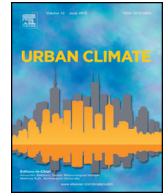




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Urban Climate

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In-vehicle and pedestrian exposure to carbon monoxide and volatile organic compounds in a mega city

Ebenezer L. Odekanle^a, Bamidele S. Fakinle^{b,*}, Lukuman A. Jimoda^c,
Oyetunji B. Okedere^d, Funso A. Akeredolu^a, Jacob A. Sonibare^a

^a Environmental Research Laboratory, Department of Chemical Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria

^b Department of Chemical Engineering, Landmark University, Omu-Aran, Nigeria

^c Department of Chemical Engineering, Ladoko Akintola University, Ogbomosho, Nigeria

^d College of Science, Engineering and Technology, Osun state University, Osogbo, Nigeria

ARTICLE INFO

Article history:

Received 7 December 2014

Received in revised form 12 June 2017

Accepted 16 June 2017

Available online xxx

Keywords:

Vehicle

Pedestrian

Exposures

Carbon monoxide and volatile organic compounds

ABSTRACT

This study is to determine in-vehicle and pedestrian exposure to carbon monoxide (CO) and volatile organic compounds (VOCs) in six roadways in Lagos mega city. Measurements were made twice a day for two weeks for four major modes of transportation in the city using the MultiRae ambient gas monitor. The levels of CO measured were 4.40–39.78 ppm while that of VOCs were 0.00–0.39 ppm. Highest average CO and VOCs concentrations were obtained inside car during morning commuting periods. These average concentrations were found to be statistically significant when compared with other three transportation modes studied. The average concentrations of the pollutants in the morning were statistically similar to average concentration in the afternoon as Student's *t*-test indicated no statistical significant difference ($p > 0.05$). This study revealed that car commuters are exposed to higher concentrations of CO and VOCs than bus and BRT commuters with pedestrians having the lowest exposure to the pollutants.

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1. Introduction

Owing to its flexibility, road transport is a major transport mode. Cars, minibuses as well as heavy buses are objects of desires and pride in many societies. If one is going somewhere, chances are it is by automobile.

* Corresponding author.

E-mail address: fakinle.bamidele@lmu.edu.ng (B.S. Fakinle).

Only few people are concerned about the nature of air quality inside their vehicles. Many are more likely to consider air pollution an outdoor problem.

Though numerous studies on personal exposure of commuters to traffic-related pollutants have been published (Alm et al., 1999, Adams et al., 2001; Kaur et al., 2007, Kaur and Nieuwenhuijsen, 2009, Kingham et al., 2011), there is currently almost complete absence of studies performed in developing world on commuters exposure to air pollution (Knibbs et al., 2011). Some separate scientific studies have revealed that human exposure to air pollution from vehicles is increasingly being linked to adverse health effect (Andrew et al., 2000; Brauer et al., 2007; Delfino et al., 2005; Hoffmann et al., 2007; Hoek et al., 2002; McConnell et al., 2010; Bruinen de Bruin et al., 2004a, 2004b). In-vehicle air typically contains more carbon monoxide, toluene, fine particulate matter and nitrogen oxides than ambient air at nearby monitoring station. (Andrew et al., 2000). Adams et al. (2001) opined that people are exposed to some of their highest concentrations of atmospheric pollutants while commuting. Although some studies show that the mean concentrations of air pollutants pedestrians are exposed to are lower than those experienced by car commuters and bus (Dirks et al., 2012; Gulliver and Briggs, 2004; Han and Naeher, 2006).

Joop and Van (1995) also observed that car commuters are exposed to higher concentrations of CO and VOCs than cyclists. Similar studies by Dor et al. (1995) reported the average VOCs concentration inside car on routes in Paris to be higher than the concentrations breathed in by other commuters, while concentrations at pedestrians sidewalks were three times lower than in-vehicle. Petersen and Rodney (1982) reported in-vehicle CO levels to be identical to those immediately outside the vehicle. In Washington DC, in-car CO levels were found to be seven times higher than those at nearby site (Flachsbart et al., 1987).

Several pollutant studies have been carried out in Nigeria. However, most of them have concentrated on outdoor pollution. The goal of this study is to assess in-vehicle and pedestrian exposure to CO and Volatile Organic Compounds (VOCs) in various modes on transport in Lagos city, Nigeria based on travel time and transport modes. The exposure levels among different modes of transport were compared. Results obtained provided information for commuters on how to choose appropriate travel behavior to minimize personal exposure.

2. Experimental

2.1. Study area

Lagos City is chosen for this study, due to some specific characteristics that the city presents. It is one of the most important and densely populated urban centers with serious air pollution problems in Nigeria. It is Nigeria's main commercial centre, with >70% of the nation's industries and economic activities carried out there, which makes it the most economically important state of the country (Somuyiwa, 2009). The city is also important to the rest of West Africa as a leading regional port and manufacturing centre with the highest number of multinational companies (Atubi, 2010). Lagos is located on latitude $6^{\circ} 22'$ and $6^{\circ} 42'$ North and longitude $2^{\circ} 42'$ and $3^{\circ} 22'$ East and has over 224 vehicles per kilometer as against 15 vehicles per kilometer in other states in Nigeria (Awoyemi et al., 2013), hence heavy traffic congestion is experienced by over 10million commuters on its roads on daily basis. Plate 1 shows the traffic nature in Lagos city.

The study assesses personal exposure to CO and VOCs along selected roadways in Lagos city, Nigeria. Two typical daily traffic situations were selected: the morning commuting period (designated as rush hour) and the afternoon commuting period (designated as non-rush hour). Concentrations of CO and VOCs were measured simultaneously on each of the roads while commuting in major modes of transportation: cars, buses, Bus Rapid Transit (BRT) as well as for pedestrians. These are the permitted and government approved modes of transportation on Lagos city major roadways, hence the choice of the routes. Other modes of transportations (e.g. motorcycles, bicycles etc.) are restricted to streets in suburb towns and villages as well as local communities. The major difference between normal bus and Bus Rapid Transit is that, the latter is a longer and bigger bus (35 passengers) which operates on a dedicated bus lanes thereby making passengers get a regular, faster and congestion-free drive, On the other hand, the former is a ten (10) passenger bus which operates on the general lanes which makes it always get stuck in traffic congestion. Bus Rapid Transit has been adjudged by transport planners and policy as a mode of transport that provides quality urban transport service which helps in tackling the huge public transport and pollution predicaments that besiege the city (Somuyiwa, 2009). All the modes of transport used for this study were not air conditioned hence, in all the

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