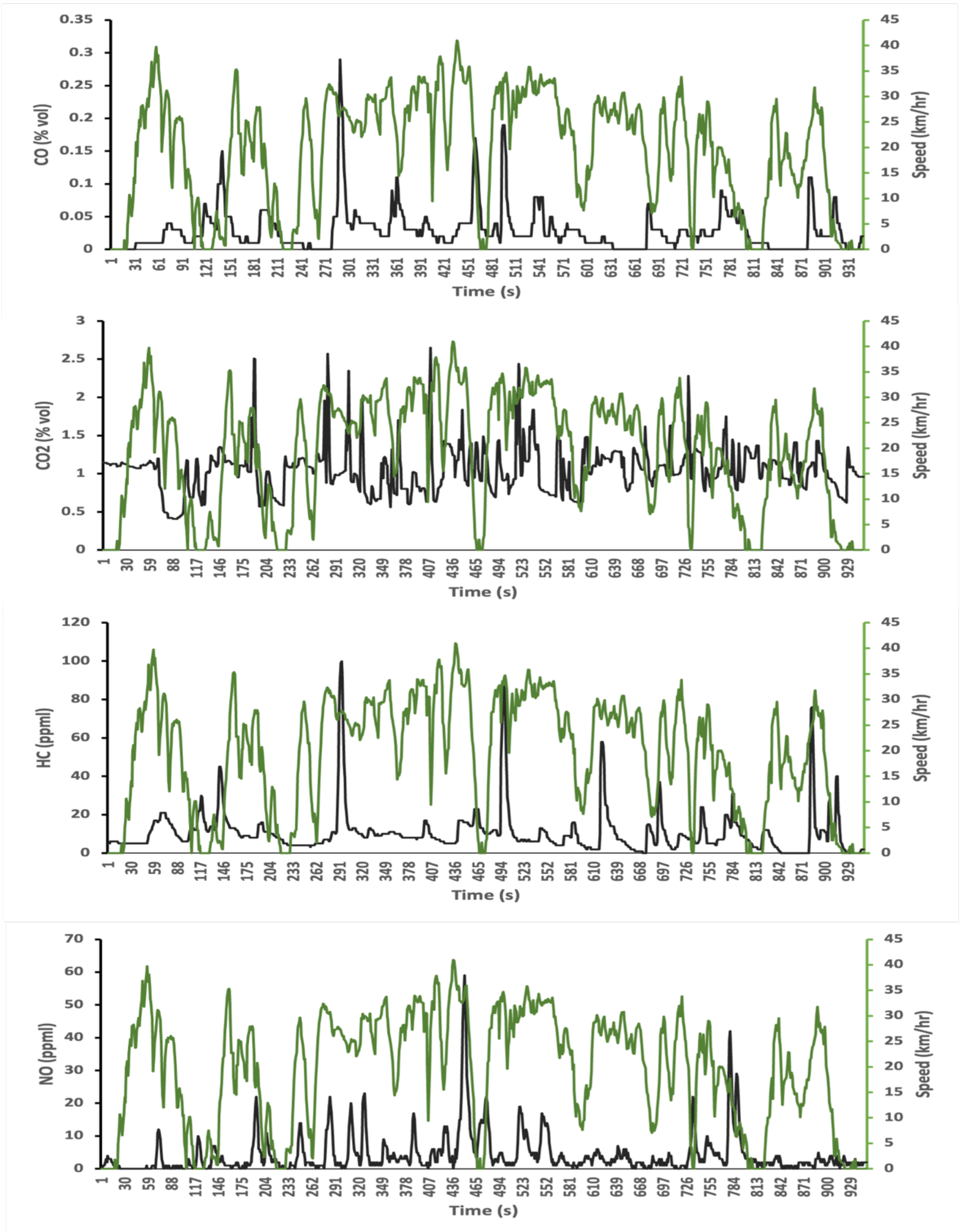
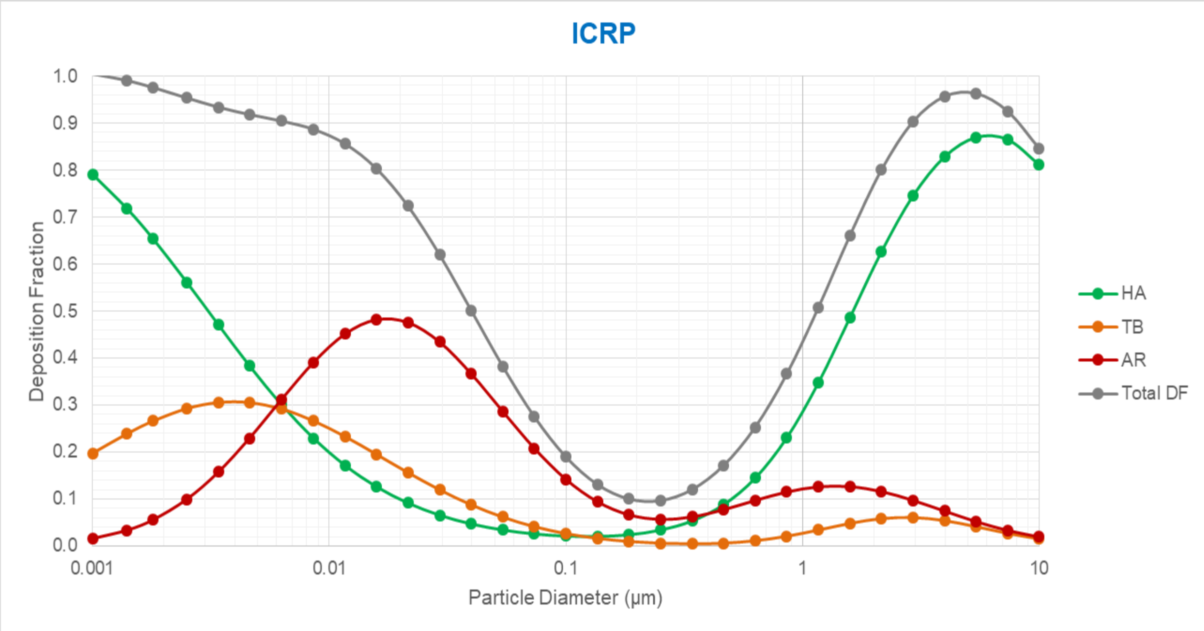
# Exploring the Nexus of Two-Wheeler Gaseous Contributions and Driver Exposure in a Million-Plus Population City

**Supporting data:**

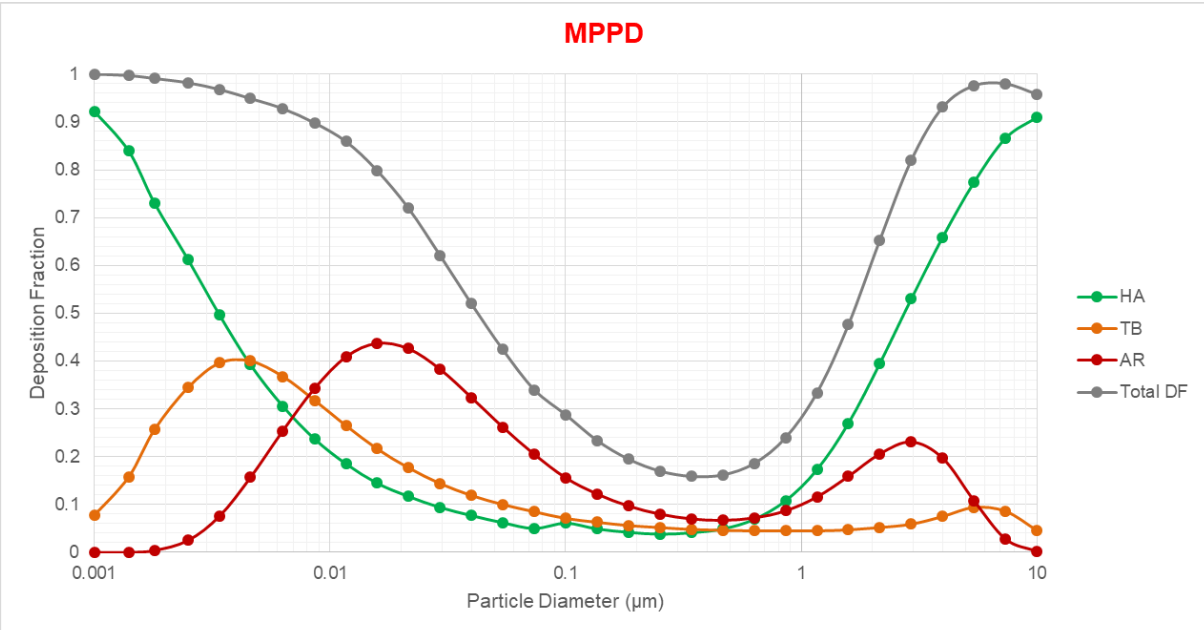
**Emission profiles (Two-wheeler)-**




*Supplementary Figure 1: (a) Speed vs. CO (%vol), (b) Speed vs. $CO_2$ (%vol), and (c) Speed vs. HC (%vol) over time on a low-density road.*




Supplement data Figure 2. Deposition fraction efficiencies according to particle size by ICRP model




Supplement data Figure 3. Deposition fraction efficiencies according to particle size by MPPD model

**Supplementary Table 1: Summary of Mobile Platform-Based Personal Exposure Studies for PM**

| Study area and period | Area type | Mode of exposure | Pollutants measured | Mean / PM Number concentration | Instruments used | Reference |
|---|---|---|---|---|---|---|
| Antwerp, Belgium 2012 | Urban Roadways | Bicycle (Aeroflex) | UFP | 32310 pt/cm$^3$ | TSI P-TRAK | Peters et al., 2014 |
| Newark, US 2012 | Urban Roadway | Walking | UFP<br>$PM_{2.5}$ | 33,330 ± 23,451 pt/cm$^3$<br>8.87 ± 7.65 µg/m$^3$ | CPC (3007 TSI)<br>SidePak | Yu et al., 2016 |
| Braddock, US 2010 -2011 | Urban City | Cab | $PM_{2.5}$<br>$PM_{10}$ | 15.5 – 46.2 µg/m$^3$<br>24.8 – 50.5 µg/m$^3$ | Hazdust monitor (EPAM 5000, Environmental devices corporation) | Tunno et al., 2012 |
| Helsinki, Finland 2010 | Urban High traffic flow area | Van | UFP<br>$PM_{2.5}$ | (10– 16)×10$^3$ cm$^{-3}$<br>21 – 39 µg/m$^3$ | Electrical low pressure impactor<br>TSI DustTrak | Lähde et al., 2014 |
| Mol, Belgium 2010 | Urban Near road | Bicycle (Aeroflex) | UFP<br>$PM_{2.5}$ | (14 – 18)×10$^3$<br>26 – 27 µg/m$^3$ | TSI P-TRAK<br>Grimm Dust Monitor 1.108(Grimm Aerosol Technik, Germany) | Van Poppel et al., 2013 |
| Antwerp, Belgium 2009 | Urban Cycling paths | Bicycle (Aeroflex) | UFP<br>$PM_{10}$ | 21722 pt/cm$^3$<br>97 µg/m$^3$ | TSI P-TRAK<br>DustTrak DRX 8534 | Peters et al., 2013 |
| Brussels, Belgium 2009 | Urban | Bicycle | PNC (dose)<br>$PM_{10}$(dose)<br>$PM_{2.5}$(dose) | 4,631,562 dose/meter<br>11.5 µg/km<br>3.4 µg/km | TSI P-TRAK<br>TSI DustTrak | Int Panis et al., 2010 |
| Mol | Urban | | UFP | 16040 pt/cm$^3$ | TSI P-TRAK | |

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|---|---|---|---|---|---|---|
| 2009 | Cycling paths | Bicycle (Aeroflex) | $PM_{10}$ | 45 µg/m$^3$ | Grimm Dust Monitor 1.108(Grimm Aerosol Technik, Germany) | Peters et al., 2013 |
| Brooklyn, US<br>2007 | Urban<br>Roadway | Walking | UFP<br>$PM_{2.5}$ | 44,000 ± 24,800 pt/cm$^3$<br>36 ± 30 µg/m$^3$ | CPC (3781 TSI)<br>TSI DustTrak 8520 | Zwack et al., 2011a |
| Mol, Belgium<br>2007 | Urban | Bicycle (Aeroflex) | UFP<br>$PM_1$<br>$PM_{2.5}$<br>$PM_{10}$ | 21,226 ± 13,795 pt/cm$^3$<br>37.4 ± 28.3 µg/m$^3$<br>38.8 ± 26.4 µg/m$^3$<br>62.4 ± 33.5 µg/m$^3$ | TSI P-TRAK<br>Grimm Dust Monitor 1.108(Grimm Aerosol Technik, Germany) | Berghmans et al., 2009 |
| Vancouver, Canada<br>2007 | Bicycle routes | Bicycle | UFP<br>$PM_3$<br>$PM_{10}$ | 33920 ± 35982 pt/cm$^3$<br>21.04 ± 7.9 µg/m$^3$<br>50.66 ± 15.3 µg/m$^3$ | TSI P-TRAK<br>Grimm Dust Monitor 1.108 (Grimm Aerosol Technik, Germany) | Thai et al., 2008 |
| New York, US<br>2006 | Urban<br>Street Canyons | Walking | UFP<br>$PM_{2.5}$ | 28,400 ± 16,300 pt/cm$^3$<br>51.4 ± 39.3 µg/m$^3$ | TSI P TRAK<br>TSI DustTrak 8520 | Zwack et al., 2011b |
| London, England<br>2004 | Urban<br>Near road | Walking | UFP<br>$PM_{2.5}$ | 80009 pt/cm$^3$<br>37.7 µg/m$^3$ | TSI P-TRAK<br>High flow personal sampler(HFPS)<br>T15 v Langan CO Measures | Kaur et al., 2005 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Los Angeles, US<br>2003 | Urban<br>Roadway | SUV | UFP (median)<br>$PM_{2.5}$ (median) | 190000 pt/$cm^3$<br>54 $\mu g/m^3$ | CPC (3007 TSI)<br>CPC 3002 A TSI | Westerdahl et al., 2005 |
| Amsterdam, Netherlands<br>2000 | Urban<br>Motorway | Van | UFP<br>$PM_1$ | 160000 $cm^{-3}$<br>>9 $\mu g/m^3$ | CPC 3022 TSI Inc<br>LAS-v PMS Inc | Weijers et al., 2004 |
| Xi'an, China | Urban roadway | Walk | $PM_{10}$<br>$PM_{2.5}$<br>$PM_1$ | 127.23±22.26 $\mu g/m^3$<br>71.59±5.11 $\mu g/m^3$<br>57.01±3.11 $\mu g/m^3$ | Grimm dust monitor1.109(Grimm Aerosol Technik, Germany) | Qiu et al., 2017 |
| Bogota, Colombia | Bike-paths | Bike | $PM_{2.5}$ | 19.0 – 156.2 $\mu g/m^3$ | DustTrack 8533(TSIInc.,USA) | Franco et al., 2016 |
| Londrina, Brazil | Urban roadway | Bicycle | $PM_{2.5}$ | 8.61 $\mu g/m^3$ | DustTrack 8520(TSI,USA) | Targino et al., 2016 |

| Supplementary Table 2: Formulations of Goodness-of-Fit Tests | |
|---|---|
| **GOF tests** | |
| Kolmogorov-Smirnov (K-S) Test | $F_n(x) = \frac{1}{n}[Number\ of\ observations \leq x]$ <br> $D = \max_{1 \leq i \leq n}\left(F(x_i) - \frac{i-1}{n}, \quad \frac{i}{n} - F(x_i)\right)$ |
| Anderson-Darling (A-D) Test | $A^2 = -n - \frac{1}{n}\sum_{i=1}^{n}(2i-1).[\ln F(X_i) + \ln(1 - F(X_{n-i+1}))]$ |
| Where D= K-S statistic, n= number of samples, x=Random sample, i=(1 to n), $A^2$= A-D statistic <br> Hypothesis Testing <br> $H_0$: the data follow the specified distribution. <br> $H_A$: the data do not follow the specified distribution. | |

| Supplementary Table 3: Effect estimates derived from global studies | | | | |
|---|---|---|---|---|
| **Study area** | **Health outcome** | **Pollutant** | **Effect estimate*** | **Reference** |
| Global | All cause mortality rate | $PM_{10}$ | 0.2 -0.6 % | WHO, 2006 |
| Europe | Cardiopulmonary | $PM_{10}$ | 6 -13% | WHO, 2013 |
| Europe | Asthma<br>COPD + Asthma<br>All respiratory | $PM_{10}$ | 1.2 %<br>1.0%<br>0.9% | Atkinson et al., 2001 |
| US counties | Risk for heart failure<br>Hospitalization<br>Cardiovascular | $PM_{2.5}$ | 1.28%<br>1.05%<br>1.49% | Bell et al., 2008; Dominici et al., 2006 |
| China | All cause mortality | $PM_{10}$ | 0.3% | Aunan & Pan, 2004 |
| India | All cause mortality | $PM_{10}$ | 0.44% | Balakrishnan et al., 2011 |

**Supplementary Text:**

The particle dose in various part of respiratory tract was estimated using the equation 1.

$$Dose(\mu g) = DF \times PM\left(\frac{\mu g}{m^3}\right) \times TV\left(\frac{m^3}{breath}\right) \times f\left(\frac{breaths}{\min}\right) \times t\,(\min) \qquad (1)$$

Where 'DF' is the deposition fraction, 'TV' is the tidal volume, 'f' is the frequency of breathing and 't' is the duration of exposure which is considered to be 60 minutes.
The attributable proportion (AP) was calculate based on equation 2.

$$AP = \frac{\sum\{[RR_c - 1] \times p_c\}}{\sum\{[RR_c] \times p_c\}} \qquad (2)$$

Where, $RR_c$ is the relative risk for the health outcome in category $c$ of exposure and was calculated based on equation 3.

$$RR_c = \frac{(C - T)}{10} \times (RR - 1) + 1 \qquad (3)$$

The other equations ( 4 to 8) used were :

$$IE = I \times AP \qquad (4)$$

$$NE = IE \times N \qquad (5)$$

$$INE = I - IE \qquad (6)$$

$$\Delta I_c = [RR_c - 1] \times p_c \times INE \qquad (7)$$

$$\Delta N_c = \Delta I_c \times N \qquad (8)$$

Where,

p(c) - proportion of the population in category c of exposure

C - ambient air concentration of a pollutant,

T - threshold level of the pollutant (recommended by the WHO)

RR - relative risk for the selected health outcome,

I- baseline frequency of selected health outcomes

IE- rate (or number of cases per unit population) attributed to the exposure in population

N- population

NE- estimated number of cases attributed to exposure

INE- the frequency of the outcome in the population that is free from exposure

$\Delta I(c)$- the excess incidence

$\Delta N(c)$- excess number of cases

**References**

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