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Characterization of chemical composition and concentration of fine particulate matter during a transit strike in Ottawa, Canada

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HIGHLIGHTS

- Analyzed only measurements that originated from the downtown area.
- During the transit strike, ambient particles were dominated by ultrafine particles.
- $PM_{2.5}$ mass, OC and EC increased by over 100% during the transit strike.
- Particle-bound PAHs increased by a factor from 3 to 8 during the transit strike.
- Concentrations of hopanes and steranes were elevated by 30–98% during the strike.

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ABSTRACT

From December 10, 2008 to February 9, 2009, a strike stopped the public transit services in Ottawa, Ontario, Canada. To understand the changes in air quality associated with the transit strike, the chemical composition and concentration of the fine particulate matter with diameters less than 2.5 microns ($PM_{2.5}$), collected before, during, and after the transit strike period, were evaluated. The collected $PM_{2.5}$ samples were analyzed to determine the particulate matter mass, the levels of organic carbon (OC) and elemental carbon (EC), as well as the particulate non-polar semi-volatiles, e.g., polycyclic aromatic hydrocarbons (PAHs), hopanes, and steranes. Particle number size distributions measured during and after the transit strike period were also compared. Results indicated that during transit strike months, particle number size distributions were entirely dominated by nucleation mode particles leading to an increase in total particle number concentration by about 79%. In addition, particulate matter, organic carbon, and elemental carbon mass concentrations also increased by over 100%. The average total PAH levels during the strike months were higher by a factor of about 7. Elevated concentrations of high molecular weight PAHs (i.e., PAH with 5 and 6 rings) observed during the strike months suggested that there were more gasoline-powered vehicles on the roads over that period. The level of carcinogenic benzo[a]pyrene was higher by a factor of 5. Mass concentrations of hopanes and steranes were 30–98% higher during the strike months than non-strike months and exhibited strong correlations with EC suggesting the primary origin of these compounds. These results indicated that the increased traffic volume due to the passenger vehicles and the change in driving pattern during the transit strike period reduced the local air quality.

1. Introduction

Motor vehicle transportation is a key feature in the daily lives of Canadians, and is becoming increasingly important as the country experiences growth in both economy and population (Transport Canada, 2007). Increased numbers of on-road vehicles contribute to rising levels of air pollutants, e.g., fine particulate matter ($PM_{2.5}$), carbon monoxide (CO), nitrogen oxides (NO_x), and volatile organic compounds (VOCs) (MOE, 2008). Studies have suggested that traffic congestion in major cities increases the exposure to air pollutants for on- and near-road commuters, as well as for residents that live close to the emission sources (Hagler et al., 2009; Zhang and Batterman, 2009; Levy et al., 2010). Recent studies reported possible correlations between elevated concentrations of fine particulate matter and various health issues, such as cardiovascular disease (Brook et al., 2010; Grahame and Schlesinger, 2010; Cakmak et al., 2011), respiratory symptoms (Moshammer and Wallner, 2011), lung cancer (Pope et al., 2011), asthma (Lavigne et al.,

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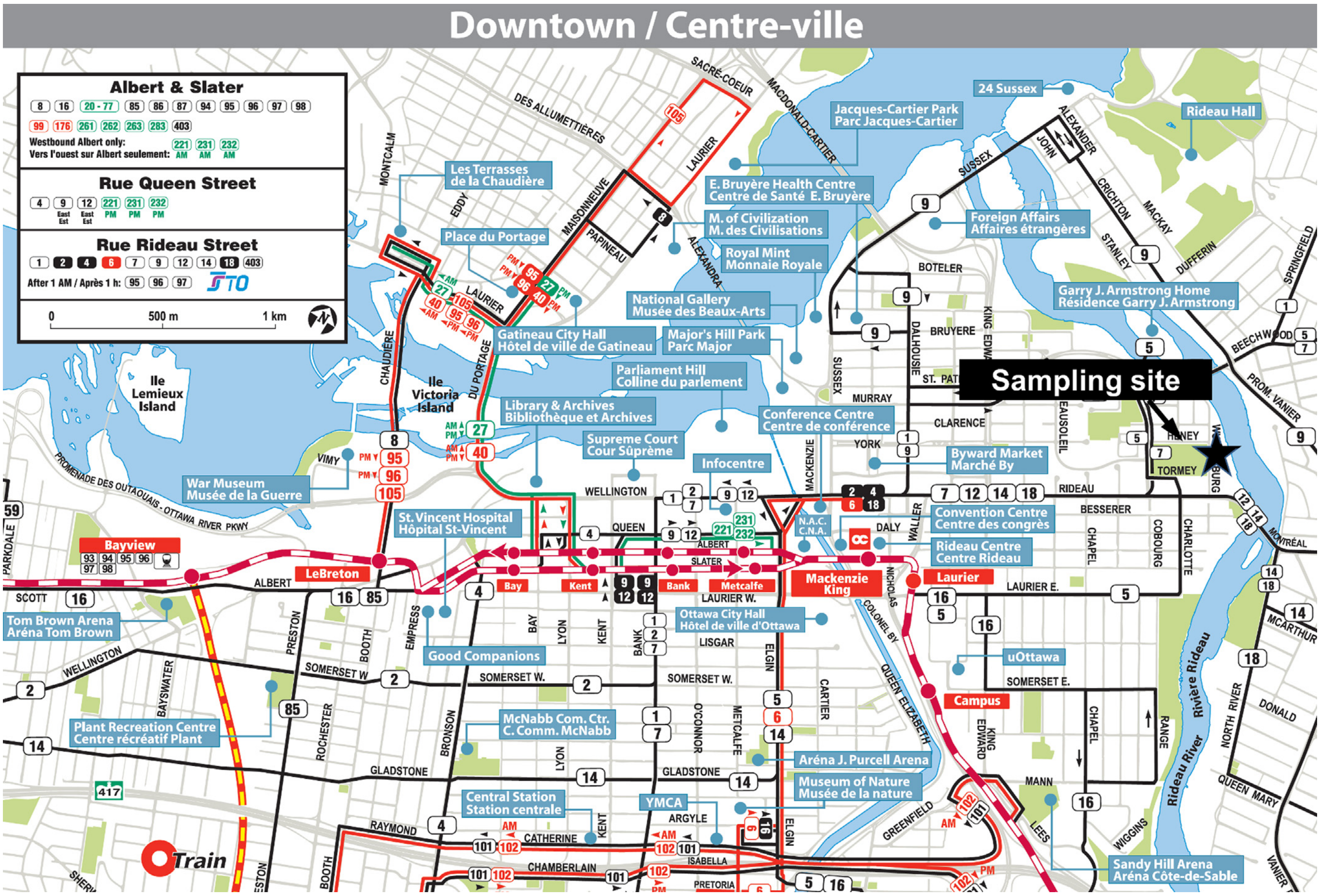

Fig. 1. Geographic location of the sampling site (star) and its relative positions to the local bus and train network.

2012), and even mortality (Elliott and Copes, 2011; Anderson et al., 2011; Yu et al., 2012).

Fine particulate matter consists of both solid and liquid particles that have different physical properties (e.g., size and morphology) and chemical compositions (e.g., organic and inorganic). These particles have both natural and anthropogenic origins. They are either emitted directly into or formed in the atmosphere. Atmospheric particles undergo various physical and chemical transformations and factors such as the source of emissions, the ambient air and meteorological conditions, all have influences on the fate of the atmospheric particles (Hasegawa et al., 2004). In many urban cities, the majority of the collected $PM_{2.5}$ is made up of carbonaceous materials, such as organic carbon (OC) and elemental carbon (EC). The rest of the composition is made up by the various amounts of sulfates, nitrates, and trace metals. In general, the organic compounds in the $PM_{2.5}$ typically include semi-volatile organic compounds (SVOCs), e.g., polycyclic aromatic hydrocarbons (PAHs), *n*-alkanes, hopanes, and steranes. PAHs are typically formed during incomplete combustion and these compounds are of particular interest because of their potential carcinogenic nature (De Martinis et al., 2002). Hopanes and steranes are known as petroleum biomarkers for lubricating oil and could be used to distinguish between vehicle exhaust emissions and wood combustion (Schauer, 2003).

Ottawa, located in eastern Ontario, is the capital of Canada and the nation's fourth largest city by population. With a population of about one million, there are nearly 370,000 people in the City of Ottawa who rely on public transportation to commute every day (Ottawa OC Transpo, 2013). The influence of the Ottawa public transportation system on the local air quality has never been assessed. From December 10 of 2008 to February 9 of 2009, the public transportation system in the City of Ottawa came to a halt due to a strike by transit workers. The halt of over 1000 buses and three trains during this transit strike provided a rare opportunity to investigate the environmental benefits associated with the public transportation system. This study investigates and reports the impact of the transportation emission pattern on the local ambient air quality in the City of Ottawa in terms of the changes in the particle number size distributions, the chemical speciation, and the mass concentration levels of the $PM_{2.5}$ measured at a downtown air monitoring site.

2. Experimental methods

2.1. Ambient air monitoring sampling site

All samples were taken at the Environment Canada operated National Air Pollution Surveillance (NAPS) network sampling site in Ottawa. The sampling site is located on Wurtemburg Street in downtown Ottawa (Fig. 1).

The sampling equipment was housed in a one-story shelter located at a city park beside Wurtemburg Street which is a two-lane road oriented north–south with a two-way traffic. The sampling inlet was located at the rooftop of the shelter, about 4 m above the ground. The sampling location was about 100 m north from Rideau Street, which is one of the busiest streets in downtown Ottawa.