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Effect of road blockages on local air pollution during the Hong Kong protests and its implications for air quality management

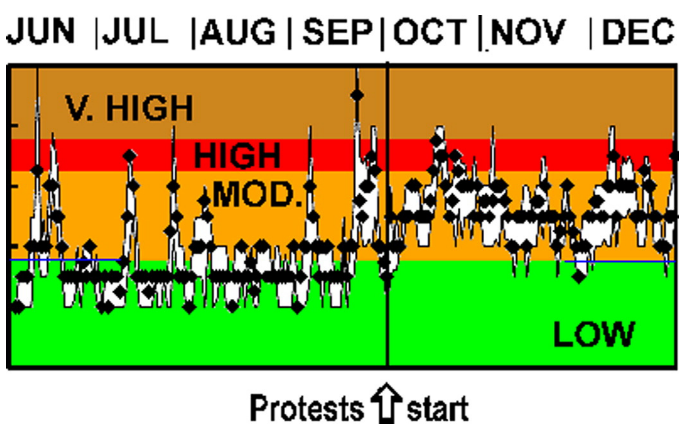
Peter Brimblecombe *, Zhi Ning

School of Energy and Environment, City University of Hong Kong, Kowloon, Hong Kong

HIGHLIGHTS

- We analyse roadside air pollution during the Hong Kong protests
- Lower concentrations of NO_x are found at the protest sites
- Comparison with more distant sites suggests slight changes in PM_{10} and $PM_{2.5}$
- The subtle changes in pollution limit air quality benefits of traffic diversion

GRAPHICAL ABSTRACT



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ABSTRACT

Roadside air quality in urban areas is largely affected by the traffic emissions. Changes in emissions and transport control policy are often assumed to yield benefits in air quality, but have often not always been effective in producing perceptible improvements due to the complexity of meteorological conditions. This study evaluates the air quality before, during and after a temporary roadway blockage event in Hong Kong that took place during Hong Kong protests from late September to mid-December, 2014. The local regulatory air quality monitoring data from both roadside and general ambient stations were used to assess the impact of roadway blockages on the air quality. There was a public perception of improved air quality, but analysis of the data shows the changes can be difficult to discern. This study showed some benefits deriving from road blockages on the local air quality, but the impact was not always apparent because of seasonal variation in meteorological conditions and synoptic transport of pollutants. The finding suggests care is required before making policy changes based on claimed benefits of shifting transport routes. The study highlights the needs to remove seasonal and meteorological change when examining air pollution data to develop strategies to improve air quality.

1. Introduction

Exposure to urban air pollutants at the roadside constitutes a threat to public health (e.g. Godri et al., 2011). Regulators have often

* Corresponding author.
E-mail address: pbrimble@cityu.edu.hk (P. Brimblecombe).

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attempted to improve air quality in urban areas by mandating vehicles with tighter emission standards, cleaner fuels and retrofitting catalytic converters and particle traps. In addition to such technical fixes there has also been an interest in socio-political mechanisms to lower vehicle use or reroute traffic, such that the exposure of urban dwellers is reduced. The impact of changed traffic flow on air pollutants has been studied, for example by examining the effect of London's congestion charges (Atkinson et al., 2009; Beevers and Carslaw, 2005), Tel Aviv's Day of Atonement (Levy, 2013), Taiwan's Chinese New Year (Tan et al., 2009) and Sunday lulls in traffic (Murphy et al., 2007; Wang et al., 2014). As with many cities Hong Kong has struggled to improve air quality by reducing the emissions from vehicles. The tropical city has a dense road network and perhaps an oversupply of bus routes (Tang and Lo, 2008), so there has also been an interest in air quality improvements that might come from rationalisation of public transport (Chai, 2015).

From late September of 2014, the traffic at a number of locations in Hong Kong was diverted as pro-democracy groups occupied important urban roads. The protests were triggered by issues related to the selection of candidates for the election of the Chief Executive, although may have derived from broader issues. During the occupation, three key areas of Hong Kong, i.e., Admiralty (near Central), Causeway Bay and Mong Kok, were affected by traffic blockages. The lack of traffic on occupied streets soon suggested that lower concentrations of traffic-derived pollutants would be likely. Quite by chance the Hong Kong Environmental Protection Department's (HKEPD) three roadside monitoring stations are close to the areas where protests took place and there were soon suggestions that the air quality was much improved (SCMP, 2014a). Over the coming weeks smaller numbers of protesters were involved, but the blockages remained, which meant that traffic still continued to move along alternate routes.

Observations of improved air quality through changes in vehicle types or routing are not always easy to confirm in the face of changing meteorological conditions. Hong Kong's administrators have often found it difficult to show that reduced emissions from fleet have led to improved air quality as reflected in the monitoring record. However, there are some hints for example in an improvement in *i*-pentane: Total HydroCarbon (THC) ratio, which suggested lower emissions from the taxi vehicle fleet as part of the catalyst replacement programme to control the VOC emissions from malfunctioning catalyst equipped LPG fleets (Ning et al., 2012). Despite reductions in NO_x emissions the concentrations of NO_2 have been more resistant to policy implementation and indications of lower NO_x can be quite subtle and not easy to present in a way that convinces a sceptical public (HKEPD, 2014). Although there is clear evidence of linkage of traffic with the roadside air quality (Rakowska et al., 2014), improvements through changes in emissions from traffic flow can be difficult to detect in the air pollution record e.g. when London implemented the congestion charge in the centre of the city, the changes in air pollutant concentrations became apparent only after careful analysis (Beevers and Carslaw, 2005). In addition even in highly urbanized environments there are potential contributions from non-combustion sources (Kassomenos et al., 2014). Hong Kong is fortunate to have several decades of air pollution monitoring data and research. Local atmospheric studies of the chemical characteristics and source apportionment of particulate pollutants (Louie et al., 2005; Li et al., 2013; Ho et al., 2006), especially for the roadside sites (Zheng et al., 2006), suggest an urban profile. This is consistent with emission inventories which reveal an urban profile with most pollutants arising from road transport and navigation emissions (HKEPD, 2012).

The blockages that arose from the 2014 Hong Kong protests offered an opportunity to explore the impact of shifts in traffic flow on local air quality. Although interest in the rationalisation of Hong Kong's bus routes started some years ago (LegCo, 2010) it continues to be regarded as a mechanism for improved air quality e.g. as in the policy address of C.Y. Leung, Hong Kong's Chief Executive (H.K.S.A.R., 2013). Nevertheless, the idea has not been easy to implement and also faces challenges, for example, from Hong Kong's Clean Air Network, which argued for replacement of old buses rather than route rationalisation (Ooi, 2010). A dramatic change in air pollution concentrations as a result of blocked roads could suggest that small changes in local traffic emissions might form part of an effective policy. Such a change might also hint that redirecting the flow could also be beneficial and perhaps add weight to the calls for bus route rationalisation. This paper analyses air pollution data from roadside and urban sites on Hong Kong Island and in Kowloon in the latter part of 2014 to assess the impact of traffic disruption on local air quality and its relevance to the development of strategies to reduce air pollution and problems in assessing their effectiveness.

2. Method

2.1. Timeline of traffic blockage

The protests began with a small demonstration on 26th September 2014, following concerns expressed by Hong Kong students in the previous week. On 28th September, other groups joined the protests, which escalated the level of involvement such that police blocked roads and bridges near the Central Government Complex. The key protest sites in Admiralty, Causeway Bay and Mong Kok were occupied and remained closed to traffic for over 70 days (Fig. 1). Mong Kok was cleared on 25th and early 26th November, while protesters had largely left the Admiralty site by 11th December and the site at Causeway Bay was cleared by the police on 15th December.

2.2. Data source and statistics

The location of the protests and the nearby HKEPD monitoring sites are shown in the Fig. 1b. The protest sites were fortuitously close to the three roadside monitoring sites at Central, Causeway Bay, and Mong Kok. There are also a number of general stations that are effectively urban background sites at Central and Western, and Eastern on Hong Kong Island, and Kwun Tong and Sham Shui Po from Kowloon East and West. Additionally there is a background site on Tap Mun (or Grass Island) in the north-eastern part of the Hong Kong Special Administrative Region (see Fig. 1a). Data from these stations are available at http://epic.epd.gov.hk/EPICDI/air/station/?lang=en.

The statistical tests were conventional. The multiple regressions used in this study took advantage of the online Wessa.net web-enabled application (Wessa, 2015).

3. Results and discussion

3.1. AQHI and public perception

There were early public reports of improved air quality during the protests, but these were not always clear about the type of pollutants that had been reduced (SCMP, 2014a). Fig. 2 shows the daily air quality and pollutant concentrations at the roadside in Central in Hong Kong from the EPD monitoring site. Air quality in the region is expressed in terms of an Air Quality Health Index (AQHI) introduced in late 2013. This derives from the percentage excess risk of daily hospital admissions based on local health statistics and air pollution data. It uses 3-hour moving average concentrations of four criteria air pollutants: ozone, nitrogen dioxide, sulphur dioxide, and particulate matter (PM_{10} or $PM_{2.5}$). The index adopts a commonly used scale with eleven points 1 to 10 and 10+ (GovHK, 2014). It also designates ranges that relate to health risks that are low (green 1–3), medium (orange 4–6), high (red 7), very high (brown 8–10) and serious (black 10+). However, it is important to recognise that a low AQHI represents a situation where air quality is high.

The median AQHI is plotted in Fig. 2a along with the upper and lower quartiles bounded by the white area. The vertical line is set at the ordinal day 271 (i.e. 28th September) and the period of the protests thus lies to the right. The *South China Morning Post* (SCMP, 2014a)