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COMEAP/2018/04 WORKING PAPER 5

COMMITTEE ON THE MEDICAL EFFECTS OF AIR POLLUTANTS

Exploratory assessment: personal exposure to fine particulate matter while commuting on the London Underground

1. This paper prepared by Dr Christina Mitsakou uses statistical estimates and time-activity patterns from the London Hybrid Exposure Model (LHEM) to estimate exposure to fine particulate matter ($PM_{2.5}$) for the population of London and while traveling by the London Underground and bus.

2. The author would like to acknowledge Kings College London for the air quality data used in the calculations.

3. Note: This is a draft working paper for discussion. It does not reflect the final view of the Committee and should not be cited.

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Travelling by London Underground (LU) and exposure to $PM_{2.5}$

The calculations of daily exposure to $PM_{2.5}$ are based on particle measurements in the London Underground (LU) carried out by King's College London (personal communication) and the London Hybrid Exposure Model (LHEM) by Smith et al. (2016).

LHEM - description
The model estimates the exposure to outdoor air pollution for the population of London while indoors, outdoors, and during journeys.

Space-time-activity data for the LHEM is based upon the London Travel Demand Survey (LTDS), provided by Transport for London (TfL) for the period 2005−2010 [household and person weighting factors, rebased following the 2011 Census and calculated by TfL, allow the scaling of the LTDS data set (45,079 people) to represent the population of London, excluding children under 5 (6.8m)]. The LTDS data set includes start and end coordinates, times of trips, and mode of transport.

For periods between trips, people were assumed to stay indoors at the previous destination point.

Exposure to outdoor air pollution was provided by CMAQ-urban (Beevers et al., 2012). Indoor exposure to outdoor sources was calculated by applying indoor/outdoor (I/O) ratios for domestic properties to the outdoor CMAQ-urban (Taylor et al., 2014). For in-vehicle exposure, the pollutant concentration was derived by solving the mass balance equation, as described in Smith et al. (2016).

Time in microenvironments
By analysing the LTDS data, the percentage of daily time spent in the different microenvironments for total population and LU users only is calculated, as shown in Table 1a,b. On average, LU adult users spend 4% of their time on LU that is equivalent to ~1h a day.

Table 1a. Percentage of time (%) spent in each microenvironment for total population (6.8m)

Microenvironment	child (5−17)	young adult (18−29)	adult (30−59)	elderly (60+)	all ages (≥5)
Walk	0.9	1.7	1.5	1.2	1.3
Cycle	0.0	0.1	0.1	0.0	0.1
Motorcycle	0.0	0.1	0.1	0.0	0.0
Driving	0.8	1.4	2.2	1.5	1.6

Bus	0.5	0.9	0.7	0.6	0.7
LU & DLR	**0.1**	**0.7**	**0.5**	**0.2**	**0.4**
Train	0.0	0.2	0.2	0.1	0.2
Indoor	97.7	94.9	94.7	96.4	95.7

Table 1b. Mean [1st Q - 3rd Q] percentage of time spent (%) on the LU for the LU users only (~2.5m)

Microenvironment	**child (5−17)**	**young adult (18−29)**	**adult (30−59)**	**elderly (60+)**
LU	3.2 [1.4 - 4.4]	3.7 [1.8 - 5.1]	4.0 [1.9 - 5.7]	3.7 [1.6 - 5.1]

Pollutant concentrations

In Table 2, the pollutant concentrations (mean and range) for the different microenvironments, as used in LHEM, are reported. For the LU microenvironment, the $PM_{2.5}$ concentration values were updated by more recent measurements conducted along the Northern line, where the values ranged within 200-300 μg/m^3 with a mean concentration of 250 μg/m^3. In order to account for less polluted microenvironments/LU lines, we perform exposure sensitivity tests for values as low as 100 μg/m^3.

Table 2. Mean concentrations (and range) for each microenvironment

Microenvironment	**$PM_{2.5}$ (ug m^{-3}) (mean, range)**	**NO_2 (ug m^{-3}) (mean, range)**
Walk	13.7 (6.4 – 40.5)	44.8 (2.9 – 372.1)
Cycle	15.1 (9.2 – 38.3)	55.3 (12.6 – 298)
Motorcycle	16.9 (9.1 – 43.0)	75.0 (11.4 – 348)
Driving	14.6 (6.0 – 53.7)	57.2 (1.8 - 404)
Bus	14.5 (5.0 – 44.0)	58.2 (7.8 - 364)
LU	**250 (94* – 300)**	**51***

Train	13.5 (5.6 – 33.4)	40.4 (2.6 – 252.7)
Indoor	7.9 (3.1 – 26.0)	10.9 (0.5 – 75.4)
Outdoor	13.6 (5.9 – 54.0)	35.7 (2.0 – 406.0)

*Concentrations used in LHEM: $PM_{2.5}$ measurements on LU platforms and trains during 22 journeys, over 450 min, using a TSI Sidepak AM510 (http://www.tsi.com/SIDEPAK-Personal-Aerosol-Monitor-AM510/, Benjamin Barratt, personal communication) and NO_2 measurements on the Paris Metro (Piechocki-Minguy et al., 2006).

Daily $PM_{2.5}$ exposure

In Tables 3a, b, the LHEM estimates of the percentage of daily $PM_{2.5}$ exposure from the LU microenvironment (LU exposure) are reported for total population and LU users only and by age groups whilst using the value of 94 μg/m^3 as concentration in the LU microenvironment.

The estimated percentage of exposure in the transport microenvironments (LU or bus) derives by the equation below:

Estimated exposure (%) =

$$\frac{Percentage\ of\ time\ spent\ in\ transport \times transport\ microenvironment\ mean\ concentration}{total\ daily\ exposure\ from\ transport\ and\ indoor\ microenvironment}$$

As an example, the estimated exposure for the LU young adult users is: $\frac{3.7 \times 100\ ug/m3}{0.037 \times 100 ug/m3 + 0.963 \times 7.9 ug/m3}\% = 33\%$, where the mean LU concentration is assumed to be 100 μg/m^3.

In Table 3a, the estimated percentage of exposure from the LU and bus microenvironments are shown for the total population; the mean concentrations considered in each transport microenvironment are a range of values within 100 – 300 μg/m^3 for the LU and 44 μg/m^3 and 14.5 μg/m^3 (that corresponds to the maximum and mean concentrations, Table 2) for the bus microenvironment.

In Table 3b, rough estimates of the exposure percentage as derived from making the LU trips by bus and assuming that the trip duration would be 2- or 2.5-time greater are presented; here, we also used the range of concentration values mentioned above for the LU and bus microenvironments.

Table 3a. Percentage of daily $PM_{2.5}$ from the LU and bus for total population (6.8m)

	Exposure (%)			
Microenvironment-concentration	**child (5−17)**	**young adult (18−29)**	**adult (30−59)**	**elderly (60+)**
LU-94 (LHEM)	0.4	5.2	3.6	1.2
LU-100	1.3	8.2	6.0	2.5
LU-200	2.5	15.1	11.3	4.8
LU-250	3.1	18.2	13.7	6.0
LU-300	3.7	21.1	16.0	7.1
Bus-maximum	2.7	4.8	3.8	3.3
Bus-mean	0.9	1.6	1.3	1.1

Table 3b. Mean [1st Q - 3rd Q] percentage of daily $PM_{2.5}$ from the LU and bus hypothetically for the LU users only (~2.5m)

	Exposure (%)			
Microenvironment-concentration	**child (5−17)**	**young adult (18−29)**	**adult (30−59)**	**elderly (60+)**
LU-94 (LHEM)	24.6 [13.3 - 34.2]	27.5 [16.5 - 37.4]	28.9 [17.5 – 40.0]	27.3 [14.8 - 37.3]
LU-100	30	33	35	33
LU-200	46	49	51	49
LU-250	51	55	57	55
LU-300	56	59	61	59
Bus-maximum (2-time trip duration)	28	31	33	31
Bus-mean (2-time trip duration)	11	13	14	13

Bus-maximum (2.5-time trip duration)	33	36	38	36
Bus-mean (2.5-time trip duration)	14	16	17	16

Main points

Low LU exposure (LU-100):

- For the total population, the bus exposure is at similar levels with the LU exposure when the maximum concentration in bus is considered; the LU exposure is about 5 times greater for adults compared to the exposure in bus when the mean bus concentration value is used.
- For the LU users, by assuming that the time is double the time needed for making by bus a LU trip, the exposure to $PM_{2.5}$ is at the same levels with the exposure received during the LU trip and higher if the bus trip is 2.5-time longer than the LU one when the maximum concentration in bus is considered; the exposure is half for the LU trips made by bus if the time on a bus is 2.5 times longer than the LU travel time and the mean bus concentration is used.

High LU exposure (LU-200, LU-250, LU-300):

- For the total population, the LU exposure is 3-4 times higher than the bus exposure to $PM_{2.5}$ for adults when the maximum bus concentration is used and about or more than 10 times higher when the mean concentration in bus is considered.
- For the LU users, the daily exposure would be at similar levels if they used the bus by considering the maximum bus concentration; by using the mean bus concentration the LU exposure is 3-5 times greater compared to the exposure received on respective bus trips.

Caveats

1. LHEM setup:
    a. Statistical issues, sample representative of London population: The LHEM provides model estimates based on the extrapolation of a population sample to the whole London population;
    b. LHEM doesn't consider indoor sources, which would modify the total daily exposure received and consequently the percentage of the exposure from specific microenvironments;
    c. 1 single concentration value for the whole LU network: no range of values, no differences in concentrations between platforms/stations/lines/etc.;
2. For the estimated percentages of daily exposure, we assumed a very simplistic scenario: people spend all day indoors apart from the time that they travel;
3. LU and bus trips are not directly comparable, they were not reproduced for the present exposure estimates;
4. Chemical composition/sources of pollution are not considered;
5. Particle size distribution is not known.

References

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