Innovative technologies for city air pollution control– challenges and opportunities for scaling up and adoption

Keynote Lecture

Expert Group Meeting on Innovative Technologies and Applications for Urban Air Pollution Control in Asia & the Pacific

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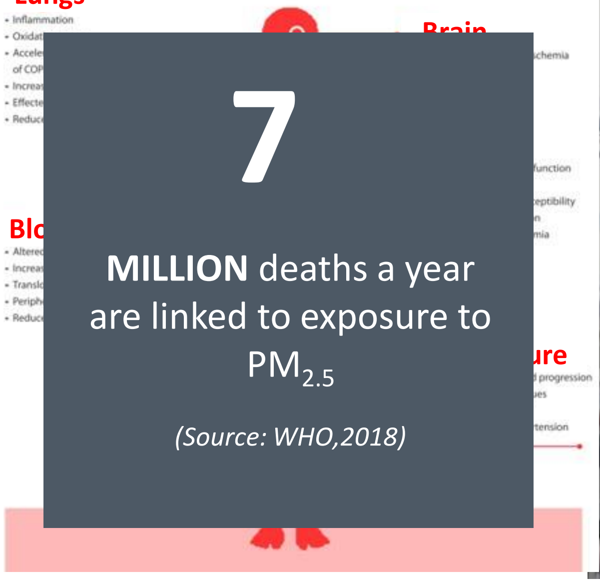
Concerns over

FINE PARTICLES ($PM_{2.5}$)

Human Health

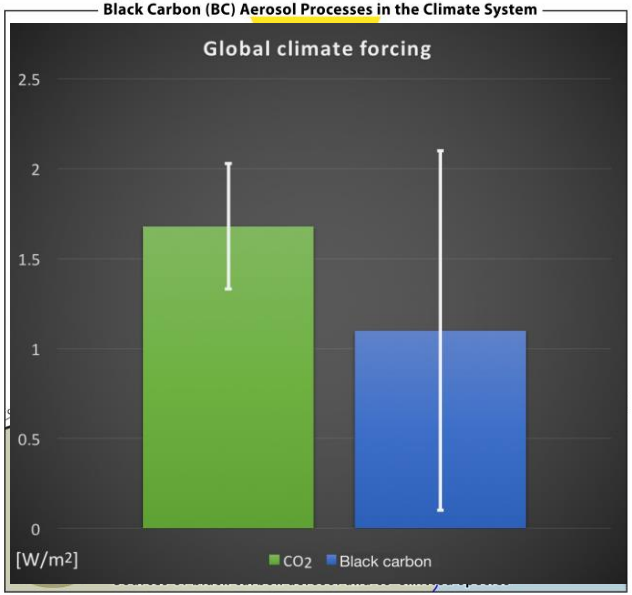


$PM_{2.5}$ penetrates into the respiratory tract and can travel into the bloodstream.

Urban Air Quality

More than 9 out of 10 people breathe in polluted air daily
(Source: WHO,2018)

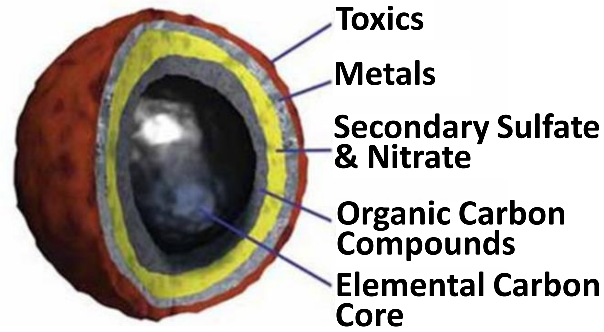
Climate Change



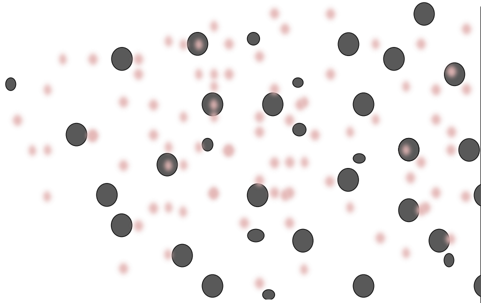
(Source: European Geosciences Union, 2016)

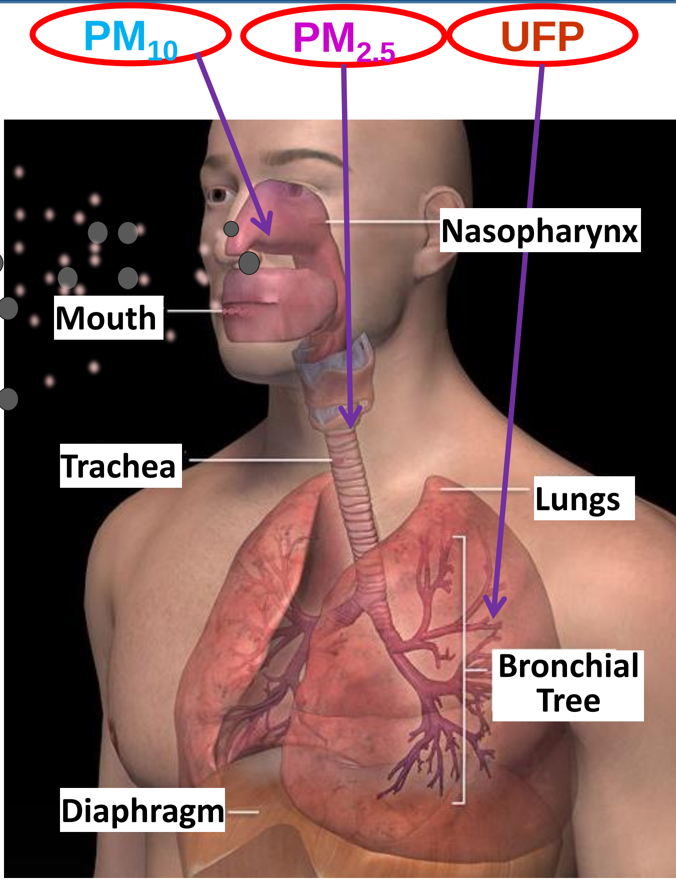
Airborne Particulate Matter (PM)

Chemical compositions

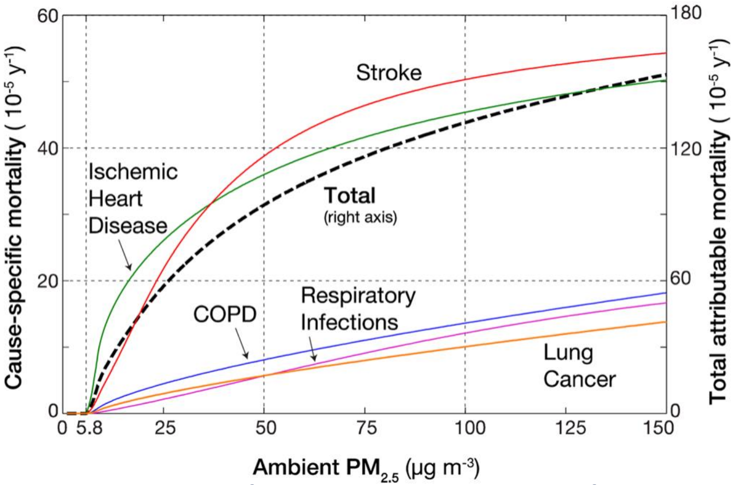


Sizes





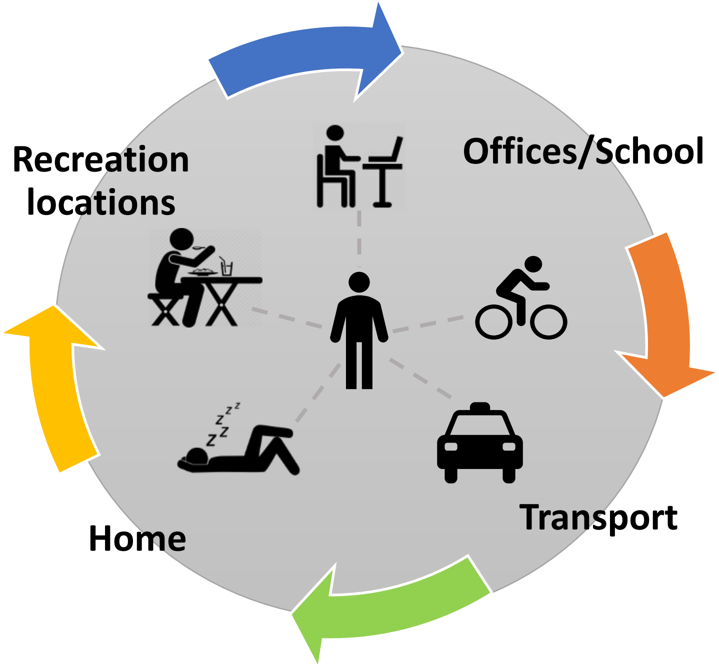
Mass concentrations



Concentration-Response Functions

Conventional Exposure assessment

Fixed PM monitoring stations (FMS)



- Lack of spatial results of PM data
- PM levels in various MEs are different from ambient levels
- Does not account for indoor air pollutants

- People are mobile, visiting multiple indoor & outdoor MEs daily, influenced by different PM generating processes

ME: microenvironment

Transport microenvironments (TMEs)

People spend ≈ **7-10%** of their time in TMEs

TMEs contribute up **30 %** of daily integrated exposure to **PM**

- Lack of comprehensive investigations of exposure to PM in TMEs in Asian cities, especially during active modes of transport while motorized traffic is still in existence.

- Studies dealing with the estimation of the actual amount of PM intake (inhaled dose of PM) are relatively sparse.

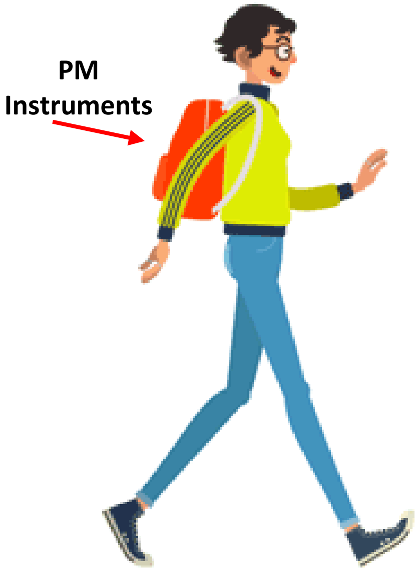
(Kumar et al., 2018); (Dons et al., 2012); (Dons et al., 2019)

Health effects of airborne particulate matter exposure

How can we make a realistic assessment of human exposure to inhaled PM and their associated health effects ?

https://nomedwaypeakerproject.wordpress.com/community-concerns/

Novel PM exposure assessment methodology



"Lab-in-a bag"
Portable PM instruments

Personal exposure (PE) assessment

- Accounts for the actual exposure to PM experienced by individuals.
- Provide spatiotemporal variations of PM; brings indoor and outdoor air quality assessments together, linking the extent, place, duration, and frequency of human exposure to PM in diverse MEs.

Case cities

Danang (DN)

Singapore (SG)

	Singapore	Danang
- Annual $PM_{2.5}$ (µg m^{-3})	14.2-24.3	15.7-21.8
- Population density (pp km^{-2})	7796	818
- Weather	Tropical monsoon	
- Ownership of motorized vehicles	29% (car + motorcycle)	1% (car)
- Public transport	53% (bus + MRT)	1% (bus)
- Walking, cycling	14%	--
- Taxi/private hire car	4%	--
- Motorcycle	--	98%

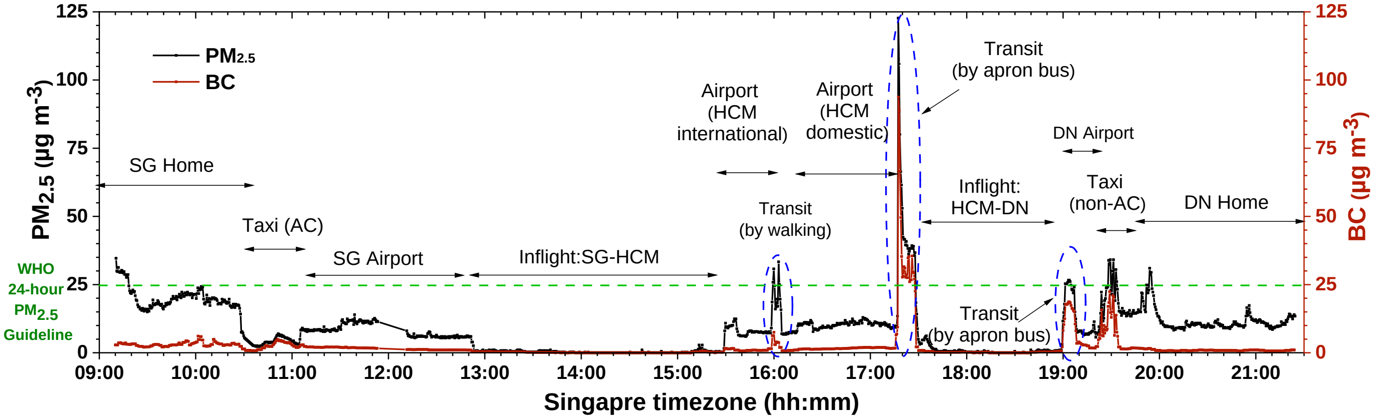
Data Collection

1. Multi-modal transport from Singapore to Danang and back
   Taxi, aeroplane, walking, and apron bus
2. On-road modes of transport in each city
   Cycling, e-scooter, motorcycle, taxi
3. Traffic counting at traffic intersections

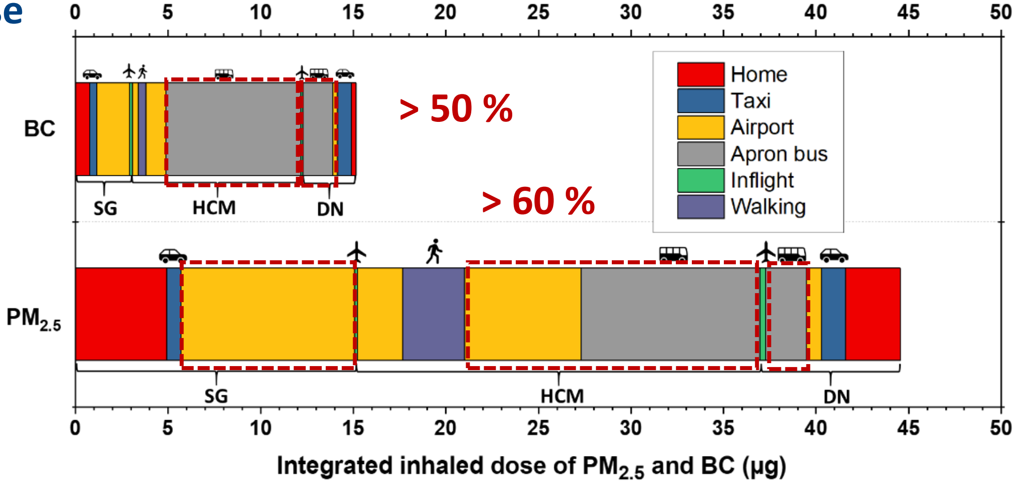
Sidepak AM520	Micro-aethalometer AE51
Realtime $PM_{2.5}$	Realtime BC

Multimodal transport from SG to DN

Time-series



Integrated inhaled dose



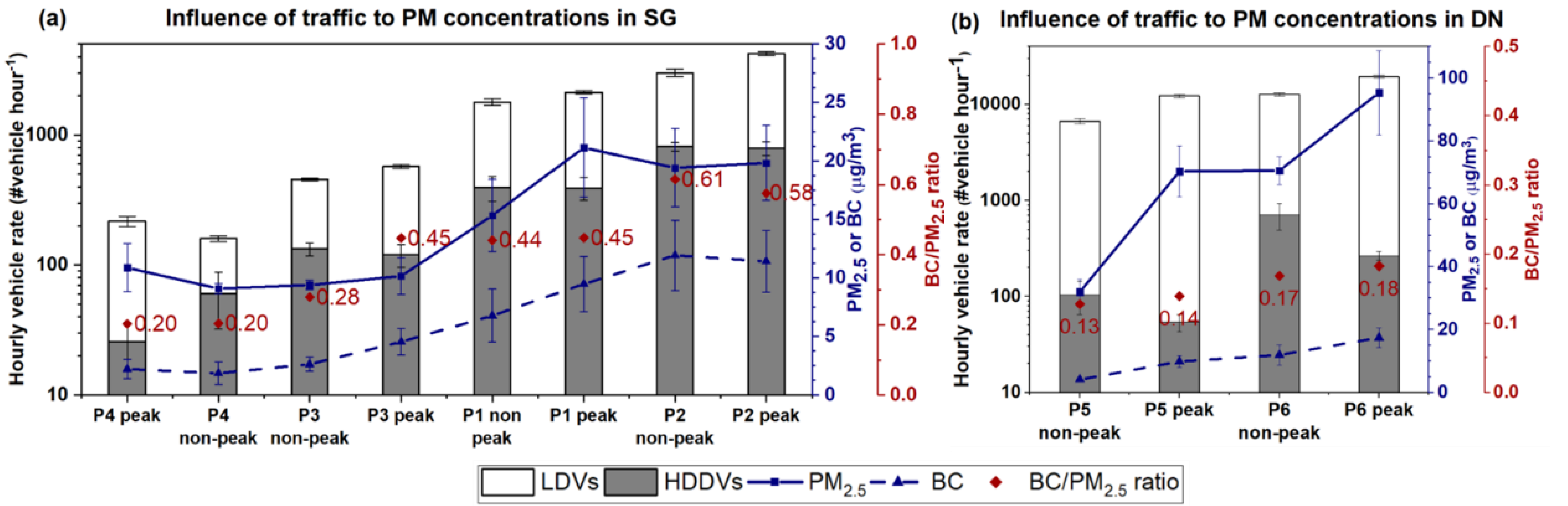
$$\textbf{Inhaled Dose}\ (\mu g) = \text{Intake Volume}\ (m^3) \times \text{PM concentration}\ \left(\frac{\mu g}{m^3}\right) \times \text{Deposition Fraction}$$

On-road modes of transport in each city

City	Mode of transport	Monitoring period		Average trip duration (min)	$PM_{2.5}$ GM ± SD (μg m^{-3})	$PM_{2.5}$ Inhaled dose (μg)	$PM_{2.5}$ Inhaled dose rate (μg km^{-1})	BC GM ± SD (μg m^{-3})	BC Inhaled dose (μg)	BC Inhaled dose rate (μg km^{-1})
SG	Cycling	Peak		41.2	19.5 ± 2.4	18.3	3.73	4.3 ± 2.4	4.1	0.83
		Non-peak		38.0	13.5 ± 1.3	11.7	2.39	2.3 ± 1.9	2.0	0.41
	E-scooter	Peak		41.8	19.0 ± 2.1	9.1	1.85	3.9 ± 2.3	1.8	0.38
		Non-peak		38.2	14.7 ± 1.3	6.4	1.31	2.4 ± 2.3	1.1	0.22
	Taxi	Peak	AC	30.2	9.0 ± 1.1	1.1	0.23	3.0 ± 1.3	0.4	0.08
			Non-AC	30.0	21.9 ± 3.4	2.7	0.55	7.8 ± 2.4	1.0	0.20
		Non-peak	AC	24.2	7.7 ± 1.2	0.8	0.16	1.0 ± 1.2	0.1	0.02
			Non-AC	23.3	20.7 ± 1.4	2.0	0.41	3.3 ± 3.0	0.3	0.06
DN	Cycling	Peak		106.5	98.6 ± 3.7	239.2	16.84	13.8 ± 2.4	33.5	2.36
		Non-peak		101.3	50.4 ± 2.4	116.4	8.19	6.6 ± 1.6	15.1	1.07
	Motorcycle	Peak		59.3	100.8 ± 11.3	68.1	4.79	15.2 ± 1.5	10.2	0.72
		Non-peak		54.3	49.2 ± 6.4	30.4	2.14	7.0 ± 2.2	4.3	0.30
	Taxi	Peak	AC	50.7	21.4 ± 1.9	4.5	0.32	3.0 ± 1.4	0.5	0.04
			Non-AC	49.5	112.6 ± 9.2	23.1	1.63	22.5 ± 1.6	3.7	0.26
		Non-peak	AC	48.0	14.8 ± 1.9	2.9	0.21	1.9 ± 1.5	0.3	0.02
			Non-AC	48.3	79.6 ± 8.3	15.9	1.12	16.6 ± 1.7	2.6	0.19

SG: Singapore, DN: Danang, AC: Air-conditioned, GM: geometric mean, SD: standard deviation.

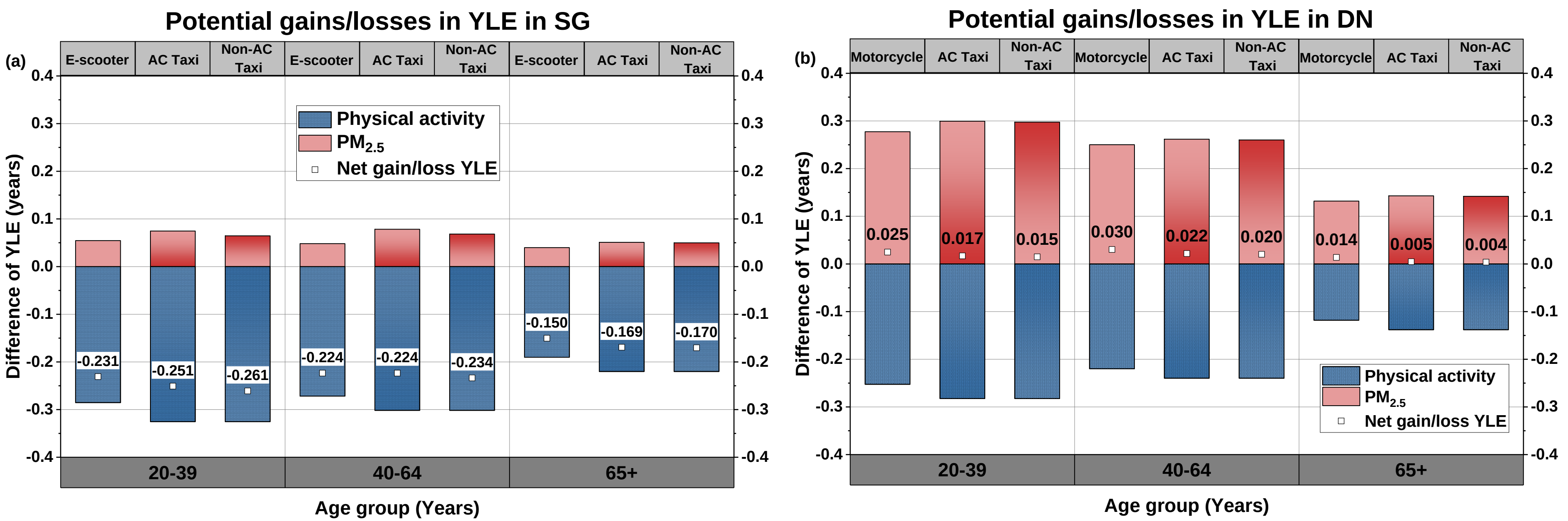
Influence of traffic volume and composition



$PM_{2.5}$ and BC concentrations as functions of hourly traffic rates in (a) Singapore , (b) Danang.
The BC-to- $PM_{2.5}$ ratios for each category are also shown.

LDVs: light-duty vehicles; HDDVs: heavy-duty diesel vehicles ; P1-P6: traffic intersections

Effect on years of life expectancy (YLE)



Potential gains or losses in YLE due to $PM_{2.5}$ exposure and physical activity compared between any mode of transport and cycling in (a) Singapore and (b) Danang.

Conclusions

- **Airport concourses** and transit MEs to/from the aeroplane by **apron buses** made major contributions to the total integrated exposure to $PM_{2.5}$ and BC.
- The PE to $PM_{2.5}$ and BC in TMEs: an order of magnitude **higher** in Danang compared to Singapore while using various on-road modes of transport in each city.
- Elevated concentrations of PM in Singapore and Danang: significantly contributed by **heavy-duty diesel vehicles** and **motorcycles**, respectively.
- A reduction in YLE is likely to occur among urban commuters while using motorized transport compared to active mobility (**cycling**).

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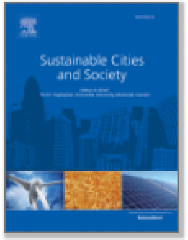
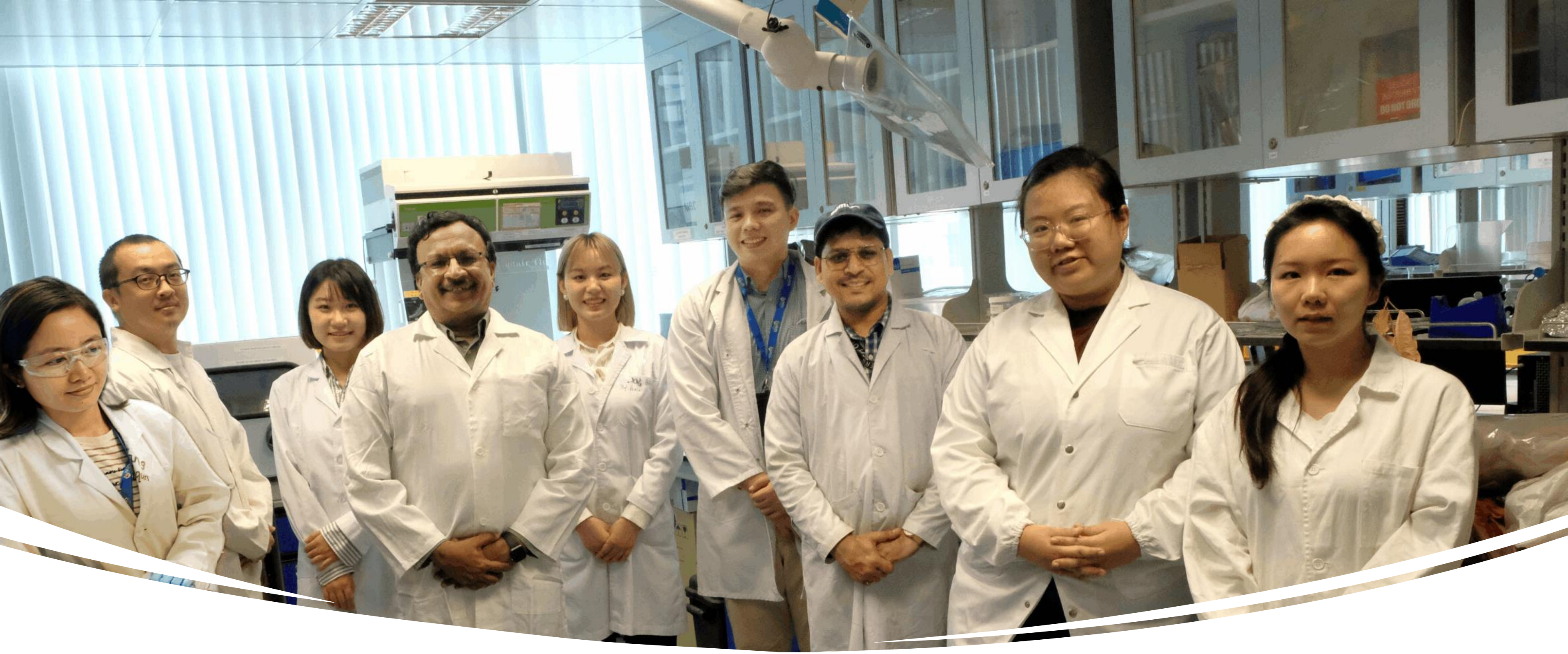


Personal exposure to airborne particles in transport micro-environments and potential health impacts: A tale of two cities

Phuong T.M. Tran [a, b], Teron Nguyen [c], Rajasekhar Balasubramanian [a]



Our Research Group

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Thank you!

Feel free to ask any questions