particles effectively (Picardo and Ghosh, 2011; Joshi and Ghosh, 2014; Varghese *et al*., 2015; Mo *et al*., 2015) (see Figure 1).

These earlier studies only concentrated on the removal of $SO_x$ and $NO_x$ from vehicles but left out quantifying $PM_{10}$ removal by vertical green facades along busy traffic junctions. This remediation using a vertical green drape, therefore forms a part of the present study.

**Figure 1.** Green façades along roads in VIT University Campus, Vellore

In order to calculate the net pollution removal rate by the creeper, a detailed Computational Fluid Dynamics (CFD) analysis of an existing green façade was carried out, varying stomatal aperture and leaf area index. The removal rates were found to be $1.01 \times 10^{-6}\ s^{-1}$ and $1.11 \times 10^{-6}\ s^{-1}$ in dry and humid conditions respectively (Joshi and Ghosh 2014). Another recent study compared pollutant cleansing ability of 28 climber species including VE (Kumar *et al.*, 2015). The experimental analysis concluded that an Air Pollution Tolerance Index (APTI) (a measure of the plant's resilience to air pollutants) for plants grown in polluted regions of tropical cities should be greater than 17. The VE creeper was found to have an APTI value of 19.75 in an industrial setting.

India is the first country to have a cooling action plan. This plan encourages the use of passive technology, including the use of green drapes to control heat absorption and dissipation through new design solutions, as is proposed in the present study.

## 2. Methodology

*2.1 Modelling vehicular emissions along Chennai's high Traffic density roads*

Air pollution modelling and dispersion studies over Chennai have been conducted by first estimating the source strengths of vehicular traffic in the region selected. The pollution load is calculated for Suspended Particulate Matter (SPM) for the selected road networks where the state highway Basin Bridge Road, National Highway (NH 32- Chennai-Renigunta Road) and other smaller arterial roads converge (Figure 2). This stretch has a heavy traffic flow throughout the day contributing to particulate emissions.

PM10 concentrations for these emissions have been modelled for four periods namely: Summer (May), Monsoon (August), Post Monsoon (November) and Winter (February) during 2011, through an air pollution modelling and dispersion tool (AERMOD) which is a steady-state atmospheric dispersion model designed for short-range (up to 50 km) dispersion of air pollutant emissions from various sources (Perry *et al.*, 1994).

Armed with the preceding information, it is then possible to calculate the pollutant load from Samaras *et al.* (2014):

$$\text{Pollution load} = T_n \times X_i \times T\,(0-5) \times L \times R1$$

where, $X_i$ is the Pollutant emissions factor ($g.km^{-1}$), $T_n$ is the Number of vehicles in 24 h, T(0-5) is the deterioration factor (DF) of vehicles in five years, L is the Road length in km and R1 is a factor representing an intermediate road link. The three wheelers have the highest deterioration factor of 1.7, and this has been accounted for in estimating the pollution


**Figure 2.** Erukanchery High Road, North Chennai surrounded by residences and streets with high traffic density

loads. This factor is dependent upon the local street conditions and the state of maintenance of vehicles (Corvalan and Vargas, 2003). Table 1 shows the various parameters used for calculating the total vehicular pollution load for the selected stretch. The vehicular mix indicated in this study shows a realistic apportioning even to this day. The total pollution load works out as 0.064 $g.s^{-1}$ $km^{-1}$.

Keeping the above in perspective, it is essential to understand the fate of these particulates, after they are emitted from the tail pipes, particularly under idling conditions. We have therefore conducted a laboratory experiment to investigate the PM size regimes and the associated concentrations from an idling vehicle operated under controlled conditions. This is discussed in the next Section.

*2.2 Experimental investigation of soot or black carbon emissions from Diesel engine exhausts*

We have estimated size regimes of PM10 emissions through an experimental investigation of black carbon particles emanating from exhausts of a four-stroke Mahindra Diesel engine (Mahindra, 5.8 kW, 2250 rpm- Figure 3) fitted to a Dynamometer under idling conditions. Exhaust emissions were collected from a High Volume Sampler (HVS) (Aerovironment- FPS 9000, particle collection range- less than 10 μm, flow rate- 1.5 $l.m^{-1}$) and sampling was done a metre away from the engine exhaust representative of high pollution concentrations proxying prevailing conditions along Erukenchary road (Figures 2 and 3). The HVS was run for 10 minutes in conformity with estimates of the maximum waiting times of vehicles. Soot particles were collected onto a glass fiber filter paper placed within the sampler.

The filter papers were further analyzed through a Scanning Electron Microscope (SEM) to ascertain the sizes of the deposited particles. The SEM has the following specifications: SUPRAA 55 ZEISS SEM attached to OXFORD PENTA FEM system designed for image acquisition and energy dispersive X-ray (EDX) analysis. The operative voltage was kept to 5 kV. Previous studies on ascertaining particle size distributions have utilized SEM imaging techniques for detecting black carbon particles (Dominko *et al.*, 2003)

We have used a combination of SEM imaging technique coupled to an additional post processing step to ascertain the sizes of the deposited particles with enhanced visibility using Image Segmentation. We now proceed to discuss methods to quantify pollutant scavenging rates by VE.

**Table 1.** Vehicular emission characterisation in Chennai

| SI. No | Category of Vehicles | $X_i$ | $T_n$ | T(0-5) | L (km) | R1 | Pollution Load (g/km·d) | Pollution Load (g/km·s) |
|---|---|---|---|---|---|---|---|---|
| 1 | Heavy vehicles (Bus, Trekkers) | 0.56 | 2434.04 | 1.35 | 1 | 1 | 1840 | 0.021 |
| 2 | Heavy Vehicles (Trucks/ Tractors/ Tailors/ Goods vehicles | 0.28 | 4320.42 | 1.59 | 1 | 1 | 1923 | 0.022 |
| 3 | Light vehicles (Cars/Taxis, etc.) | 0.08 | 3103.40 | 1.28 | 1 | 1 | 318 | 0.004 |
| 4 | Three-wheeler (Tempo, Auto-Rickshaw) | 0.05 | 11014.03 | 1.7 | 1 | 1 | 936 | 0.01 |
| 5 | Two wheelers (Motor cycle, Scooter, moped) | 0.02 | 24401.25 | 1.3 | 1 | 1 | 634 | 0.007 |
| | | | | | | | | **Total: 0.064** |

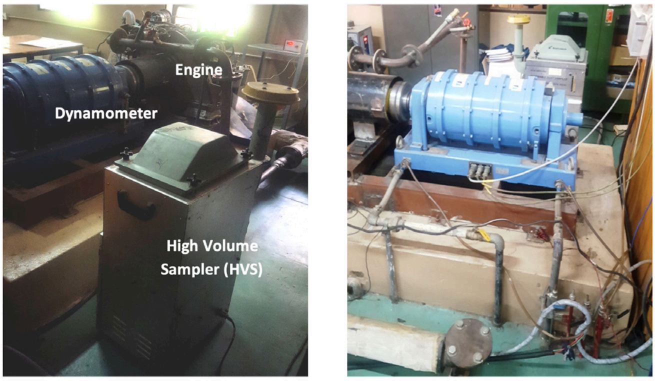


**Figure 3.** a) $PM_{10}$ High Volume Sampler (HVS) placed near the exhaust of the diesel engine. b) Diesel engine rig consisting of Mahindra 4 stroke diesel engine connected to a dynamometer (blue)

*2.3 Quantifying $PM_{10}$ removal rates and thermal comfort levels using living green drapes*

In this paper, $PM_{10}$ pollution scavenging studies have been performed on three academic buildings; located 500 m to the west of the road network (Figure 4a). Due to their proximity to NH-32 and other arterial roads, it is a vulnerable region which receives copious amounts of $PM_{10}$ (about 50 μg.m^(-3) from vehicle generated pollution alone see Figure 5). Since, the eastern side of these buildings is directly exposed to pollution from vehicular traffic on NH-32, we chose to selectively model the living drape on the east facing walls of these buildings (Figure 4d). The removal of particulate air pollutants at a given location can be expressed as:

$$Q = F \times S \times T$$

where Q (kg) is the amount of air pollutant removed by plants in a given time, F is the pollutant removal flux (μg.$m^{-2}$ $s^{-1}$) ,S the total area of green cover ($m^2$) and T the exposure time period in seconds (s). The east facing wall of the buildings in question have a glazing to wall ratio of 0.3, yielding an effective value of S as 336 $m^2$. A formal way to mathematically quantify the flux F is given by:

$$F= -v_d \times C$$

where $v_d$ is the deposition velocity (m.$s^{-1}$) and C the ambient pollutant concentration (μg.$m^{-3}$ ). In section 3, we show how this quantification illustrates the versatility of the chosen drape to restore ambient PM10 levels. A green facade is found to be 97.3 % more efficient than a concrete wall. However, in the next section we show that additionally, the VE drape lowers the Heating Ventilation and Air Conditioning (HVAC) loads, adding to the overall thermal comfort of the occupants.

*2.3.1 Thermal comfort analysis*

Several studies on the thermal comfort levels in buildings have shown that structures draped with green facades show a potential reduction of up to 11.6 °C in their surface temperature (Eumorfopoulou and Kontoleon, 2009; Wong *et al.*, 2010). It could be an apt restorative measure for a city like Chennai also which has an average temperature of 25 °C and has very high traffic density.

Energy simulations and comfort modelling studies have been carried out on three academic buildings, located to the west of Basin Bridge traffic junction in Chennai- 1) Don Bosco Polytechnic building (DBP) and 2) Administrative block (AB) located in the Don Bosco Technical campus along with 3) St. Joseph technical institute building (SJT). These buildings occupy a total floor area of 1767 $m^2$ (DBP), 476 $m^2$ (AB) and 1633 $m^2$ (SJT) (mapped through satellite imagery) and have an occupancy of 385, 49 and 103 persons on each floor respectively. An overview and 3D rendition of these buildings have been shown in Figure 4a, b. In order to have a thermal analysis done, we need to state the desired comfort levels. This is best described by ASHRAE (Table 2) through Predicted Mean Vote (PMV) index (ANSI/ASHRAE Standard 55).

We have used Design Builder for calculating the PMV values for all the three buildings, taking into account the fabric and orientation of each of these buildings. In the hot and humid environment of Chennai, turning the HVAC off altogether is futile because the overall temperature is 25 °C and relative humidity is 70 %. However, the presence of a green drape may well reduce the HVAC loads. This may yield substantial cumulative savings.

In order to achieve these objectives, we use Design Builder (Version 4.5.0.148) and Energy PlusTM. The first requirement is the design input which is supplied along with the material properties. These are shown in Tables 3 and 4. Apart from the material properties, the code requires detailed design specification corresponding to the building form and its interaction with the incoming radiation. This is shown in Table 4.

The green wall characteristics supplied as input to Design Builder model include: 1) Thickness of the plants- 0.2 m 2) Leaf Area Index (LAI) - it is the projected leaf area for shrubs and wall plantations per unit area of soil and is taken as 3.0 (Varghese *et al.*, 2015) 3) Leaf reflectivity- it is the fraction of incident solar radiation that is reflected by the individual leaf surface and is taken to be 0.320 4) Minimum stomatal resistance has been set to 180 $sm^{-1}$ (Pacetti *et al.*, 2012).

The creeper's almost 100 % coverage rarely wanes beyond 85 % (during the harshest summers) (Varghese *et al.*, 2015). Therefore, as far as the drape's thermal performance is concerned, one can use a single representative U value for the purposes of modeling temperature distributions and comfort indices. This has been reported and discussed in Section 3.

**Table 2.** Input parameters for computing PMV. Note: The superscripts 1, 2, 3 indicate values chosen for Don Bosco Polytechnique College, Administrative Block and St. Joseph Technical Institute, respectively

| Parameters | Monthly Averaged Value |
|---|---|
| Dew Point Temperature (°C) | 22.55 |
| Air temperature (°C) | 25.73 |
| Direct Normal Solar ($kW/m^2$) | 114.80 |
| Diffuse Horizontal Solar ($kW/m^2$) | 78.69 |
| Wind Speed (m/s) | 2.26 |
| Clothing Factor (clo) | $0.61^1$, $0.61^2$, $0.96^3$ |
| Metabolic rate (met) | $1.5^1$ (Walking), $1.0^2$ (Sitting/Working), $2.2^3$ (Workshop operations*) |

*Workshop operations involve working on heavy machinery in laboratories

**Table 3.** Wall properties for Green wall and normal wall

| Green wall | | Normal wall | |
|---|---|---|---|
| Brickwork | 0.1 m | Brickwork | 0.1 m |
| Gypsum insulating layer | 0.053 m | Gypsum insulating layer | 0.053 m |
| Cement (Medium) | 0.1 m | Cement (Medium) | 0.1 m |
| Green Façade | 0.20 m | | |
| **Total** | 0.413 m | **Total** | 0.213 m |

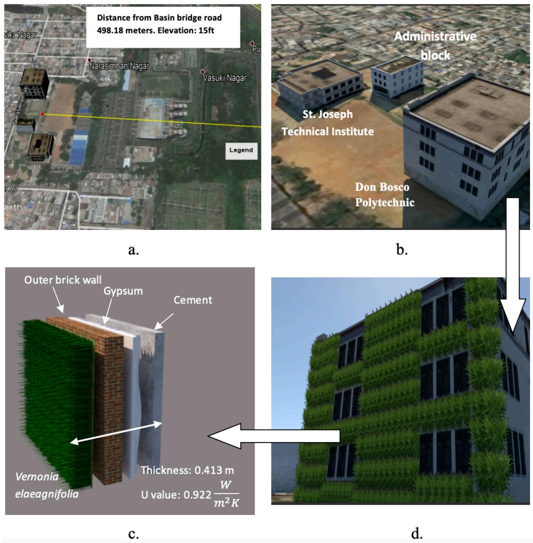


**Figure 4**. a) Overview of buildings showing distance of Don Bosco Technical campus from the nearby traffic junction. b) A magnified view of the rendered building. c) Green wall composition and characteristics. d) Don Bosco Polytechnic Institute building draped with a green wall

**Table 4.** Design specification of the three buildings

**1. Don Bosco Polytechnique College**

| **Building Type: Hall/Lecture Hall/Assembly area** | | |
|---|---|---|
| **S. No.** | **Property Variable** | **Value** |
| 1 | Floor Area ($m^2$) | 1767 |
| 2 | Occupancy Density | 0.2183 |
| 3 | Power Density ($W/m^2$ ) | 2 |
| 4 | Radiant Fraction | 0.2 |

**2. Administrative Block**

| **Building Type: Office/Consulting areas** | | |
|---|---|---|
| **S. no.** | **Property Variable** | **Value** |
| 1 | Floor Area ($m^2$) | 476 |
| 2 | Occupancy Density | 0.103 |
| 3 | Power Density ($W/m^2$ ) | 11.99 |
| 4 | Radiant Fraction | 0.2 |

**3. St. Joseph Technical Institute**

| **Building Type: Workshop** | | |
|---|---|---|
| **S. No.** | **Property Variable** | **Value** |
| 1 | Floor Area ($m^2$) | 1633 |
| 2 | Occupancy Density | 0.0633 |
| 3 | Power Density ($W/m^2$ ) | 6.19 |
| 4 | Radiant Fraction | 0.2 |

## 3. Results and Discussion

### *3.1 Simulation results*

Seasonal $PM_{10}$ concentrations are now discussed. Nested contours are observed along the main thoroughfare, and branched arterial roads. $PM_{10}$ concentrations vary from a minimum of 26 μg.m$^{-3}$ for the month of May to a maximum of 100 μg.m$^3$ for the month of November with other months having intermediate values.

The $PM_{10}$ pollutant concentration varies both spatially and temporally, and in addition, there is substantial variability in their atmospheric residence times (varying from a few hours to a few days) (Jayaraman *et al.*, 2001). However, because of the city's close proximity to the equator, extreme seasonal temperature variations are not observed.

We observe low $PM_{10}$ concentrations during Summer (Figure 5a) because of greater mixing heights (~ 1000 m) and high wind speeds (64.5 % points in the frequency distribution table fall within the wind class 3.60-5.70 m.s$^{-1}$. PM10 concentrations are higher during Post-Monsoon (November) and Winter months (February) attributed to the lower mixing depths (~ 600 m and 700 m, respectively) and lower wind speeds evident from Figures 5c and 5d. Local air quality during these months is exacerbated when vehicles are left to idle at street junctions. Although engine warming is not a requirement for modern day direct injection diesel engines, a majority of drivers tend to exceed the 30 s threshold for idling (Carrico *et al.*, 2009).

A laboratory experiment was indeed necessary to investigate the PM size regime and

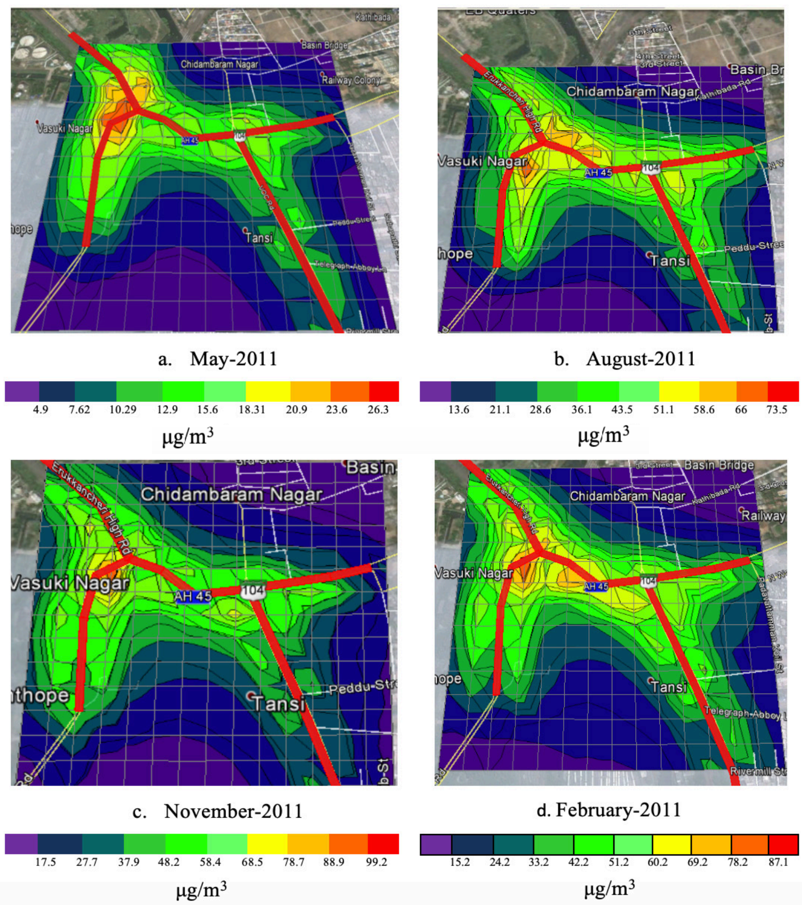


**Figure 5.** 8 hourly averaged $PM_{10}$ concentration (μg/m$^3$) profile over Erukenchery traffic junction

concentration from an idling vehicle operated under similar conditions. Deposition of PM can be observed by a marked greyness in the filter paper colour as can be seen from Figure 6a. From Figure 6b (a SEM micrograph), we observe sharp color gradients around the edges of the PM particles, allowing them to be differentiated from the fiber strands. These segmented regions (PM particles) were then masked with a pale-yellow shade enhancing the overall visibility of the SEM image. We observe numerous sub- micron size particles with a few large particles to the tune of 1 μm.

A Particle Size Distribution (PSD) from the diesel engine exhaust is shown in Figure 7. PM mode diameter and particles per $cm^3$ of air collected after dilution has been observed to be ~0.25 μm and ~450,000 $cm^{-3}$ respectively. Several studies using a diesel engine at low idling conditions have observed a similar order of particle count (Kittleson, 1998; Zhu *et al.*, 2002). We deliberately chose to take measurements, after release from the tail-pipes, proxying idling conditions along busy streets- the nucleation mode particles quickly convert to larger accumulation mode particles owing to the presence of ambient moisture. It is observed from Figure 7 that the majority of the particles are still in the submicron range.

The overhanging pollutant pall will naturally get deposited onto surfaces- the downward settling on the paved roads can potentially scavenge small amounts of some of the pollution. This is accounted for in our model estimates. A deposition velocity ($v_d$) value for a concreted road (like Erukenchary) is 0.0036 $cm.s^{-1}$ which is very low value- ~100 times lower than that for a vegetated surface (Roupsard *et al.*, 2013).

With such low $v_d$, the pollutant particles are majorly air borne along this road. Our own modelled velocities ($v_d$) for the deposition of PM10 over a green wall during day-time (3:00 pm IST) and night-time (2:00 am IST) for November (Post Monsoon) are: 0.2088 $cm.s^{-1}$ and 0.1161 $cm.s^{-1}$ respectively (see Section 2.3).

(a) (b)

**Figure 6.** a) Colour change-greyness showing soot or black carbon deposition on a glass micro fibre filter paper (Dimensions: 20.3 ×25.4 $cm^2$). b) SEM micrograph image depicting size and number of black carbon deposited

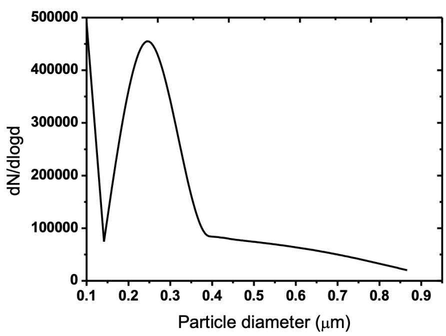


**Figure 7.** Particle size distribution of diesel emissions from engine after dilution. The mode diameter is ~0.25 μm

We observe higher $v_d$ during the daytime due to a higher turbulence over a well-mixed boundary layer. These results are coherent with existing literature pertaining to experimentally-derived particle v_d values on vegetated surfaces (Nemitz *et al.*, 2002; Leonard *et al.*, 2016).

We have extracted modeled PM concentrations vertically for this purpose. With the placing of a vertical green drape (VGD), on specific buildings (see Figure 4d), the subsequent scavenging rates can be extracted at any desired height from each building. We compute Q undraped, this yields Q = 0.0448 gm for a $v_d$ value of 0.0036 cm.s$^{-1}$. In contrast, a VE drape mounted on a wire frame with a total thickness of 0.2 m, yields Q = 1.68 gm for a $v_d$ value of 0.162 cm.s$^{-1}$. (Figure 4d) (A VE draped green facade is 97.3 % more efficient than a normal concrete wall).

The individual U value along with the admittance and solar absorptance values of each layer composing the wall has been listed in Table 5. The overall U for both, the green and normal wall has been found to be 0.922 W.m$^{-2}$ K$^{-1}$ and 1.343 W.m$^{-2}$ K$^{-1}$ respectively. There is a drop of 31.34 % in the U value due to the vegetation on the external layer of the wall which acts as an insulation against heat flow and helps dissipate solar energy by evapo-transpiration.

The modelled Mean Radiant Temperature (MRT), decreases between 2-4 °C, over a 24 h period for Don Bosco Polytechnic building draped with the green creeper (Figure 8).

With the observed temperature drop, one expects, a better PMV. The PMV values with and without the green facade for all the three buildings have been reported in Table 6.

Finally, it is important to give an overview of the net energy savings. This has been shown in Table 7. Calculations also yield overall annual HVAC savings of 104,999.96 USD for all the three buildings.

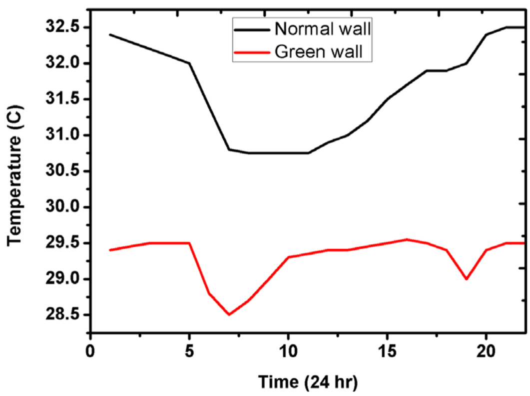


**Figure 8.** Mean Radiant Temperature (MRT) over a 24 period for Don Bosco Polytechnic building as on 21 June

**Table 5.** Individual U value, admittance and solar absorptance of each layer composing the green wall

| Façade Specifications | U-Value (W/m²·K) | Admittance (W/m²·K) | Solar absorptance |
|---|---|---|---|
| *Vernonia elaeagnifolia* | 2.040 | 4.96 | 0.41 |
| Brick Work | 3.460 | 4.24 | 0.7 |
| Gypsum Insulating layer | 2.153 | 2.24 | 0.5 |
| Cement | 3.237 | 4.210 | 0.6 |

**Table 7.** Net savings with partial and full HVAC loads with and without the green wall (The green wall is draped only on the east-facing wall)

| | Green Wall (kWh) | Normal Wall (kWh) | Net Savings (kWh) | Net Savings (%) |
|---|---|---|---|---|
| **Partial HVAC** | 8,34,283.4 | 8,45,231.6 | 10,948.2 | 1.3% |
| **Full HVAC** | 13,95,432.1 | 14,88,765.4 | 93,333.3 | 6.3% |

## 4. Conclusions

A combination of air quality modelling and laboratory observational studies using a BS IV diesel engine, along with a detailed SEM analysis of the resulting PSD, found that the modal particle diameter and number of soot particles collected after dilution were ~0.25 μm and ~450,000 per $cm^3$, respectively. The advective impacts of pollution captured by a Green wall are more important in the context of evaporative cooling. During Post Monsoon and Winter months (November and February respectively), we observe a strong westward wind component blowing pollutants downwind over the east-facing walls of the selected buildings. Although, the pollutant concentrations diminish downwind in a Gaussian profile but the east-facing walls would still be directly exposed to wind velocity fluctuations. The impinging carrier wind speed varies from 2 to 8 $m.s^{-1}$, much larger than the settling speeds of the particles ~ 0.2 $cm.s^{-1}$. This ensures that the particles 'flow with the wind' and upon touching the receptacle, i.e. the VE foliage, are lodged there. This study shows that the green wall on buildings intercepts PM2.5 via advection majorly on the adaxial surface. An energy and comfort modelling study was conducted using *Vernonia elaeagnifolia* draped onto the east facing wall of the buildings. We see a reduction in the PMV value from 1.73 (uncomfortably warm) to 0.98 (comfortable) for the Don Bosco Polytechnic building. A reduction in PMV had an effect on the overall HVAC loads as well- calculations yielded annual HVAC savings of 104,999.96 USD (93,333.3 kWh) when all 3 buildings were considered.

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