Sustainable Strategies to Minimise Vehicular Pollutant Concentrations - A case of Vijayawada City

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Need for the study

- Rapid development activities from 1990’s have resulted in increased demand for transportation network
- Transportation networks direct the economic and spatial development of a region
- Transportation sector is a major contributor in global climate change, accounting for almost 23% of world's carbon dioxide emissions from combustion of fossil fuels
- Emissions from various transport systems is Road – 72%, Rail – 8%, Air – 10% & Water – 10% (IPCC)
- Road Transport emissions are maximum and are still increasing, keeping pressure on oil demand & fuel prices
- India’s Urban Population are predominantly dependent on Road Transport, with a share of 85% of total passenger trips and 65% of freight movement
Need for the Study

CO – Poisonous gas that directly enters into haemoglobin of humans leading to headaches, fatigue and even death.
Conceptual Framework

**LITERATURE REVIEW**
- Pollution Calculation
  - Pollutant assessment
  - Dispersion Models
- Green Cover Absorption
  - Quantifying absorption capacities of urban green
- Green Transport solutions
  - Alternative Fuels
  - Policies & Schemes

**AIM**
To achieve Sustainability by establishing a relation between vehicular pollutant concentrations and green cover along urban roadways

**SCOPE**
- Study addresses three dimensions – Pollutant Concentration, Absorption by Green Cover and strategies for Suitability
- Green cover absorption capacities and Impact of Pollutant concentrations are predicted till 100m on either side of the roads
- Pollutant estimates are done for Three Arterial roads of the city

**LIMITATION**
- Traffic survey – 1 hr.
- Pollutant considered – Carbon Monoxide (CO)
- Study does not consider age of vehicles

**RESEARCH GAP**
No research on relation between Ambient Air Quality and the absorption capacities of green cover along sides and median of roads

Pollution Calculation → Green Cover Absorption → Green Transport solutions
**Road Hierarchy Length ROW(m)**

<table>
<thead>
<tr>
<th>Road</th>
<th>Hierarchy</th>
<th>Length</th>
<th>ROW(m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH 16</td>
<td>4 lane divided + 2 lane undivided</td>
<td>6.5 km</td>
<td>32 – 60</td>
</tr>
<tr>
<td>NH 65</td>
<td>4 lane divided</td>
<td>7 km</td>
<td>24 – 34</td>
</tr>
<tr>
<td>Eluru Rd.</td>
<td>4 lane divided</td>
<td>7 km</td>
<td>24 – 26</td>
</tr>
</tbody>
</table>

**Study Area - Vijayawada Municipal Corporation**

*Growth in registered vehicles*

- Non - Transport Vehicles
- Transport Vehicles

**Ambient Air Quality**

<table>
<thead>
<tr>
<th>Year</th>
<th>PM 2.5</th>
<th>PM 10</th>
<th>NOx</th>
<th>CO</th>
<th>SO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>39.6</td>
<td>88.72</td>
<td>33.98</td>
<td>1.13</td>
<td>16.16</td>
</tr>
<tr>
<td>2018</td>
<td>49.16</td>
<td>102</td>
<td>65.52</td>
<td>1.21</td>
<td>13.71</td>
</tr>
<tr>
<td>2019</td>
<td>38.07</td>
<td>47.12</td>
<td>25.07</td>
<td>1.79</td>
<td>10.73</td>
</tr>
</tbody>
</table>

**Area**

- 61.88 sq.km

**Population**

- 10.48 lakhs

**Year**

- PM 2.5
- PM 10
- NOx
- CO
- SO2
Estimation of CO Concentrations

**CALINE MODEL** is used for estimating CO concentrations along selected roads

- Originally developed for Carbon Monoxide (CO)
- Principle – dividing road into series of elements; Concept of ‘Mixing Zone’

- Units - Metres
- Aerodynamic Roughness Coefficient – 300 (for major roads of large towns)
- Run Type – **Worst case wind direction**
- CO Emission Factor (g/mi) for 1 hr
- Pollutant - Carbon Monoxide
- Molecular Weight – 28
- Altitude above sea level – 23m for Vijayawada
- Link Type – **At Grade**
- Mixing Zone Width – **ROW + 3m on either side of the road**
- Wind Direction Standard Deviation - 5°
- Ambient CO Concentration – 3 ppm
Model simulation for stretch “H – A” of NH-16

- Receptor points are given using X, Y and Z coordinates so as to ensure accuracy of observed values with predicted values.
- The output of model is given in results tab, where concentrations of CO are noted in terms of ppm.
- Similarly, entire process if performed for the three stretches to obtain the concentration of the stretch.

Coordinates of each link point are taken from GIS software (after georeferencing) in metres and used as input data for CALINE model as (X1, Y1); (X2, Y2) for each link.

Valid:
- Receptors – 8
- Stretches – 7
- Link Points – 66

Receptor Coordinates are noted from GIS as (X,Y) and Z is taken as 1.8 (as per model specifications).
# Predicted CO Concentrations along NH-16

## Assessment of Pollution Concentrations

<table>
<thead>
<tr>
<th>Receptor</th>
<th>Observed (CO) - ppm</th>
<th>Predicted (CO) - ppm</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>13.9</td>
<td>14.7</td>
<td>5.75%</td>
</tr>
<tr>
<td>A</td>
<td>12.7</td>
<td>13.6</td>
<td>7.09%</td>
</tr>
<tr>
<td>B</td>
<td>13.8</td>
<td>14.4</td>
<td>4.35%</td>
</tr>
<tr>
<td>C</td>
<td>13.4</td>
<td>14.4</td>
<td>7.46%</td>
</tr>
<tr>
<td>D</td>
<td>12.1</td>
<td>13.3</td>
<td>9.91%</td>
</tr>
<tr>
<td>F</td>
<td>13.9</td>
<td>15.2</td>
<td>9.35%</td>
</tr>
<tr>
<td>E</td>
<td>14.7</td>
<td>15.5</td>
<td>5.44%</td>
</tr>
<tr>
<td>G</td>
<td>12.6</td>
<td>13.2</td>
<td>4.76%</td>
</tr>
</tbody>
</table>

## Impact of CO concentration till 100m

Average CO Emission Concentration = 14.3 ppm

CO2 Emission Concentration = CO emissions concentration x 44 / 28

= 14.3 x 44 / 28 = **22.47 ppm of CO2**
The biomass of trees has been estimated based on GBH (Girth at Breast Height) and tree height. Girth of tree is measured at breast height (1.3m).

\[
AGB \ (Kg/tree) = Volume \ of \ tree \ (m^3) \times Wood \ density \ (Kg/m^3)
\]

\[
Volume \ of \ Tree = 0.4 \times (GBH)^2 \times H / 3.14
\]

\[
BGB \ (Kg/tree) \ or \ (ton/tree) = AGB \ (Kg/tree) \ or \ (ton/tree) \times 0.26
\]

Total Biomass = AGB + BGB

Carbon Storage = 1% of total biomass per species
Green Cover Absorption Capacities along NH-16

<table>
<thead>
<tr>
<th>Tree Name</th>
<th>GBH (m)</th>
<th>Height (m)</th>
<th>Bio-Volume</th>
<th>Wood Density (Kg/m³)</th>
<th>AGB</th>
<th>BGB</th>
<th>Total Biomass</th>
<th>Carbon Storage/ Tree</th>
<th>Total Carbon Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albizia Lebbeck</td>
<td>0.18</td>
<td>3.5</td>
<td>0.0144</td>
<td>630</td>
<td>9.1009</td>
<td>2.3662</td>
<td>11.4671</td>
<td>0.114671</td>
<td>4.586849</td>
</tr>
<tr>
<td>Azadirecta Indica</td>
<td>0.22</td>
<td>5</td>
<td>0.0308</td>
<td>650</td>
<td>20.0382</td>
<td>5.2099</td>
<td>25.2482</td>
<td>0.252482</td>
<td>2.272334</td>
</tr>
<tr>
<td>Delonix Regia</td>
<td>0.13</td>
<td>4.5</td>
<td>0.0097</td>
<td>600</td>
<td>5.8127</td>
<td>1.5113</td>
<td>7.3241</td>
<td>0.073241</td>
<td>3.662025</td>
</tr>
<tr>
<td>Ficus Religiosa</td>
<td>0.15</td>
<td>5.2</td>
<td>0.0149</td>
<td>600</td>
<td>8.9427</td>
<td>2.3251</td>
<td>11.2678</td>
<td>0.112678</td>
<td>2.591587</td>
</tr>
<tr>
<td>Mangifera Indica</td>
<td>0.12</td>
<td>4.5</td>
<td>0.0083</td>
<td>590</td>
<td>4.8703</td>
<td>1.2663</td>
<td>6.1366</td>
<td>0.061366</td>
<td>1.043222</td>
</tr>
<tr>
<td>Tamarindus Indica</td>
<td>0.15</td>
<td>4.2</td>
<td>0.0120</td>
<td>700</td>
<td>8.4268</td>
<td>2.1910</td>
<td>10.6177</td>
<td>0.106177</td>
<td>1.061771</td>
</tr>
<tr>
<td>Terminalia Arjuna</td>
<td>0.17</td>
<td>4.8</td>
<td>0.0177</td>
<td>680</td>
<td>12.0165</td>
<td>3.1243</td>
<td>15.1408</td>
<td>0.151408</td>
<td>0.605632</td>
</tr>
<tr>
<td>Bougainvillea</td>
<td>0.025</td>
<td>0.45</td>
<td>0.0000</td>
<td>200</td>
<td>0.0072</td>
<td>0.0019</td>
<td>0.0090</td>
<td>9.03E-05</td>
<td>0.072229</td>
</tr>
<tr>
<td>Conocarpus Erectus</td>
<td>0.05</td>
<td>1.2</td>
<td>0.0004</td>
<td>230</td>
<td>0.0879</td>
<td>0.0229</td>
<td>0.1108</td>
<td>0.001108</td>
<td>0.276879</td>
</tr>
<tr>
<td>Tecoma Stans</td>
<td>0.06</td>
<td>1</td>
<td>0.0005</td>
<td>210</td>
<td>0.0963</td>
<td>0.0250</td>
<td>0.1213</td>
<td>0.001213</td>
<td>0.018202</td>
</tr>
</tbody>
</table>

**CARBON STORAGE (CO2) = 16.19073 ppm**

CO2 concentration = emissions – absorption = 22.47 – 16.19 = 6.28 ppm ≈ 4 ppm of CO

Therefore, 4 ppm of CO is not being absorbed by the vegetation along NH – 16
Scenario Building

Based on Population & Traffic projections, the following scenarios are considered to estimate for 2030:

**SCENARIO I**
Desirable modal share based on city size/population

**SCENARIO II**
Desirable proportion of Electric Vehicles - NEMMP

**SCENARIO III**
Tress species suitable for along side and median of roads

**BUSINESS NEUTRAL SCENARIO** – Vehicle and Fuel Composition are taken same as present

**SCENARIO – I** : Change in Vehicular Composition & respective variation in Fuel Composition

**SCENARIO – I + II** : Change in Vehicular and Fuel Composition, shift to e-mobility is considered

**SCENARIO – III** : Increased Green Cover and introduction of suitable new species

**BUSINESS NEUTRAL+ SCENARIO** – III : Vehicle & Fuel Composition as present + Increased Green Cover

**SCENARIO – I + III** : Change in Vehicular Composition + Change in Green Cover

**SCENARIO – I + II + III** : Change in Vehicular Composition + Shift to e-mobility + Green Cover change
# Results

## Summary of Scenarios along three roads

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>NH - 16</th>
<th>NH - 65</th>
<th>Eluru Road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td>4 left</td>
<td>9 left</td>
<td>8 left</td>
</tr>
<tr>
<td>I + II</td>
<td>0.7 left</td>
<td>3.37 left</td>
<td>2.56 left</td>
</tr>
<tr>
<td>Business Neutral + III</td>
<td>3.74 left</td>
<td>11.26 left</td>
<td>9.23 left</td>
</tr>
<tr>
<td>I + III</td>
<td>3.46 left</td>
<td>9.74 left</td>
<td>8.83 left</td>
</tr>
<tr>
<td>I + II + III</td>
<td>3.16 left</td>
<td>1.65 left</td>
<td>1.02 left</td>
</tr>
</tbody>
</table>

Thus the two scenarios falling within the standard of 3.4 ppm - Scenario I + II and Combination of all three scenarios (I + II + III) are recommended, highlighting the need of shift towards electric vehicles and increased green cover.