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Road traffic as an air pollutant contributor within an industrial park environment

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ABSTRACT

This study aims to understand the relationship of the composition of pollutants and road traffic volume in an industrial environment. Two sampling stations were selected and samples were taken at two points, 1 m and 100 m from the roadside for each station, comparing a working day to a non-working day. The concentration of particulate matter with diameters of less than 10 µm (PM_{10}), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and ozone (O_3) and the number of vehicle travelling the road on a site in an industrial area were monitored. The results show that the concentrations of pollutants at the sampling point 1 m from the roadside were significantly higher than at the sampling point 100 m from the roadside for PM_{10} and CO, while the opposite was observed for the concentration of O_3 ($p \leq .05$). The levels PM_{10}, CO and SO_2 were significantly higher on a working day compared to a non-working day ($p \leq .05$). The number of vehicles on a working day and the concentration of PM_{10} and CO were significantly correlated with $r = 0.62$ and 0.81, while O_3 showed a negative significant correlation $r = -0.86$ at the 0.05 level (2-tailed). The results demonstrate that the concentration of pollutants relates to the number of vehicles on the road and the distance from the road. Even though the selected sampling site is an industrial area, the majority of the pollutants detected were related to the road traffic activity.

1. Introduction

The development process is unavoidable as countries keep up with global development and the growth of the human population. With fast urbanization and industrialization, transportation and accommodation have become important issues. Increasing activities and energy production to meet daily human needs are causing more pollutants to enter our environment, which can lead to issues such as severe air pollution and subsequent effects on human and environmental health (Grahame and Schlesinger, 2010; Ramos et al., 2016; Zhang and Batterman, 2013). It is well established that industrial activities are usually the main contributors of air pollution (Alyuz and Alp, 2014; Jerrett et al., 2005; Zhang et al., 2010). However, there are decreasing trends in the emissions of air pollutants from factories and now vehicular traffic is considered the main source of contaminants (González et al., 1996). Most factories prioritize cleaner production processes and focus on manufacturing and assembling products using less materials and energy, while at the same time generating less waste, effluents and air pollutants (Luken et al., 2016). However, as the industrialization process continues, this leads to increasing activities and numbers of vehicles within industrial areas (Luken et al., 2016). Thus road traffic has replaced factories as the main contributor to air pollutants.

Traffic systems were developed to allow mobility, and road transport is undoubtedly the most preferred system for the transport of people and goods, which results in the use of diesel- and petrol-fuelled vehicles (Gruden, 2003). Research has been carried out relating to air pollution problems originating from the development process and also from road traffic in urban areas (Cárdenas Rodríguez et al., 2016; Lee et al., 2011; Smith et al., 2015; Wahid et al., 2013). The products of combustion are mainly gases, particulate matter and ozone (O_3) precursors, including oxides of nitrogen (NO_x) and volatile organic carbons (VOCs), which are then emitted into the environment as exhaust gases (Sánchez-Ccoyllo et al., 2009). It has been determined that fossil fuelled vehicles are the main sources of carbon monoxide (CO), hydrocarbons (HCs), lead (Pb), oxides of nitrogen (NO_x), particulate matter (PM), sulphur dioxide (SO_2), ozone (O_3) and methane (CH_4), among others (Colvile et al., 2001; D'Angiola et al., 2010; Soylu, 2007). Yan et al. (2011) carried out a global emissions projection of particulate matter focusing on exhaust emissions from road vehicles and discovered that the total emissions of particulate matter could decrease 1.3–2% each

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year with control measures and the introduction of better vehicles, proving that vehicular emissions play an important role in global emissions of particulate matter (Yan et al., 2011). It was reported by Giovanis (2017) that attempts to reduce road traffic activities reduced the concentrations of nitrogen dioxide (NO_2), SO_2, CO and particulate matter with a diameter size of below than ten micrometres (PM_{10}) in the atmosphere. It was also discovered that traffic emissions make a greater contribution to ground level concentrations of NO_2 than industrial sources per unit emission (Leksmono et al., 2006).

The abundance of anthropogenically-sourced substances in the atmosphere contributes to a very uncomfortable environment to live in. The complex mixture of different air pollutants means that the exact composition varies both over time and between individual towns and cities due to changes in patterns and sources of emissions. This results in complications in the management of pollution as a whole (Colvile et al., 2001). The Klang Valley area in Malaysia has been the central focus of development since Malaysia gained independence in 1957; it is also the central pollutant emission source area (Latif et al., 2014). It was observed that there are higher concentrations of NO_2 and PM_{10} in highly constructed and fragmented cities compared to densely populated cities, which suffer from higher SO_2 concentrations (Cárdenas Rodríguez et al., 2016). Focusing on road traffic as one of the major contributors to urban air pollution problems, this paper discusses the five major vehicular pollutants: PM_{10}, CO, SO_2, NO_2 and O_3. This study aims to understand the relationship of the composition of pollutants and road traffic volume in a cleaner-production industrial environment with low emissions from the industrial activity by looking at the relationship of selected pollutants to road traffic activity.

2. Materials and methods

2.1. Study area

Shah Alam is the state capital of Selangor, Malaysia. It is located about 25 km from Kuala Lumpur, the capital city of Malaysia. Shah Alam is a popular industrial city among multinational companies as it is well equipped with modern infrastructure and has a strategic location close to the port and airport. Persiaran Kuala Selangor was chosen to be studied as it is the major road running through the Shah Alam Industrial Estate, one of the biggest industrial estates in Shah Alam and Malaysia as shown in Fig. 1. However, within the study area, most of the industrial activity is focused on the storage, marketing and trading, assembly, and packaging of electronic products (MIDA, 2014) as shown in Fig. 2. These activities are expected to involve less combustion and so produce less air pollution emissions. Very little activity that involves combustion and the emission of air pollutants can be found in the area. As the area is expanding, the industrial area is now located in close proximity to several housing estates with facilities including banks, health clinics, restaurants, and shopping centres, among others.

2.2. Field sampling

This study monitored the concentrations of PM_{10}, SO_2, CO, NO_2 and O_3 using the methods as outlined by Latif et al. (2011). Two sampling stations (St1 and St2) were selected along the Persiaran Kuala Selangor to monitor the concentrations as shown in Fig. 1. At each sampling station, two sampling points were used: i) 1 m by the roadside; and ii) 100 m from the roadside. The data were collected from 9th September 2014 to 24th October 2014.

2.2.1. Concentration of gases

The SO_2, CO, NO_2 and O_3 concentrations were determined using a colorimetric method using the LaMotte Company air pollution sampling and measurement kit (LaMotte Company, USA). Air was absorbed into the respective absorbing solutions in test tubes using an air sampling pump with a flow rate of 1.0 L/min for an hour. The absorbing solutions were as presented by the LaMotte Company. The intensity of the colour developed for each gas was determined using a colorimeter for the respective pollutants and the absorption was compared with the chart produced by LaMotte Company to get the value of the concentrations of respective pollutants. The concentration readings were collected four times daily, at 7 a.m., 9 a.m., 3 p.m. and 5 p.m.

2.2.2. Concentrations of PM_{10}

PM_{10} was collected using a PM_{10} low-volume sampler MiniVol™ PM_{10} portable air sampler (Air Metrics, USA) equipped with pre-weighed filter paper (diameter size 47 mm, pore size 0.45 μm) that had been dried in a desiccator for 24 h beforehand. Air was collected at a flow rate of 5.0 L/min hourly from 7 a.m.–11 a.m. and 3 p.m.–7 p.m. The filter papers with particulate samples were transferred to the laboratory and placed in desiccators for 24 h and weighed again. The concentration of PM_{10} was calculated from the difference in the weight of the filter paper before and after sampling for the volume of air absorbed by the low-volume sampler.

2.2.3. Traffic count

The number of vehicles utilising the road in both directions was obtained by manually counting vehicles at a cross section of the road from 7 a.m. to 7 p.m. both on a working day and a non-working day.

2.3. Continuous air quality monitoring analysis

Air quality data used as a reference in this research was collected from the Department of Environment (DOE) Continuous Air Quality Monitoring Station (CAQMS) at TTDI Jaya Primary School, Shah Alam with coordinates N03° 06.287, E101° 33.368, located about 7 km away from the sampling site at Persiaran Kuala Selangor. The air quality data has been collected through continuous monitoring programme by Alam Sekitar Malaysia Sdn. Bhd. (ASMA) assigned by the Air Quality Division of the Malaysian Department of Environment. The air quality data used in this study was obtained from 2014. The parameters used in this study were PM_{10}, SO_2, NO_2, CO and O_3. The instrument used to monitor PM_{10} was a BAM-1020 Beta Attenuation Mass Monitor (MetOne Instrument, Inc., USA) which was equipped with a cyclone and PM_{10} head particle traps, fibre glass tape, flow control and a data logger. This instrument has a fairly high resolution of 0.1 μg/m^3 at a 16.7 L/min flow rate, with lower detection limits of < 4.8 μg/m^3 and < 1.0 μg/m^3 for 1 h and 24 h, respectively. The instrument used to monitor SO_2 was a Teledyne API Model 100A/100E based on the UV fluorescence method where the lowest level of detection was 0.4 ppb. The instrument used to monitor NO_2 was a Teledyne API Model 200A/200E based on the chemiluminescence detection method with a detection limit of 0.4 ppb. The instrument used to monitor CO was a Teledyne API Model 300/300E using the non-dispersive, infrared absorption (Beer Lambert) method with 0.5% precision and a limit of detection of 0.04 ppm. O_3 was determined using a Teledyne API Model 400/400E through the ultraviolet absorption (Beer Lambert) method with a detection limit of 0.4 ppb (all instruments were from Teledyne Technologies Inc., USA). The measurements of SO_2, CO, NO_2 and O_3 were at a precision level of 0.5% (Latif et al., 2014). Wind speed (WS) was recorded using a Met One 010C sensor and wind direction (WD) was measured using a Met One 020C sensor at 10 m measuring height. Ambient temperature (AT) and relative humidity (RH) were measured using a Met One 062 and Met One 083D sensor respectively (Met One Instrument, Inc., USA) (Latif et al., 2014).

3. Results and discussion

3.1. Air quality near to the roadside

Based on the observations, PM_{10}, SO_2, CO, NO_2 and O_3 were present in the atmosphere of Persiaran Kuala Selangor. A summary of pollutants