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Projecting impacts of two-wheelers on urban air quality of Douala, Cameroon

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ABSTRACT

Douala, one of the fastest developing cities of Cameroon, has been experiencing unprecedented growth of two-wheelers (motorbikes) and poor perceived air quality. The city has no air quality monitoring system and no air quality data. The only survey that reported the carbon monoxide (CO) levels was carried out by the World Bank under the Clean Air Initiative in 2002 and another study of traffic counts in 2008. In this study, the World Bank CO concentration levels of 2002 have been validated by back projecting the 2008 traffic scenario using vehicular emission and line source dispersion models and future scenarios up to 2015 have been projected at one of the busiest traffic intersections. The potential impacts of Euro emissions standards to improve the roadside air quality in Douala were studied. The results showed that the CO levels increased by a factor of 18 for a period from 2002 to 2015 with an annual increase of 65% in two-wheelers and 31% in cars. The estimated population of two-wheelers in 2015 was found to be 23 times higher than in 2002, which, by 2035, is expected to grow by 533% and the car ownership by 146%. If Euro II and III emissions standards are gradually implemented on two-wheelers in Cameroon, CO levels along roadways are expected to be reduced by about 70%. These results may be helpful to policy makers to prepare an air quality management plan for the city.

1. Introduction

Unprecedented growth in the number of vehicles led by increasing population in rapidly urbanising cities has contributed to the growing problems of air quality throughout the African continent and developing countries (Shiva Nagendra et al., 2016; UNEP, 2005). In Cameroon, in 2005, 48.8% of the population lived in urban areas such as Douala, the economic capital (BUCREP, 2011). The growth in vehicles is mainly seen in two-wheelers, a new mode of transport in Cameroon, where two-wheelers are used as taxis, called 'ben skin' locally (Olvera Diaz et al., 2007; Sahabana, 2006). The major share of two-wheelers in the traffic is due to the shortage of public transport, inadequate road infrastructure, and a loose regulatory framework (Olvera et al., 2012). Most of the motorbikes in Cameroon are imported from Asian countries, particularly China and there are no clear regulations for emissions standards (CUD, 2008; Khan et al., 2009; Sietchiping et al., 2012).

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A study was carried out in Yaoundé, Cameroon, on ambient particulate matter (PM). Mass concentration levels, size fractions and the share of carbonaceous fractions were measured for an averaging period of 24 h for a period of 9 days from a fixed monitoring station located roadside or a traffic junction. The average concentration of $PM_{2.5}$ was about 49 ± 12 μg m^{-3} and of PM_{10} was 65 ± 21 μg m^{-3} (Antonel and Chowdhury, 2014; Doumbia et al., 2012).

In Douala, only one study on air quality has been done. This was in 2002 by the World Bank under the Clean Air Initiative, in which the average roadside pollutant concentration levels at some traffic intersections were measured. The study predicted an increase in CO concentration levels by 210% in future years (years not mentioned in the report) (WorldBank, 2004). In African countries, while air continues to deteriorate due to high growth in two-wheelers and cars, the relevant issues such as awareness of air pollution caused by increasing road vehicles and the associated risks to human health remain untouched. One of the risks is the aggravation of diseases such as asthma, respiratory problems and cardiovascular illnesses (Anderson et al., 2013). It is known that exposure to high levels of CO during pregnancy results in high risk for the mother by increasing the short-term complication rate and for the foetus by causing developmental disorders and chronic cerebral lesions (Prockop and Chichkova, 2007; Raub et al., 2000). The WHO (World Health Organization) has recommended the limits for exposure to CO of 9 ppm for 8 h averaging period, 26 ppm for 1 h, 52 ppm for 30 min, and 87 ppm for 15 min averaging period (Levy, 2015; Raub, 1999). In the last few years, several studies demonstrated a link between outdoor air pollution and autism (Becerra et al., 2013; Levy, 2015). In African continent or West Africa, only a few studies related to the risks and impacts of air quality on human health are available. For example, in Nairobi, a study reported that residents are exposed regularly to high levels of fine PM and, therefore, are prone to serious health risks in the long run (Kinney et al., 2011). Another study reported that exposure of Sudanese, Malian and Senegalese to Saharan dust has potential health effects (De Longueville et al., 2013). Studies on vehicular emissions and air quality modelling do not exist, however.

The main aim of this study was to predict CO concentration levels based on the data collected in 2002 by the World Bank and to study the impacts of two-wheelers at a highly-trafficked intersection in Douala, Cameroon. The busiest junction of Ndokoti and the focus on CO as the study area and pollutant have been chosen contingent on the data available from the World Bank survey of 2002. The study includes estimates of the traffic growth, vehicular emissions and projection of the CO concentration levels till the year 2015 using the World Bank CO concentration levels of 2002 and also the traffic data of 2008 collected by the Douala Urban Council. The prior CO concentration levels have been first validated by the traffic data of 2008. Further, we investigated to what extent the air quality can be impacted with the implementation of Euro emissions standards in Douala. For this, the number of two-wheelers and cars was projected using the Gompertz model (Dargay et al., 2007), vehicular emissions were estimated using a semi-empirical model (Dirks et al., 2003) and the CO concentration levels were estimated using CALINE4 (Benson, 1992) line source dispersion model for two-wheelers and cars. The semi-empirical model predicts the effects of changes in traffic-flow pattern on CO concentration levels (Dirks et al., 2002, 2003). The model is applied in several studies with a good accuracy for pollutant dispersion at traffic intersections, for modelling the benzene levels in a street canyon and air quality in urban neighbourhoods (Elangasinghe et al., 2014; Gokhale and Pandian, 2007; He et al., 2009; Kassomenos et al., 2004). In this study using hourly traffic flow, for a random day of the year, the corresponding CO emissions can be obtained.

The CALINE4 model is applied at traffic intersections and roadways in several studies (Batterman et al., 2010; Gokhale, 2011; Wang et al., 2014; Yura et al., 2007). Assuming steady state at downwind in space and time, the CALINE4 model is widely applied due to fewer input data requirements, direct applicability to street scale air quality predictions and good performance. This study presents the methodology in detail and the results of the air quality predictions from 2002 to 2015, vehicle growth and the impact of two-wheelers on roadside air quality. The study has been targeted at providing traffic-originated air quality over a longer period, in the light of the unavailability of data, to help local regulatory bodies to plan a long-term strategy to improve urban air quality by regulating the importation of vehicles (old cars and motorbikes) into the country and also by adopting emissions standards.

2. Methodology

Fig. 1 shows the flow of the methodology followed in this research and the details are explained in the following sections.

2.1. The base study of the World Bank

In 2002, the World Bank under the Clean Air Initiative carried out a measurement study of air pollutants in different African cities including Douala in Cameroon. The measurements in Douala were made at three intersections including Ndokoti junction during peak and off-peak hours. The study reported significant ambient air concentration levels of CO and oxides of nitrogen (NOx), mainly added by the motorised transport to the air pollution of Douala. The World Bank predicted a significant increase in CO concentration in Douala in future. Douala is economic capital of Cameroon with a population of about 3 million in 2015, which has increased from 1.9 million in 2005 at a growth rate of 4.7 per annum over a period of 10 years (BUCREP, 2010). This has also increased vehicular population. The traffic intersections are, therefore, congested with a high density of vehicles including buses, cars and motorbikes. Ndokoti is one of the most congested junctions in Douala (Fig. 2), located in the busiest urban centre having a high population density, high traffic and poor air quality. For this reason, this intersection has been selected for the study for which air quality data and some traffic characteristics are available for