Evaluation of personal exposure to air pollutants and estimation of the inhaled dose for commuters in the urban area of Milan, Italy

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INTRODUCTION

Several studies in the literature concerning the evaluation of commuter exposure, considering the different micro-environments **(MEs)**
[de Nazelle et al., 2017; Karanasiou et al., 2014]

Only the assessment of exposure to different pollutants is considered and not the estimation of the dose of pollutants inhaled by subjects

Dose: Concentration x Time x Ventilation rate

→ Via direct-reading monitors

→ Via Time Activity Diary (TAD)

→ Via direct-reading instruments for the acquisition of physiological parameters (pulmonary ventilation rate): **Some logistics problems**

MATERIALS AND METHODS

ROUTE

Determined a priori

Como (45° 47′ N 9° 01′ E) - Milan (45° 27′ N 9° 11′ E) - Italy

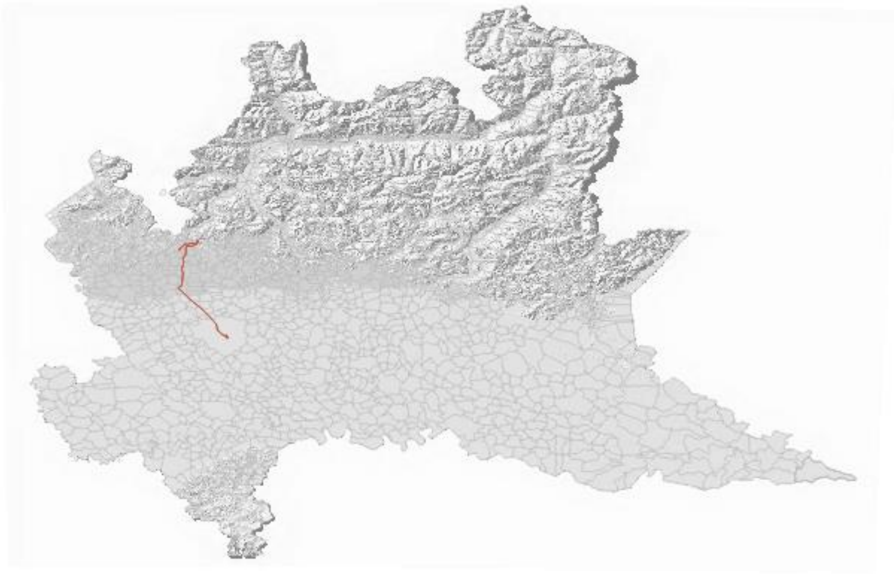
Different MEs

- Car
- Walking – LT
- Train
- Walking – LT
- Walking – HT
- Underground
- Walking – HT
- Cycling*
- Indoor

MONITORING PERIOD

2 weeks – March 2019 (Monday-Friday)

2 weeks – July 2019 (Monday-Friday)



MATERIALS AND METHODS

INSTRUMENTATIONS - PARTICULATE MATTER AND NO_2

Acquisition rate: 60s; breathing zone

I. UFP (particle number; particle dimension; concentration)
(DiSCmini, Matter Aerosol AG, Wohlen AG, Swiss - DSC)

II. PM (concentration of PM_1, $PM_{2.5}$, PM_4, PM_{10} and TSP)
(Aerocet 831-MetOne Instrument Inc., Grant Pass, Oregon, USA - Aerocet)

I. PM ($PM_{2.5}$ concentration)
(AirBeam, HabitatMap Inc., Brooklyn, New York, USA - AB)

I. NO_2 (concentration)
(CairClip NO_2, Cairpol; La Roche Blanche - France - CC)

INSTRUMENTATION – HEARTBEAT AND GPS

V. Physical effort - heartbeat
(SUUNTO 9)

RESULTS

DOSE ESTIMATION

Dose: Concentration x Time x Ventilation rate

(μg) (μg/m³) (min) (m^3/min)

Method		Source	Formula
(Physical) activity type	1.1	Dons, 2012 [19]	Fixed values per activity type (Supporting Information Table S2a)
	1.2	Johnson, 2002 [20]	Fixed values per METs level (Supporting Information Table S2b)
	1.3	Tainio, 2016; WHO, 2011 [10, 21]	Fixed values per activity type (Supporting Information Table S2c)
Energy expenditure, METs and VO_2	2.1	Johnson, 2002 [20]	$VO_2 = ECF * EE$ $VE/BM = e^{a + b*\ln(VO2/BM)}$ $
Heart rate	3.1	Zuurbier, 2009 [22]	Male: $VE = e^{1.03+(0.021*HR)}$ Female: $VE = e^{0.57+(0.023*HR)}$
	3.2	Hart, 1998 [23]	$VE = e^{0.01894\,(HR-HRrest)+0.01052(Weight+1.9008)}$
	3.3	Satoh, 1989 [24]	$VE = 10^{(9.38*(HR-HRrest)+4.22*Height+1.19*Weight+2.22*Age+HRrest)*10^{-3}-0.0439}$
	3.4	Cozza, 2015 [25]	$VE = e^{0.58+(0.025*HR)}$
	3.5	Ramos, 2015 [26]	Male: $VE = e^{1.17+(0.02*HR)}$ Female: $VE = e^{0.99+(0.02*HR)}$
	3.6	Do Vale, 2015 [27]	$VE = 0.00071 * HR^{2.17}$
	3.7	Greenwald, 2016 [28]	$VE = (-3.859 + (0.101 * HR)) * FVC$
Breathing rate	4.1	McArdle, 2001 [29]	$VT = 1.8028 * \ln(BR) - 3.8881$ $VE = BR * VT$
	4.2	Bigazzi and Figliozzi,2015 [16]	$VT = -0.5702 + (16.454 * BRamplitude)$ $VE = BR * VT$
	4.3	Greenwald, 2016 [28]	$VE = (-1.913 + (0.439 * BR)) * FVC$
Heart rate and breathing rate	5.1	Greenwald, 2016 [28]	$VE = (-4.247 + (0.0595 * HR) + (0.226 * BR)) * FVC$
	5.2	Adams, 1993 [30]	Formulae per activity type (Supporting Information Table S2d)

Abbreviations: VE=ventilation; VO_2=oxygen uptake; ECF=energy conversion factor; EE=energy expenditure; BM=body mass; HR=heart rate; HRrest=resting heart rate; FVC=forced vital capacity; BR=breathing rate; BRamplitude=breathing wave amplitude; VT=tidal volume
$ Male, age 18-44, a=3.991, b=1.197; Male, age 45-64, a=4.018, b=1.165; Female, age 18-44, a=4.357, b=1.276; Female, age 45-64, a=3.454, b=1.021 [20]

[Dons et al., 2017]

$$VE = 0.00071 \times HR^{2.17}$$

[Do Vale et al., 2015]

RESULTS

DESCRIPTIVE STATISTICS – EXPOSURE CONCENTRATION AND PHYSIOLOGICAL PARAMETERS

Parameter	N	Min.	Max.	Mean	S.D.
UFP number[*]	*8179*	*212*	*74436*	*9640*	*7027*
UFP diameter[**]	*8228*	*<LOD*	*300.0*	*49.2*	*15.2*
UFP ldsa[***]	*8228*	*0.6*	*203.9*	*24.4*	*15.9*
UFP mass	8239	*<LOD*	197.3	3.7	4.1
PM_1	8365	0.1	174.8	10.2	12.5
$PM_{2.5}$	8342	0.2	160.8	13.1	15.4
$PM_{2.5}$ (AB)	7394	1.4	134.9	35.5	22.6
PM_4	8348	0.3	189.0	16.2	18.9
PM_{10}	8345	0.6	378.5	24.0	28.4
TSP	8340	0.6	480.6	28.2	33.0
NO_2	8690	0.9	478.5	30.5	52.7

SUUNTO (Heart rate (bpm))	4308	45.7	197.0	82.6	23.2
Heart rate (SUUNTO) + Do Vale et al. 2015 (VE (l/min))	4308	3.0	68.0	11.3	8.1

RESULTS

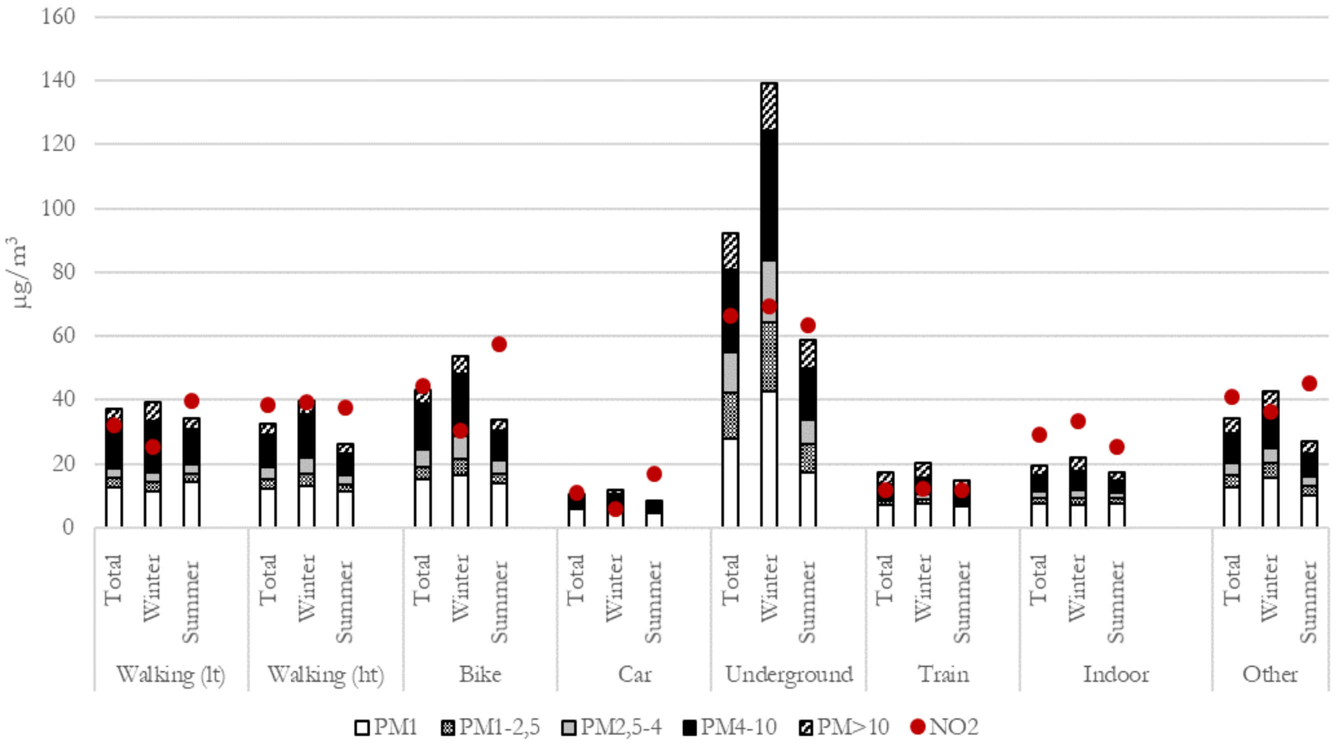
DESCRIPTIVE STATISTICS – EXPOSURE CONCENTRATION IN MEs

MEs descriptive statistic (mean) performed on the total dataset (μg/m^3)

	Walking (lt)	Walking (ht)	Bike	Car	Underground	Train	Indoor	Other
UFP mass	*3.3*	*4.5*	*4.6*	*6.3*	*4.5*	*2.6*	*3.4*	*3.9*
PM_1	12.8	12.3	15.0	5.8	27.9	7.1	7.5	12.5
$PM_{2.5}$	15.5	15.2	19.1	6.8	42.1	8.2	9.2	16.3
$PM_{2.5}$ (AB)	38.5	37.5	37.5	31.1	54.4	32.0	32.1	35.6
PM_4	18.6	19.0	24.6	7.7	54.8	9.4	11.3	20.2
PM_{10}	32.1	29.2	38.9	9.3	80.9	13.4	16.3	29.6
TSP	37.1	32.7	43.3	10.4	92.1	17.5	19.5	34.1
NO_2	32.3	38.5	44.6	10.8	66.3	11.9	29.1	41.1

RESULTS

DIFFERENTIAL CONCENTRATION



Exposure levels to PM (differential concentration: PM_1, $PM_{1\text{-}2.5}$, $PM_{2.5\text{-}4}$, $PM_{4\text{-}10}$, $PM_{>10}$) and in different MEs (reported as total, winter and summer average)

RESULTS

DESCRIPTIVE STATISTICS – INHALED DOSE

Descriptive of the inhaled dose (µg) of airborne pollutants, reported as an average for each MEs and as total

Pollutant	Walking (lt)	Walking (ht)	Bike	Car	Underground	Train	Indoor	Other	*Total*
UFP	0.6	3.8	1.3	1.5	1.4	1.7	2.2	4.9	*17.4*
PM_1	2.3	10.5	4.3	1.3	8.7	4.5	4.8	15.6	*52*
$PM_{2.5}$	2.8	13.0	5.5	1.6	13.1	5.2	5.9	20.3	*67.4*
$AB_{2.5}$	6.9	32.1	10.8	7.2	17.0	20.4	20.7	44.4	*159.5*
PM_4	3.3	16.2	7.1	1.8	17.1	6.0	7.3	25.2	*84*
PM_{10}	5.8	25.0	11.2	2.1	25.2	8.5	10.5	36.9	*125.2*
TSP	6.7	28.0	12.5	2.4	28.7	11.1	12.6	42.6	*144.6*
NO_2	5.8	32.9	12.8	2.5	20.7	7.6	18.7	51.3	*152.3*

CONCLUSIONS

The combined use of different monitoring tools allowed to continuously characterize the concentrations of pollutants investigated according to the most appropriate measurement metrics

The exposure data were associated with the subject's residence time in a given MA and to the subject's pulmonary ventilation value, in order to obtain the inhaled dose values

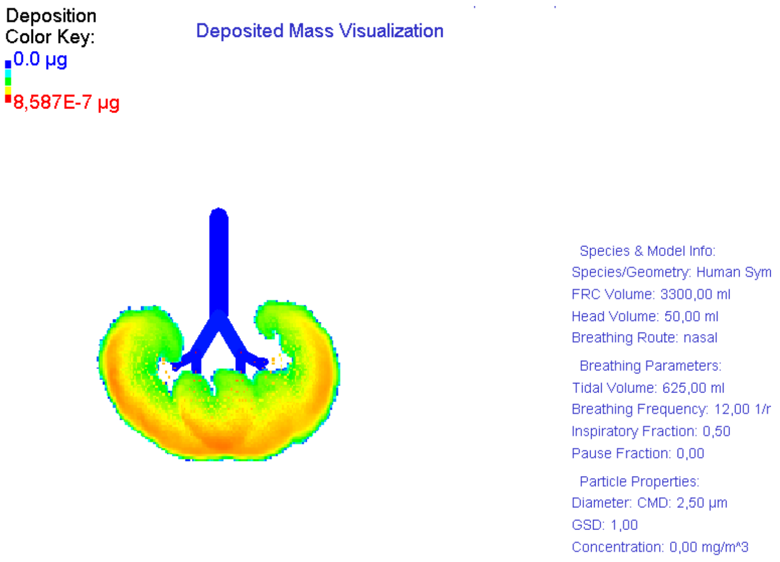
The inhaled dose values would seem to be mainly influenced by the time spent in a given environment and by the exposure concentrations (although this trend would seem to vary depending on the pollutant and the ME considered)

Few studies in the literature regards the evaluation of inhaled dose (contrariwise to the studies concerning exposure in different ME)

FURTHER DEVELOPMENTS

1. Comparison of different methods present in the scientific literature for the calculation of ventilation rate
2. Evaluation of the parameters that may influence the inhaled dose (different exposure conditions - winter and summer period)
3. Data processing using the MPPD model

MPPD©
MULTIPLE-PATH PARTICLE DOSIMETRY MODEL



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Thank you for your attention

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