Supporting Information

Estimating Personal Exposures from a Multi-Hazard Sensor Network

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Supporting Information includes:

- 1 page of text
- 2 tables
- 1 figure

Results for Stationary Routine

Comparisons of stationary routine personal DRI measurements and network-derived exposure estimates are shown in Table S2. The number of five-minute pairs of network-derived exposure estimates and DRI measurements, N, ranged between 84 (PM, August 2017) and 772 (CO, March 2018). The RMSE for the combined time period was 0.10 mg/m^3 for PM, 1 ppm for CO, 29 ppb for O_3 and 1 dBA for noise . For the stationary routine, the fraction of estimates within a given percentage of the reference DRIs was highest for noise, with ≥0.99 combined network-derived exposure estimates falling within 10% of the personal DRIs. In comparison, 0.07, 0.20 and 0.1 of combined network-derived estimates were within 10% of personal DRI measurements for PM, CO and O_3, respectively. Correlation between network-derived estimates and personal DRI measurements varied for each hazard as well, and for the combined time period, the Pearson's correlation coefficient, r, was equal to 0.51 for PM, 0.62 for CO, 0.67 for O_3, and 0.75 for noise. However, for some specific sampling periods, the correlation was much higher than the combined period. For example, the Pearson's correlation coefficient for PM in August 2017 was equal to 0.82, for CO in December 2017 it was equal to 0.84, and for O_3 in August 2017 it was 0.80.

The difference between network-derived stationary exposure estimates and personal DRI measurements against their mean are presented graphically in Figure S1. For PM, CO, and O_3, there was a general trend of underestimated exposure estimates with increasing hazard intensity. For noise, there was an even distribution of differences between network-derived exposure estimates and personal DRI measurements, near zero across the mean noise SPL observed.

Supplementary Figure and Table captions:

Table S1. Low-cost sensors and personal DRIs used to measure occupational hazards.

Table S2. Comparison of personal DRI measurements and network-derived exposure estimates (pairs of five-minute averages) for the stationary routine.

Figure S1. Bland-Altman plots of the difference between network-derived exposure measurements and personal DRI measurements versus their mean for a) PM, b) CO, c) O_3, and d) noise. The solid line indicates the mean difference and the dashed lines are the bounds of agreement. Circles are data from August 2017, squares are data from December 2017, and triangles are data from March 2018.

	Network Sensor	Personal DRI	OELs	
Hazard	**$10–$200**	**$100–$15,000**	**PEL**	**TLV**
PM	GP2Y1010AU0F (SHARP Electronics, Osaka, Japan) Range[1]: 0.026 – 1.50 mg/m^3 Principle: light-scattering	pDR-1500 (Thermo Scientific, Franklin, MA) Range: 0.001-400 mg/m3 Principle: light-scattering	5 mg/m^3	5 mg/m^3
CO	CO-B4 (Alphasense Ltd., Essex, UK) Range[2]: 0.01-12 ppm Principle: electrochemical	EasyLog CO-300 (Lascar Electronics Ltd., Erie, PA) Range: 0-300 ppm Principle: electrochemical	50 ppm	25 ppm
O_3	OX-B431 (Alphasense Ltd., Essex, UK) Range[1]: 4-150 ppb Principle: electrochemical	POM (2BTechnologies, Boulder, CO) Range: 0-10,000 ppb Principle: UV absorption	100 ppb	50-200 ppb
Noise	Custom Range[1]: 65-94 dBA Principle: sound pressure level	Spark 703+ (Larson-Davis Inc., Depew, NY) Range: 40-143 dBA Principle: sound pressure level	90 dBA	85 dBA

Notes:

[1] Range characterized as the sensor's limit of detection (LOD) to the highest concentration included in calibration experiments.

[2] Range characterized as the sensor's limit of detection (LOD) to the electronically imposed ceiling.

OEL: Occupational Exposure Limit

PEL: Permissible Exposure Limit set by the Occupational Safety and health Administration (OSHA)

TLV: Threshold Limit Value set by the American Conference of Governmental Industrial Hygienists (ACGIH)

Hazard	Time Period	# Simulated Work Shifts, K	# 5-min Pairs, N	DRI GM (GSD)	DRI AM (ASD)	RMSE	Pearson Correlation	Fraction within Percent of DRI[1] 10	25	50	100
PM						units: mg/m^3					
	Aug-2017	2	84	0.32 (1.36)	0.33 (0.10)	0.07	0.82	0	0	0.14	0.65
	Dec-2017	4	351	0.22 (1.47)	0.24 (0.09)	0.08	0.42	0.11	0.35	0.55	0.7
	Mar-2018	4	380	0.58 (1.67)	0.65 (0.27)	0.08	0.62	0.05	0.22	0.78	0.99
	Combined	**10**	**815**	**0.36 (1.88)**	**0.44 (0.28)**	**0.10**	**0.50**	**0.07**	**0.25**	**0.62**	**0.83**
CO						units: ppm					
	Aug-2017	3	207	5 (4)	7 (3)	1	0.66	0.12	0.39	0.94	0.98
	Dec-2017	6	553	5 (1)	5 (1)	0	0.84	0.34	0.95	1	1
	Mar-2018	8	772	5 (3)	6 (3)	1	0.56	0.12	0.29	0.61	0.9
	Combined	**17**	**1532**	**5 (3)**	**6 (2)**	**1**	**0.62**	**0.2**	**0.54**	**0.8**	**0.95**
O_3						units: ppb					
	Aug-2017	3	204	28 (2)	32 (15)	8	0.80	0	0	0	0
	Dec-2017	2	180	29 (1)	30 (7)	25	0.62	0	0	0	0.03
	Mar-2018	8	664	94 (2)	110 (55)	33	0.57	0.15	0.34	0.55	0.69
	Combined	**13**	**1048**	**60 (2)**	**80 (58)**	**29**	**0.67**	**0.1**	**0.22**	**0.35**	**0.45**
Noise						units: dBA					
	Aug-2017	3	207	82 (2)[2]		1	0.65	1	1	1	1
	Dec-2017	6	553	80 (3)[2]		1	0.77	1	1	1	1
	Mar-2018	8	634	83 (11)[2]		1	0.65	0.99	1	1	1
	Combined	**17**	**1394**	**82 (10)[2]**		**1**	**0.75**	**1**	**1**	**1**	**1**

Notes:

[1] Fraction of network-derived estimates that were within (±) 10, 25, 50 and 100% of the personal direct-reading instrument (DRI) measurements for each hazard.

[2] Noise calculations were performed on data transformed to the linear scale then transformed back to the dBA scale, and are not technically GMs and GSDs.

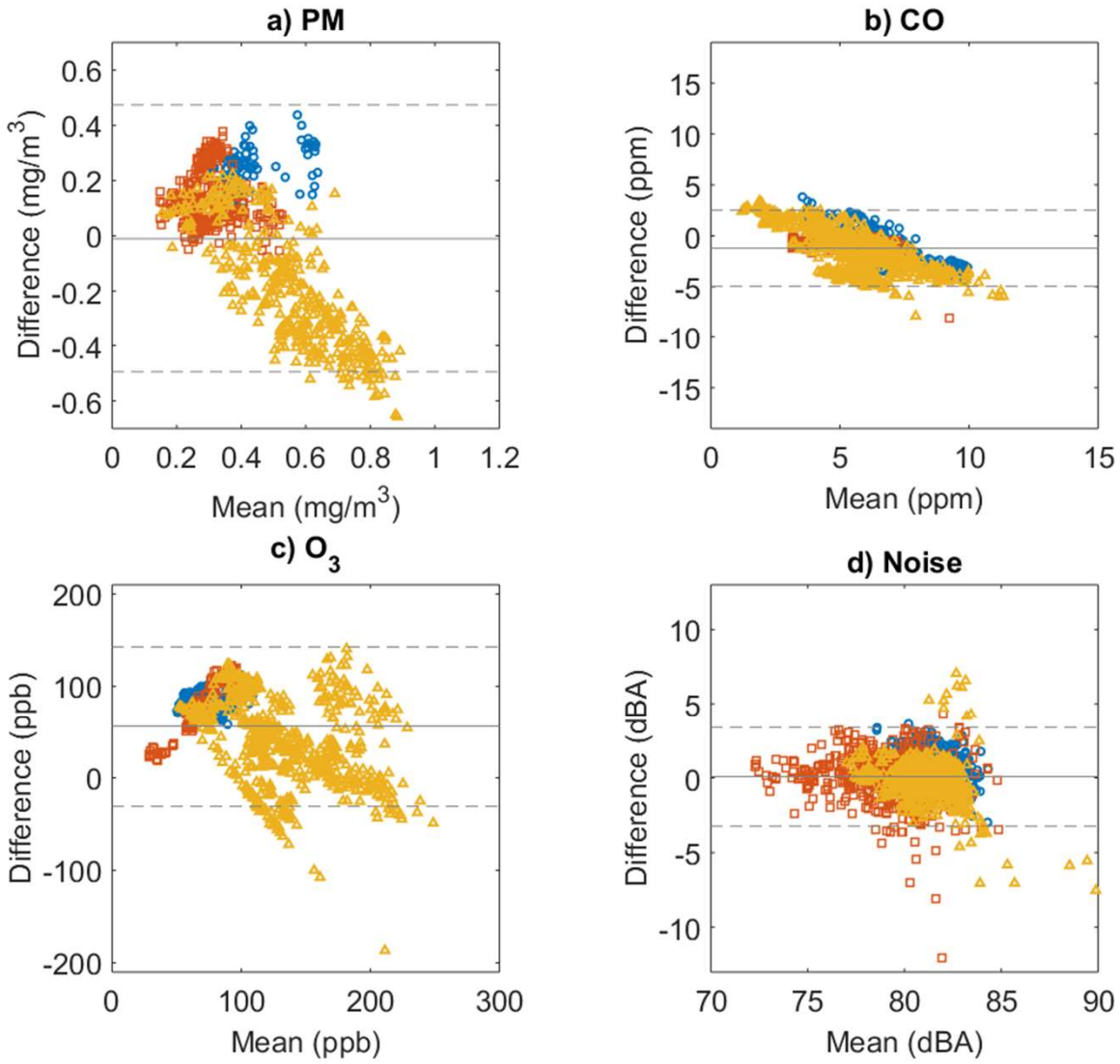
GM: geometric mean

GSD: geometric standard deviation

AM: arithmetic mean

ASD: arithmetic standard deviation

RMSE: root mean square error


a) PM
Difference (mg/m3)
Mean (mg/m3)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
0
0.2
0.4
0.6
0.8
1
1.2
b) CO
Difference (ppm)
Mean (ppm)
15
10
5
0
-5
-10
-15
0
5
10
15
c) O3
Difference (ppb)
Mean (ppb)
200
100
0
-100
-200
0
100
200
300
d) Noise
Difference (dBA)
Mean (dBA)
10
5
0
-5
-10
70
75
80
85
90