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Traffic control oriented impact on the persistence of urban air pollutants: A causeway bay revelation during emergency period

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ABSTRACT

The continuous traffic flow is always considered to take a great extent responsibility for the air quality deterioration in urban areas. Meanwhile, traffic control is assumed to be one of the most effective ways to mitigate the high concentration situation as this may cut off the emission directly and satisfy the air quality objectives. Unfortunately, the overdevelopment of central business district area in megacities not only complicates the control plan, but also troubles the process of plan assessment. Because of the road blockages caused by the radical behavior during the Hong Kong protest in 2014, it offers an unexpected chance to evaluate the influence of traffic control oriented plan on urban (i.e., Causeway Bay) air pollution. Hence, we here investigated the six air pollutants concentrations that measured in the time series before, during and after the Hong Kong Protest period. The impact of traffic flow restriction on pollutants' persistence has been quantified both qualitatively and quantitatively in this study. The results showed that the persistence of pollutants was a general property in Causeway Bay which dominated by the traffic flow pattern. The road blockages, considered as one kind of extreme traffic control plan, would strengthen the persistence of most pollutants (except ozone). Moreover, it also indicated that comprehensive consideration and further balance among different pollutants were necessary when try to reduce pollution in urban area by traffic control.

1. Introduction

The air quality in metropolitan area has deteriorated gradually ever since last century along with the increasing urbanization process and received worldwide attention in recent two decades (Chelani, 2009; Nieuwenhuijsen et al., 2014; Pan et al., 2016; Bari and Kindzierski, 2016). Meanwhile, the land planning of central business district (CBD) in mega city is functionally orientated with large amount of buildings and people concentrated. Yet this mode left little room for environmental improvements. Besides, transportation planning that aims at covering the weakness of existing urban planning, is usually being aware afterwards. Hence, an air quality management scheme based on thorough understanding of the trends in air pollutants dataset (Anh et al., 2000) is necessary.

The persistence (i.e., long-memory property) of atmospheric time series not only threatens the public health in long-term timescale, but also makes management and control of air pollution very difficult (Farah et al., 2014). Due to this, relevant

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topics have received much attention (Chelani, 2009; Pérez et al., 2011; MuSa and IbrahIM, 2012; Liu et al., 2015; Arizabalo et al., 2015; Willers et al., 2016). Fractal behavior is shown to be associated with long-memory as it reflects the self-similarity of the system, which is helpful in making further projections (Chelani, 2016). However, compared to the more general multifractal models, there are limitations for fractal theory to provide more information when describing a physical system (Arizabalo et al., 2015). Besides, the multifractals represent a very general theoretical framework for analyzing and modelling the nonlinear dynamics of environmental distribution of pollutants (Salvadori et al., 1997), and it has been used to analyze air pollutant sequences in multi-time series (Lee, 2002; Chelani, 2009; Diosdado et al., 2013; Lu et al., 2014; Xue et al., 2015; He et al., 2015).

To satisfy the demand of commuting in CBD areas, some similar user oriented systems were built (Biancardi et al., 2008) with underground transportation (e.g., metro) and ground transportation (e.g., buses, good vehicles, and private cars mainly) intensively integrated. However, substantial works showed that the transport sector, especially ground ones, was one of the most important sources of air pollutants in urban areas (Pant and Harrison, 2013). Besides, transportation planning and decision making should seriously consider environmental concerns as part of the design process (Amekudzi and Meyer, 2006). Hence, the pressure from growing car ownership and worsening air quality has spurred some authorities to take strict traffic control (e.g., plate number limit line, period of time that only buses can change direction while other vehicles should keep straight, etc.) for the sake of enhancing vehicle mobility and reducing emitted automobile exhaust. However, the gap between this top-down management and its evaluation in the full-scale observational database is difficult to obtain, especially in the CBD and its vicinity area. Lucky or not, the emergence of road blockages during Hong Kong protest from late September to mid-December in 2014 offered an unexpected chance to explore the impact of traffic flow control on local air pollution level.

Although the case was different, Klemm and Lange (1999) tried to evaluate whether the location change of a monitoring site in Germany would introduce systematic bias by analyzing the measurements of pollutant sequences from both the old and the new stations, in which autocorrelation and Hurst analysis (semi-multifractal detrended fluctuation analysis) are included. In light of this, we use combined statistical methods, i.e., autocorrelation and multifractal detrended fluctuation analysis (MF-DFA) to analyze pollutant data from a roadside station (Causeway Bay) and a background station (Tap Mun) to evaluate the influence of traffic related air quality management (i.e., traffic control) on local air pollutant levels. It was of great interest in this study to investigate whether the implementation of the above idea would induce any unnoticed influence but profound concern on air quality.

2. Database and methodology

2.1. Database

The key protest emerged ever since 27th September 2014 with traffic closed for more than 70 days in Admiralty, Causeway Bay and Mong Kok, which were in the vicinity of three Hong Kong Environment Protection Department (HKEPD) roadside monitoring stations at Central, Causeway Bay and Mong Kok respectively. For the sake of analyzing the impact of protest-made road blockage on the local air pollution, the timeline of the study period was set to be 79 days that counts from the first day of the protest till the last day when the traffic blockage in Causeway Bay was cleared on 15th December, i.e., the pre-protest (from 11th July to 27th September), the on-going protest (from 28th September to 15th December), and the post-protest (from 16th December to 4th March 2015). Each period sequence contains 1896 hourly data points. All the data and were provided by HKEPD, which could be download from its official site http://epic.epd.gov.hk/EPICDI/air/station/.

Moreover, in this study, we picked the Causeway Bay monitoring station on Hong Kong Island as the target site, and Tap Mun (or Grass-Island) station as the background site. The spatial positions of these two monitoring stations were shown in Fig. 1(a). The Causeway Bay and its vicinity together formed the most important business and entertainment center in Hong Kong with high-rise building lining up on both sides and shared huge pedestrian volume every day. The Causeway Bay monitoring station (i.e. No. 1 Yee Wo Street), located at one of the busiest road junctions in Hong Kong that connect the arterial road (i.e. Hennessy Road) to central business district (Fig. 1(b) and (c)), was the scene witness of air quality change during the protest period, which was considered as the most strongly affected monitoring station by the traffic blockage since it was more deeply embedded in the protest area compared to other two roadside sites in Central and Mong Kok (Brimblecombe and Ning, 2015). Contrary to the Causeway Bay site, Tap Mun was an isolated island on the north-eastern part of Hong Kong, a suburban area that far away from the protest region with least traffic interference (Fig. 1(a)). Hence, the Tap Mun monitoring station (Fig. 1(d)) presented its natural advantage in providing background trend information for comparison and discussion.

The surrounding areas of the Causeway Bay station and the Tap Mun station are two kinds of extremes scenarios. Different from the Tap Mun station retains the original landscape largely, the vicinity of Causeway Bay station is highly developed with bunch of high rise buildings line up along the roadsides, and leaves little space for further urban planning to change the landform in only few months. Hence, the spatial geomorphology impact for two areas is relatively stable during the study period which could be neglected. Because the temperature changed with the seasons and have influence on the pollutant diffusion process, it should be considered as the other major impact factor in this study. Due to this, study here took the meteorological data of Happy Valley as reference (Fig. 1(a)), as there was no individual weather station in Causeway Bay