Urban Accelerator

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Work report: PM2.5 monitoring for secondhand smoke appraisal

Secondhand smoke (SHS) from cigarettes is a public health issue, and yet there is no literature on the subject for Hong Kong. In October 2018, we devised three studies using PM2.5 as a marker for SHS. The experiments aimed to add to local knowledge about SHS and specifically assess the environmental impact of cigarette smoking on pedestrians. We found outdoor smoking areas to be unsafe for non-smokers, with average PM2.5 = 3.8 times baseline in smoking areas; and found cigarette pollution from walking behind smokers on busy streets accounted for 20% of the pollution breathed during a 35 minutes walking test. We also found that moving smokers do not significantly impact stationary PM2.5 measurements, meaning stationary air quality monitoring may not capture the full impact of smoking on walking pedestrians. We conclude there is a strong justification for moving smoking areas away from pedestrian paths; and that the environmental and roadside pollution aspects of smoking warrant further study.

There is no literature about the secondhand smoke (SHS) health impact on pedestrians in Hong Kong. There are more than 4000 chemicals in tobacco smoke, of which at least 250 are known to be harmful and more than 50 are known to cause cancer[1]. Worldwide, SHS causes 890,000 deaths per year[1], while in China, 6.9% of all smoking-related cancer deaths are due to SHS breathed by non-smokers[2]. The World Health Organization has said there is no safe level of exposure to SHS[3], creating an imperative to study the issue. At the same time, policymakers need to be candid about where science shows, or does not show, specific harm[4]. Why is smoking banned on wide-open beaches or crowded transport interchanges but not on busy sidewalks? Arguments can be made for banning smoking in wide-open spaces (e.g. denormalizing smoking, protecting children, cigarette litter), but a scientific approach to measuring actual SHS exposure can help policymakers introduce consistent fact-based policy across the city. Our research aims to start a science-based discussion for Hong Kong policymakers.

Study hypotheses

We hypothesised that:

- cigarette smoking and sidewalk SHS produces measurable and dangerous levels of air pollution for pedestrians;
- that the air quality in outdoor smoking areas is at dangerous levels and unsafe for pedestrians, such that non-smokers should not be required to walk through such areas; and
- that cigarette smoking from passers-by worsens air quality at a fixed point.

We devised a series of studies to assess the issue of SHS, particularly where it would impact non-smokers in a densely-crowded pedestrian or roadside setting. The studies designed were as follows:

- Study 1: Air quality impact of cigarette smoking on walking pedestrians.
- Study 2: Air quality in outdoor smoking areas.
- Study 3: Measuring smoke from passers-by: air quality impact of passing cigarette smokers.

Technical note

For all air quality measurements, we used a TSI SidePak AM510 aerosol monitor, with PM2.5 attachment, which local NGO Clean Air Network (CAN) kindly lent us. The AM510 was calibrated and zeroed at the CAN offices in early October 2018. We set up the machine using TSI's *TrakPro* software, setting a 1-second interval for data logging. We used a Calibration Factor of 0.32, as, recommended for SHS experiments[5,6]. The machine was attached to the outside of a backpack on the shoulder straps, to be at "breathing height".

1. Air quality impact of cigarette smoking on pedestrians

Hong Kong's busy sidewalks mean it is often difficult to get away from SHS when a smoker is nearby. To study the impact of SHS on pedestrians, we adopting a methodology from cigarette litter researchers[7], devising a circular walking route technique to ascertain the air quality impact of walking behind smokers.

The route passed from Central Station Exit D (Theatre Lane), Queen's Road Central, Pedder Street and back through the MTR alleyway to Theatre Lane (see Figure 1). We would walk this circular route, taking measurements set to 1-second intervals, until we walked up behind an actively smoking cigarette smoker (designated simply the "smoker"). At this point we would then match speed with the smoker to walk behind them until they quit the cigarette, or walked into a path we could not follow without being spotted, e.g. into an alleyway. We found markers for SHS significantly raised when following the smoker. On our outdoor smoking route on our longest test (35 minutes) we found the area under the PM2.5 curve attributed to smoker pollution was around 20% of the total area under the curve - i.e.,

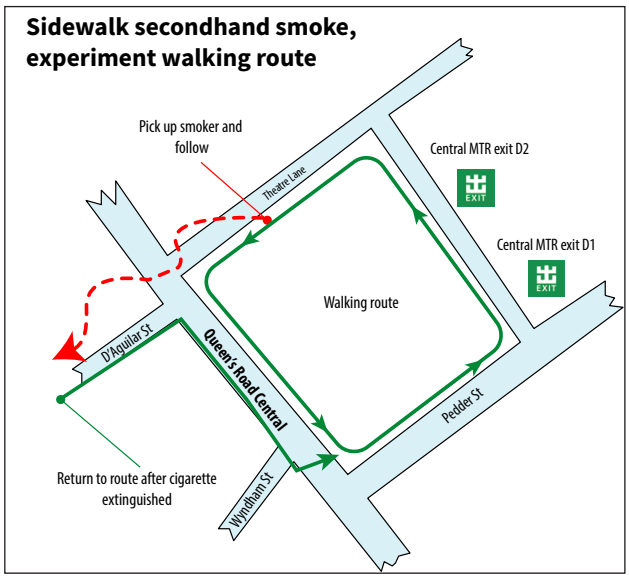

Figure 1: Walking route map

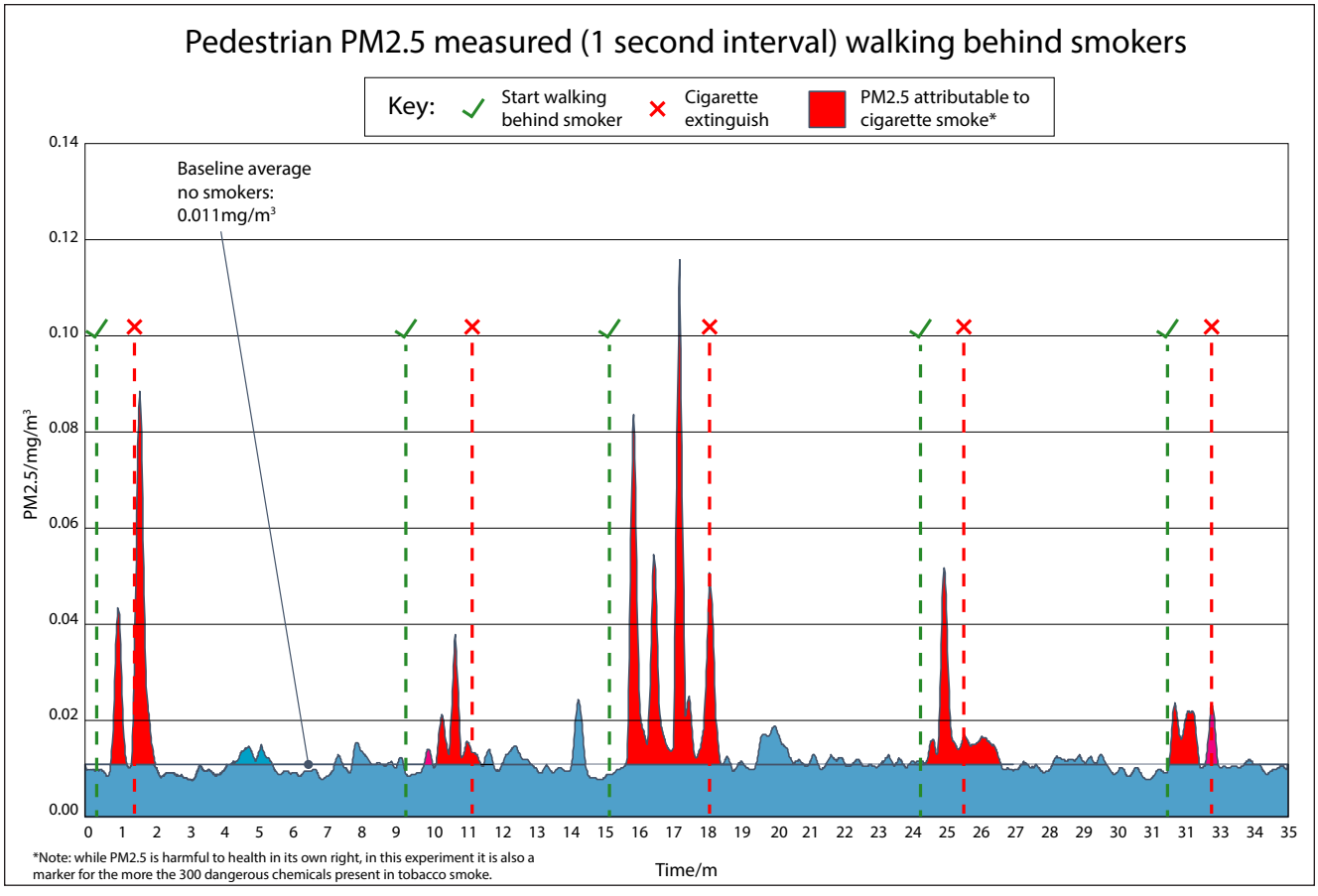

Figure 2: Study 1, air quality impact on pedestrians. PM2.5 and SHS breathed by the pedestrian is significantly higher than the baseline average when walking behind smokers. Actual exposure × *t* (the area of the blue + red shaded areas) for this 35-minute period is around 25% higher than the baseline exposure × *t* (blue shaded area), due to five smokers encountered.

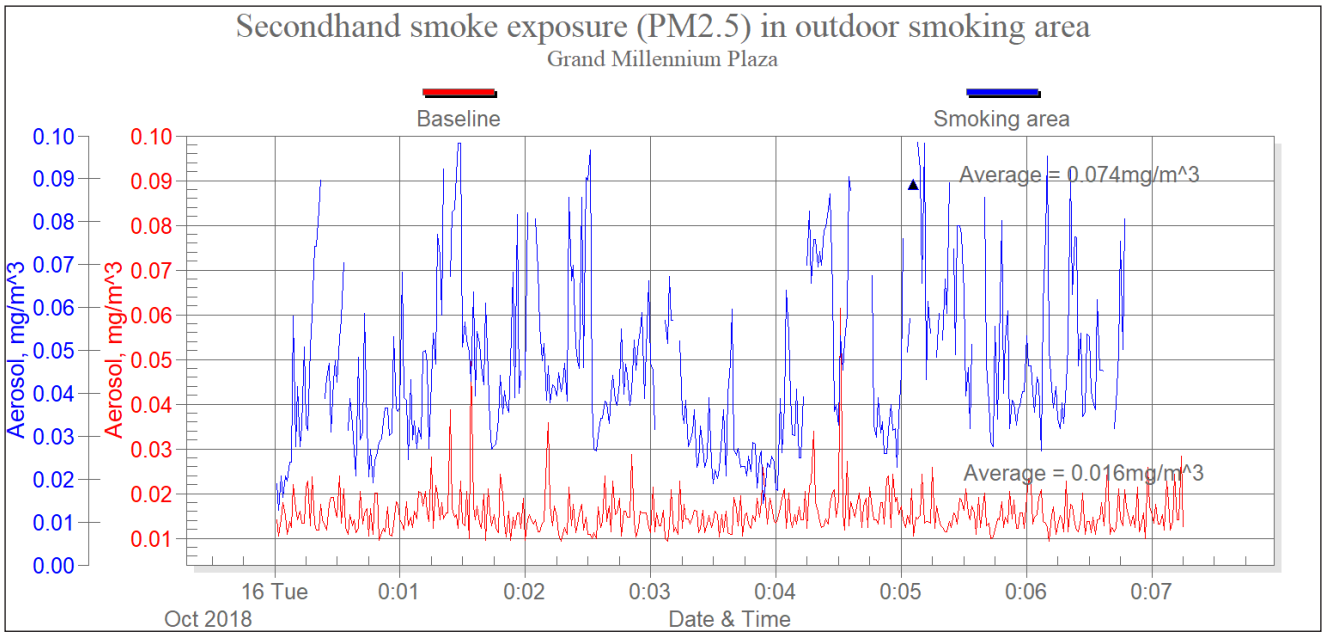

Figure 3: Study 2, outdoor smoking areas Sample output from TSI's TrakPro software, showing the baseline and smoking area PM2.5 for Grand Millennium Plaza. The smoking area PM2.5 is 74µg/m^3 against a baseline of 16µg/m^3, a multiple of 4.6 and an absolute rise of 58µg/m^3.

the smoker pollution accounts for 20% of the total pollution experienced. This represents not just a significant increase in PM2.5 inhaled but also is a marker for the toxins and chemicals found in SHS, of which PM2.5 is simply a marker.

Study 1 discussion

This walking study has value in public health and walkability studies. We have demonstrated that pedestrians in a busy Hong Kong district are breathing a quantifiable and large amount of cigarette pollution – pollution to which the WHO has said there is no safe level of exposure[3]. SHS causes a significant (20%) increase in PM2.5 and other chemicals inhaled by pedestrians at the roadside.

We believe cigarette smoking and SHS should become a key component of walkability studies and urban environmental studies. As a point source, each cigarette may be small when compared to a power plant chimney or car engine exhaust. However, as we have shown, the cigarette "exhaust" is regularly concentrated right in the midst of the pedestrian crowd.

As a result of this study, we recommend policymakers to consider sidewalks in the same way they consider other crowded areas, such as transport interchanges, when setting smoking policy.

2. Air quality in outdoor smoking areas

As others have found, air quality near building entrances and in outdoor smoking areas can be poor when smokers are present[8,9,10].

We identified six outdoor smoking areas in Hong Kong, with a view to measuring the secondhand smoke through a PM2.5 proxy.

The smoking areas we chose had some area away from traffic/cars, to reduce contamination of the results from vehicle emissions; and an area where we could take baseline measurements at least 20m away from the smoking area. For each, we noted whether the smoking area was a "through-path", i.e. whether non-smoking pedestrians needed to pass through the area or if it was solely a standalone place for smokers, out of the way of regular pedestrians.

We used the AM510 machine on a one-second recording interval, and took baseline measurements for 5-10 minutes in the non-smoking area and then took readings for 5-10 minutes in the smoking area.

The results showed significant rise in PM2.5 in the outdoor smoking area; an average of 3.8 times the baseline, with a maximum of 10.9 times and a maximum absolute rise of 69µg/m^3. The median multiple in PM2.5 is 2.2 and the geometric mean 2.8. The lower multiple for 3 Garden Road is due to less smokers observed in this smoking area and 3

large standalone fans in the 3 Garden Road smoking area which help disperse the SHS. A summary of the results from the six smoking areas tested is given below.

Smoking area (by building name)	Pedestrian thru-path	Smoking area PM2.5/ baseline PM2.5	Absolute PM2.5 rise / µg/m³
Pacific Place Podium	Y	2.4	36
Grand Millennium Plaza	Y	4.6	58
Revenue Tower/ Immigration Tower	Y	10.9	69
Cheung Kong Centre	N	1.5	16
3 Garden Road	N	1.4	12
International Finance Centre (IFC)	Y	2	35
Average		3.8	38
Median		2.2	36
Geometric mean		2.8	31

Study 2 discussion

The results are in-line with other international studies, e.g. Cameron *et al*[10] found PM2.5 raised by 3.25 times in smoking areas. These results taken in Hong Kong are a clear justification for moving outdoor smoking areas out of pedestrians' routes, whether it be a route across a square (Revenue/ Immigration Tower); or the entrance to a building (IFC, Grand Millennium Plaza, Pacific Place).

As one good example of urgent action, the Wan Chai Revenue Tower smoking area is in the path of pedestrians travelling to Revenue Tower from the Wan Chai bridge (the most common path to Revenue Tower from the MTR). (See Figure 5 right). Pedestrians must walk through this highly polluted area, with PM2.5 raised 69 µg/m³ above the baseline, presenting an unpleasant experience and, upon regular exposure, health risks.

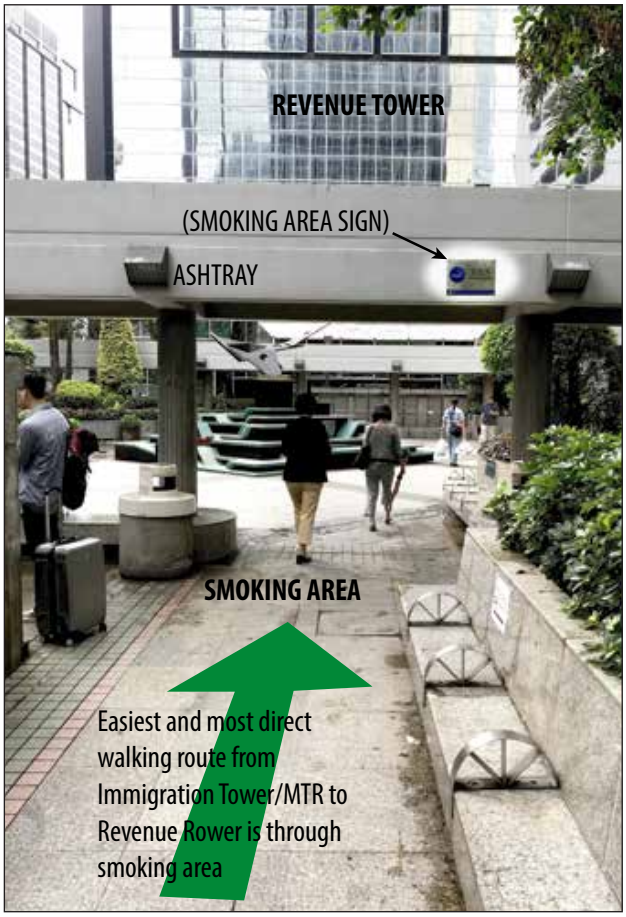

Figure 5: Photo illustrating pedestrians taking the short-cut through to Revenue Tower and passing through the smoking area.

Figure 6: Staff at 3 Garden Road take steps to move the smoking area 10 metres from the entrance.

Study 2 success story

While conducting the tests we engaged with management from 3 Garden Road (owned by Champion REIT). We had suggested moving the smoking area away from the door, since, during the ongoing building work, the only way into the building from Hong Kong Park side was through the smoking

area. We revealed some early data from other sites showing the high PM2.5 and SHS levels in smoking areas. Champion/3 Garden Road agreed and moved the smoking area 10 metres away from the building entrance (see Figure 6). After this move took place, we took a brief sample by the park entrance to 3 Garden Road, and found the PM2.5 at the door to be in-line with the baseline, a good socially responsible move from Champion and something to promote to other building managers in line with this result.

3. Measuring smoke from passers-by

The study aimed to measure if the number of walking smokers impacted average roadside air quality at a single point. We hypothesised the many smokers passing a point near a construction side on Bonham Road would raise the average roadside PM2.5. We stood at a convenient point where many construction workers walk past every morning on the way to work. An average of 72 smokers per hour were found to walk past this point. After tests of varying length, we discovered the average PM2.5 was not significantly raised by smokers walking past, unless the smoker was actively puffing on the cigarette at the point they walked past. We found the AM510 SidePak machine does not pick up smoke from a passing cigarette smoker to any measurable degree unless the smoker is actively exhaling at the time of passing. Therefore, using the machine to monitor, count or visualise the number of passing smokers is not effective. At the same time, a small number of passing smokers (<2 per minute) does not raise the average PM2.5 at a particular point.

Study 3 discussion

Using a static PM2.5 or other SHS detector to measure pollution from a moving smoker is not effective. Our other studies show there is significant pollution emanating from smokers: this study protocol is therefore not a good technique for capturing this pollution.

The fact that fast-moving smokers do not pollute the air at a specific point does not weaken the case for banning smokers in large uncrowded outdoor areas: there are still many cases and arguments to be made for such bans, including denormalising smoking, keeping smoking away from children and youngsters, cigarette litter issues. The study does show that assessing pedestrian SHS exposure to moving smokers requires different techniques (e.g. walking techniques) than traditional air quality measurement protocols.

Acknowledgements

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