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IN-VEHICLE AIR POLLUTANTS EXPOSURE AND RESPIRATORY SYMPTOMS AMONG COMMERCIAL ('TROTRO') DRIVERS AND PASSENGERS IN MADINA, A SUBURB OF THE LA-NKWANTANANG MUNICIPALITY

BY

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DECLARATION

This is to declare that this is a result of my own original research under the supervision of Dr. Reginald Quansah. Other academic works that have been cited have been duly acknowledged. This work has not been submitted to this or any other university for any degree.

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(SUPERVISOR)

DEDICATION

I humbly dedicate this thesis to my loving mother, Mary Abena Frimpomaa, my foster parents; Mr. and Mrs. Philip Ofori-Asante and my wife, Juliet Owusu Yankyera, who trusted and believed in me.

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ABSTRACT

Background: Vehicular air pollutants have been known to be one of the chief sources of respiratory health symptoms. Growing urbanization associated with rising population has given the situation an alarming rate particularly in developing nations like Ghana. Studies have linked exposure to pollutants from motor vehicles to a number of respiratory symptoms and diseases including chronic cough, excessive phlegm production and lung cancer. However, not many studies have considered commercial drivers and passengers who travel many hours while working intercity and intracity journeys and are exposed to harmful air pollutants.

Objective: The objective of the study was to ascertain the association between vehicular levels of CO, $PM_{2.5}$ and respiratory symptoms among commercial (‘‘trotro’’) drivers and passengers in Madina.

Methodology: A cross-sectional study was conducted from May to June 2017 among commercial ‘trotro’ drivers and passengers. 89 drivers and 89 passengers who use the Madina to Accra, Kasoa and Dansoman routes were recruited. The data collection tools included a self-administered questionnaire, a CO and vehicular levels of CO monitoring with a LASCAR CO monitor. The PM was monitored using SidePak Personal Aerosol monitor model AM 510

Findings: Median concentrations of personal levels of CO were lower among drivers than among passengers. In addition, the median concentrations of vehicular levels of CO and $PM_{2.5}$ were higher at the passenger compartment compared to the driver compartment of the vehicle.

Respiratory symptoms reported include cough, phlegm production, wheezing and breathlessness.

Conclusion: There was significant difference in the median concentration of personal levels of CO among drivers and passengers. Moreover, prevalence of respiratory symptoms was higher among passengers than among drivers.

Key words: Commercial 'trotro' vehicles, respiratory symptoms, carbon monoxide, particulate matter

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LIST OF ABBREVIATIONS

CO	Carbon monoxide
COPD	Chronic Obstructive Pulmonary Diseases
O_3	Ozone
PM	Particulate Matter
UN	United Nations
UNEP	United Nations Environment Programme
VOCs	Volatile Organic Compounds
WHO	World Health Organization

DEFINITION OF TERMS

'Trotro' - the local name for commercial vehicles that ply intracity in Ghana

Pollutants- A pollutant is a substance or energy introduced into the environment that has undesired effects, or adversely affects the usefulness of a resource

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

An increasing number of vehicular air pollutants exposure has been reported in recent times (Abi-Esber,2009). This is because transportation has become an important component of human activities; and it is proven that staying longer on vehicles increases level of exposure to pollutants (Firdaus & Juliana, 2014). The greatest environmental risk to health is air pollution (WHO, 2016a). This is explained by the fact that when air is polluted it ''affects 100% of the population from cradle to grave''(Perez & Rapp, 2010, p.1). Though every region of the world is affected by air pollution; the World Health Organization (WHO, 2016a) posits that air pollution levels are rising in many of the poorest cities around the world. This is confirmed by the latest urban air quality report in which the WHO (2016) states that ''98% of cities in low and middle income countries with more than 100 000 inhabitants do not meet WHO air quality guidelines''. When urban air quality declines, the risk of diseases such as stroke, heart disease, lung cancer, chronic and acute respiratory diseases, including asthma, increases for the people who live in them (WHO, 2016).

Vehicular emissions are one of the major sources of air pollution. In furtherance to the above, it is known that rising rates of urbanization in sub-Saharan Africa is related to increased number of motor vehicles. This has resulted in rapid increased levels in pollutants emitted by vehicles. Thus the most important process that causes air pollution relates to the combustion of fossil fuels used in vehicles(Perez et al., 2010).

The cabin of a vehicle has been known to be an important microenvironment which exposes drivers and passengers to high levels of pollutants such as carbon monoxide (CO), volatile organic compounds (VOCs), carbon dioxide (CO_2) and particulate matter (PM) (Firdaus & Juliana, 2014). In addition, fuel exhaust particle pollutes the atmosphere as well as infiltrates inside the car. Hence, pollutants could be received by people during typical levels of activity in different microenvironments.

Transportation has always been seen as a key ingredient in making the exchange of goods and services accessible to populations. The Global Initiative on Transport Emissions (GITE) a joint World Bank/United Nations project predicted in 2002 that with growth in the economy of developing countries, coupled with income rise and urbanization, demand for transport services is expected to grow at a rate of 3.6 percent per year up till 2020 (Gorham, 2002). The implication of this prediction is that fossil fuel combustion that has been known to have adverse effect on air quality and subsequently the health of humans and the ecosystem would continue to increase consistently in proportions (Gorham, 2002). Moreover, studies have proven that exposure to indoor air pollutants is high inside buildings and in vehicles such as buses (Taylor et al., 2015; Pindus et al., 2016). Both long term and short term exposures to polluted air have various health effects on both individuals and populations (Firdaus & Juliana, 2014). These health effects include increased cardiovascular mortality, sub-clinical lung diseases and increased admissions in the hospital (Huang & Hsu, 2009).

The WHO air quality guidelines prove that air quality is affected by a number of pollutants and the pollutants include carbon monoxide, nitric oxide, carbon dioxide, sulphur, particulate matter (PM) and ozone (Krzyzanowski & Cohen, 2008). Though exposures may occur at different levels, guidelines on threshold concentrations of pollutants such as particulate matter (PM) and ozone (O_3) show that there is no level below which there are no adverse health effects (Krzyzanowski & Cohen, 2008). Reducing the levels and exposure to PM alone would cut down the number of deaths in affected countries by 15 percent (World Health Organization, 2006).

In Ghana, the use of commercial vehicles also known as 'trotro' requires that both drivers and commuters stay on the vehicle for either a short period or a long period. More often, commuters are more likely to stay on a vehicle for shorter period than drivers. This is a particular case where drivers either drive over ten hours a day or drive on long journeys. In a study, to determine the exposure to pollution from within buses, it was known that staying longer on vehicles increases negative health risk due to the level of exposure to pollutants (Firdaus & Juliana, 2014). Several factors such as excessive vehicle use, age of vehicle, poor maintenance as well as type of fuel used by vehicles contribute and compound the problem of poor indoor air quality in vehicles (Gorham, 2002). Therefore, the health risk of air pollution from within and without vehicles has become a consistently challenging issue for sub-Saharan nations such as Ghana and thus, a motivation for the present study.

1.2 Problem Statement

The World Health Organization recognizes air pollution as the world's largest single environmental health risk and causes more than 3 million premature deaths yearly in the world (WHO, 2016a). Moreover, in Africa, 170, 000 people die prematurely each year due to outdoor air pollution and the largest exposure to indoor air pollution occurs in the developing world(Smith, 2002). Ghana in particular has recorded acute respiratory tract infection as one of the top ten causes of death, killing 22.4 thousand people in 2012 (WHO, 2016a).

Motor vehicles have been identified to contribute greatly to poor air quality (Kadiyala & Kumar, 2013). They emit different pollutants such as carbon monoxide, sulphur, particulate matter (PM) and ozone. These pollutants have disabling and fatal consequences on human life (Chang, Lee, & Huang, 2016). Clearly, transportation has become a vital aspect of human activity (Luke, 2011) and high levels of air pollution generated inside public transport vehicles are known to be of a great health concern in sub-Saharan Africa (Jones et al., 2016). According to the United Nations Environment Programme (UNEP), the average PM levels in Accra exceeds the WHO guideline (Akumu, 2014). With the increasing urbanization in developing countries like Ghana, there is an associated increase in population resulting in increase in the use of vehicles both for private and public use.

In addition to the disease burden caused by air pollution, there is a huge economic loss associated with it. The UNEP says the cost of air pollution can be as high as 2.7% of the gross domestic products in African cities (Akumu, 2014). In Kenya, economic loss per year due to vehicle emissions is 1.3 million US dollars according to a Nairobi University study (www.unep.org).

The study done in Nottingham by Clifford, Clarke and Riffat (1997), which is one of the few earlier studies conducted among drivers in the United Kingdom, concluded that it is often drivers and passengers that are exposed to the highest levels and highest doses of air-pollutants. Monitoring exposures was therefore suggested by authors to be necessary in ensuring that drivers do not receive potential harmful doses of pollutants. Ekpenyong et al. (2012) has also assessed the respiratory health effect of city outdoor ambient air pollutants on transit and non-transit workers and compared such effects by transportation mode, occupational exposure and socio-demographic characteristics of participants. Findings showed that exposure to ambient air pollution by occupation and transportation mode was associated with respiratory functions impairment and incident respiratory symptoms among participants. Other studies have looked at traffic air pollution, however these have not assessed the potential health risk of exposure to drivers and passengers in a developing country like Ghana (Houston, Li, & Wu, 2014; Huang & Hsu, 2009; Dionisio et al., 2010).

Therefore this study seeks to determine the exposure of on-road in-vehicular air pollutants among commercial 'trotro' drivers and passengers and its implication on their respiratory health.

1.3 Conceptual Framework

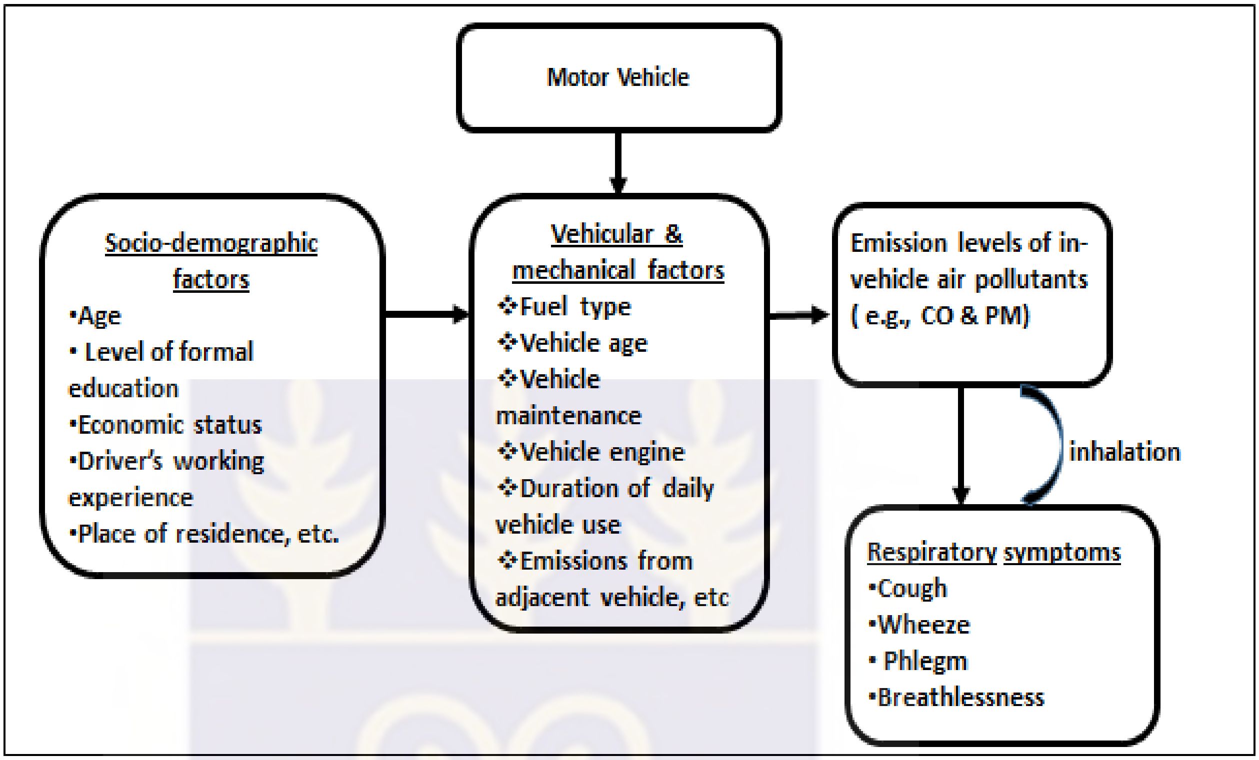

Figure 1.1 Framework of factors that influence vehicular emissions and exposure to air pollutants

Source: Adopted and modified from (Clifford et al., 1997b)

The conceptual framework presented above (see figure 1.1) indicates all the relevant variables that may contribute to excessive air pollution in motor vehicles of commercial drivers in an urban population such as Madina in Ghana. Vehicles produce different levels of emissions leading to exposure through inhalation. Inhalation into the respiratory system induces susceptibility to respiratory diseases, with different responses that are likely to result in respiratory symptoms such as coughing, production of phlegm, wheeze without cough and breathlessness (Pindus et al., 2016). The emission and exposure levels are influenced by a number of factors such as vehicle age and frequency of maintenance, fuel type use and duration of daily vehicle use. In addition, the educational status of a driver has influence on his knowledge of the effect of pollutant emission as well as laws that govern environmental pollution. Economic status also influences the affordability for a new vehicle and also affects the regular maintenance of the vehicle.

1.4. Justification of the Study

Motor vehicles have been known to contribute immensely to poor air quality (Krzyzanowski & Cohen, 2008). Different pollutants that contaminate air quality have different capacities of toxic activity on humans and the ecosystem. The disease burden on developing nations such as Ghana results in high levels of mortality (WHO, 2016b).

Measurement of vehicular levels of pollutants have been done in few earlier studies in Nottingham in the United Kingdom (Clifford, Clarke, & Riffat, 1997), Malaysia (Firdaus, & Juliana, 2014) and Hong Kong (Cheng et al., 2015). Of these studies, only the one carried out in Malaysia directly looked at respiratory health effects on drivers of buses (or commercial vehicles).

In Ghana, no published study has been carried out on in-vehicle levels of CO and PM among commercial 'trotro' drivers and passengers. Therefore this study would add to knowledge on the health effects of high levels of exposure to vehicular air pollutants on commercial drivers and passengers in Ghana, a developing country. Findings would serve as a reference point for policy formulation to support exposure reduction interventions for pollutants generated in and out of motor vehicles.

1.5. Research Objectives

The general objective of the study is to ascertain the association between vehicular levels of CO, $PM_{2.5}$ and respiratory symptoms among commercial (''trotro'') drivers and passengers in Madina. Specifically, the study intends to achieve the following objectives:

i. To determine and compare the prevalence of respiratory symptoms among drivers and passengers

ii. To determine levels of CO and $PM_{2.5}$ in commercial vehicles

iii. To compare personal levels of CO among commercial drivers and passengers

CHAPTER TWO

LITERATURE REVIEW

2.0 The Scope of the Review

This chapter provides a brief introduction to vehicular air quality, particularly in reference to carbon monoxide and particulate matter. In addition, empirical studies on the subject in relation to health consequences of exposure levels are also reviewed.

2.1 Air Pollution

Air pollution is a major global environmental and public health challenge (Liu et al. 2014). Air pollution refers to ‘‘ the contamination of air by unwanted gases, smoke, particles and other substances’’(Azizi, 2011). The World Health Organization also defines air pollution as ‘‘the contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere’’ (WHO 2016a). Common sources of air pollution include: household combustion devices, motor vehicles, industrial facilities and forest fires. From these sources several air pollutants are emitted which may include particulate matter, carbon monoxide, ozone, nitrogen dioxide and sulphur dioxide. The levels of air pollutants from motor vehicles have been known to be higher inside vehicles than in ambient air (Kadiyala & Kumar, 2013).

Air pollutants of major public health concern poses a global health challenge (Liu et al., 2014). This is because pollution can cause respiratory and other diseases, which has fatal consequences. The present study focuses on the association between in-vehicular air pollution and respiratory symptoms among commercial “trotro” drivers and passengers.

2.2. Air Pollutants

There are several air pollutants and they include particulate matter, carbon monoxide, ozone, nitrogen dioxide and sulphur dioxide. The present study concentrates on particulate matter and carbon monoxide emitted inside commercial vehicles.

2.2.1 Particulate matter (PM)

Rasmussen and Knudsen (2012) define Particulate Matter (PM) as ''fine particles and soot which are tiny subdivisions of solid matter suspended in a gas or liquid''. These fine particles have the capacity to be media for the spread of diseases. The World Health Organisation further explains that Particulate matter (PM) ''affects more people than any other pollutant'' (WHO, 2016a). PM may have primary or secondary sources. This implies that they could be emitted into the atmosphere directly from a source or be formed through the chemical reaction of some precursor gases (Akimoto, Keating, & Dentener, 2010).

The main components of PM include sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water. It is made up of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air. Particles that have a diameter of 10 microns or less (e.g. $PM_{2.5}$, PM_{10}) have the most health damaging effect. This is because they can penetrate and lodge deep inside the lungs. Chronic exposure to particles poses a risk to developing lung cancer, cardiovascular and respiratory diseases (WHO, 2016a). Long-term exposure to particulate matter air pollution has been associated with increased cardiopulmonary mortality in the USA (Hoek et al., 2002).

Measurements of air quality are typically reported in terms of daily or annual mean concentrations of PM particles per cubic meter of air volume (m^3). Sensitive measurement tools are often required to report concentrations of fine particles ($PM_{2.5}$ or smaller) (WHO, 2016a). In a study undertaken in Hong Kong by Cheng et al. (2015), PM levels were measured 24-hourly every sixth day for a year to determine the annual mean. The annual average of $PM_{2.5}$ was recorded as 55+/-25 µg/m^3. In that study, emissions from vehicles were known to account for 30% of all PM_{10} levels thus emphasizing the fact that on-road vehicles contribute greatly to air pollution. The study also confirmed previous knowledge from Sweden and Switzerland that PM has different source and chemical composition even in the same traffic-environment (Ferm & Sjoberg, 2015; McAlister et al, 2010). A similar study to assess the variation of PM was done in Accra and measurements were done 24-hourly for a three week period (Arku et al., 2008).

Whiles $PM_{2.5}$ is predominantly originating from combustion sources like engines and biomass burning, PM_{10} is mainly from re-suspended road dust and mechanical processes such as tire and brake emissions of vehicles. Another study recorded that studded tires give rise to high levels of particulate matter when they run on dry roads. Thus giving indication that PM levels are low when roads are wet but rise when roads are dry and thereby suggesting the influence of the weather on emissions (Ferm & Sjoberg, 2015).

The WHO (2016a) states that ‘‘Small particulate pollution have health impacts even at very low concentrations’’ and that there has been no threshold identified below which no damage to health is observed. ‘‘There is a close, quantitative relationship between exposure to high concentrations of small particulates (PM_{10} and $PM_{2.5}$) and increased mortality or morbidity, both daily and over time''(WHO, 2016a). Therefore when concentrations of small and fine particulates are reduced, related mortality will also go down presuming other factors remain the same. Cardiovascular and chronic obstructive pulmonary diseases have been stated as some other health effects (Ferm & Sjoberg, 2015). Thus there could arise as a health effect to exposure of PM, both respiratory and non-respiratory diseases.

Recognizing the harmful effects of particulate matter on health, the WHO (2016a) has air quality guideline values that aim at specific levels of concentration of PM_{10} and $PM_{2.5}$ in order to have lower concentrations. The guideline values for fine particulate matter from the World Health Organization are: 10μg/m^3 annual mean; 25 μg/m^3 24-hour mean for $PM_{2.5}$ and 20 μg/m^3 annual mean, 50 μg/m^3 24-hour mean for PM_{10}.

2.2.2 Carbon monoxide (CO)

Carbon monoxide (CO) is a colourless, odourless and highly toxic gas (Corcoran & DiLoreto, 2012). Exposure to CO, a few hundred parts per meter (pm), can lead to permanent health damage or death. Therefore, CO could be considered as one of the most hazardous environmental pollutants and its removal and detection is of extreme importance for safe living. Studies have observed the harmful health effects of CO to include cardiac effects following intoxication. It has a high affinity to haemoglobin and therefore impairs oxygen transport resulting in hypoxia. Its intoxication is one of the main causes of mortality in the world. This is because its tastelessness, colourlessness, and odourlessness without irritating properties, lead to unawareness of excessive inhalation of potentially lethal amounts for victims (Corcoran & DiLoreto, 2012).

CO constitutes one of the highest traffic emissions. Several studies have recorded high level of CO emissions at traffic sites and even higher inside vehicles (Kadiyala & Kumar, 2013; Houston et al., 2014). A study in Nigeria to undertake air pollution emission inventory recorded 80-90% of CO levels among the air pollutants (Effiong, 2016). In another study on air pollution in Accra, it was noticed that CO measurements were higher at motor traffic sites than at residential sites (Dionisio et al., 2010). This confirms that excessive emission of CO is actually released by motor vehicles on roads. Perez et al. (2010) say that the public health impact of this is enormous not only for drivers and commuters but also people residing on busy roads. They have a higher exposure to pollution resulting from motor traffics than people living some 100 meters away. (Perez et al., 2010)

In considering motor vehicles and emissions, it is known that societies have advanced, and so with modernity, many have activity patterns that make them mobile (Luke, 2011). These include vehicles and other forms of transportation. In a study to assess commuter exposure to ultrafine particles in vehicles, Luke (2011) says ‘‘time spent in-transit’’ makes up between 5 and 10% of the day depending on location. This makes the use of alternate means of transportation a necessity. With increasing population and urbanization particularly in sub-Saharan Africa, urban areas see numerous forms of means of transportation notably public transport (Arku et al., 2008) . Transportation has thus become the chief source of outdoor air pollution in developing countries (Azizi, 2011).

For a vehicle to have high levels of exposure to CO, emissions from its exhaust, as well as from its cabin compounded by infiltration of other particulate matter play significant roles (Hsu, & Huang, 2009). Moreover, the speed of a vehicle and the distance travelled has an impact on the exposure that a driver has from CO and PM emissions. If the vehicle travels in a heavy traffic jammed environment, the exposure is higher because it stays longer on the road (Huang & Hsu, 2009; Tramuto et al., 2011; Hoek et al., 2002)

A number of health risks already stated come about with different levels of exposure. In a study undertaken to assess effect of fresh and aged vehicular particulate emission, it came out that exposure to traffic aerosols increase both the systolic and diastolic blood pressure (Lamoureux et al., 2013).

In urban traffic environments, the concentrations of CO measured inside motor vehicles are higher than those measured in ambient air (Nielsen et al., 2011). The carbon monoxide levels are highest in personal cars, the mean concentrations being 2–5 times the levels measured in streets or inside subway trains. Traffic patterns, car model and maintenance, vehicle ventilation conditions and season are factors that affect the carbon monoxide levels inside the cars. The recommended WHO guidelines for CO are: 100 mg/m^3 (87 ppm) for 15 minutes • 60 mg/m^3 (52 ppm) for 30 minutes • 30 mg/m^3 (26 ppm) for 1 hour and 10 mg/m^3 (9 ppm) for 8 hours(WHO, 2004).

Other studies report several other respiratory, cardiovascular, cerebrovascular and neurobehavioral diseases as well as death to exposure to CO (Kheirbek, Haney, Douglas, Ito, & Matte, 2016);WHO, 2004). Therefore, the health impact of exposure to in-vehicle CO levels cannot be overemphasized. Sub-Saharan Africa has been known to have increasing levels of vehicular air pollution as a result of the increasing population associated with increasing urbanization. In addition to the aforementioned, there is an increase in number of motor vehicles on the streets due to the multiplicity of human activity and lack of adequate means of alternate forms of transportation (Arku et al., 2008).

Furthermore, model of cars, type of fuels, road infrastructure whether dusty or not, vehicle age and level of maintenance have been known to contribute significantly to pollutant levels in vehicles (Gorham, 2002; Nielsen et al., 2011). This leads to the debatable issue of the influence of socio-economic factors. Whiles some studies attribute high levels of pollution to low-income countries others say otherwise. Thus suggesting that socio-economic levels may either play a positive contributive role or a negative contributive role to excessive emissions (Houston et al., 2014).

2.3. Empirical Studies on Vehicle Air Pollution and Respiratory health symptoms

Ekpenyong et al. (2012) examined the urban city transportation mode and respiratory health effect of air pollution. The study was a cross-sectional study among transit and non-transit workers in South-South Nigeria. 168 respondents participated in the study and comprised of 50 taxi drivers, 60 motorcyclists and 58 civil servants who had worked within Uyo metropolis for at least a year before the study, and had no history of respiratory disorders or any other debilitating disease. The adjusted ORs for respiratory function impairment using Global Initiative for Chronic Obstructive Lung Diseases (GOLD) and National Institute for Health and Clinical Excellence (NICE) criteria were calculated. In order to assess specific occupation-dependent respiratory function impairment, a comparison was done between the ORs for respiratory impairment in the three occupations. Adjustments were made for some demographic variables such as age, (body mass index) BMI and area of residence. Results revealed that exposure to ambient air pollution by occupation and transportation mode was independently associated with respiratory functions impairment and incident respiratory symptoms among study participants. Motorcyclists had the highest effect, with adjusted OR 3.10, 95% CI 0.402 to 16.207 for FVC<80% predicted and OR 1.71, 95% CI 0.61 to 4.76 for FEV1/FVC<70% predicted using GOLD and NICE criteria. Moreover, uneducated, currently smoking transit workers who had worked for more than 1 year, with three trips per day and more than 1 hour transit time per trip were significantly associated with higher odds for respiratory function impairment at $p<0.001$, respectively. The findings of this study give weight to existing literature on the adverse respiratory health effect of ambient air pollution on city transit workers globally.

Pindus et al. (2016) investigated the association between health symptoms and particulate matter from traffic and residential heating. Data on respiratory and cardiac diseases were collected within the framework of RHINE III (2011/2012) in Tartu, Estonia. Respondents' geocoded home addresses were mapped in ArcGIS and linked with local heating-related $PM_{2.5}$, traffic-related PM_{10} and total $PM_{2.5}$ concentrations. The association between self-reported health symptoms and PM was assessed using multiple logistic regression analysis. Results showed that there is a relationship between traffic induced PM_{10} as well as all sources induced $PM_{2.5}$ with cardiac disease, OR=1.45 (95%CI 1.06−1.93) and 1.42 (95% CI 1.02−1.95), respectively. However, they did not find any significant association between residential heating induced particles and self-reported health symptoms. People with longer exposure period were also significantly associated with traffic induced PM_{10}, all sources induced $PM_{2.5}$ and cardiac diseases. Pindus et al. (2016) concluded that traffic-related PM_{10} and all sources induced $PM_{2.5}$ is associated with cardiac disease, whereas residential heating induced particles do not.

A cross-sectional study in Nicosiain in Cyprus, was conducted by Middleton et al. (2010) on residential exposure to motor vehicle emissions and the risk of wheezing among 7-8 year-old schoolchildren. About 1,735 children participated in the original survey. The level of exposure of each child was assessed using distance and emission-based indicators (i.e. estimated levels of particulate matter and nitrogen oxides emissions due to motor vehicles on main roads around the residence). Also, the odds ratios of wheezing and asthma diagnosis in relation to levels of exposure were estimated by using logistic regression models, of which person-based factors, co-morbidity and intra-school clustering were adjusted for. Findings showed increased risk of wheezing at distances less than 50 meters from a main road and/or only among those experiencing the highest levels of exposure. Findings implied that children who experience highest exposure to traffic emissions in Nicosia seem to be at a higher risk of reporting asthmatic symptoms or respiratory disease. The present study also assesses the level of exposure to vehicular air pollution and respiratory symptoms (such as wheezing) using logistic regression. However, it would rather measure in-vehicular emission level, and adults (drivers and passengers) would be the respondents of the present study instead of children.

Baccarelli et al. (2014) evaluated the effects of traffic-related $PM_{2.5}$ and its elemental components on lung function in two highly exposed groups of healthy adults in Beijing, China. The two groups they evaluated included 60 truck drivers and 60 office workers in the year 2008. Authors used covariate-adjusted mixed-effects models including $PM_{2.5}$ as a covariate to estimate the percentage change in lung function associated with an inter-quartile range (IQR) exposure increase. Analysis of $PM_{2.5}$ and nine elemental components [such as silicon (Si), aluminium (Al), calcium (Ca), and titanium (Ti)] of $PM_{2.5}$ during eight hours of work showed associations with lung function only among truck drivers, and no significant association among office workers.

Effiong (2016) investigated the likely impact of high traffic volume along a major roadway (the Ojoo-Mokola road) within the Ibadan metropolis on atmospheric air quality. Of the eight sampled roadway, the traffic density and air quality were monitored. Data was collected monthly over a period of four months in the morning peak, off peak and evening peak hours. CO, nitrogen dioxide (NO_2), sulphur dioxide (SO_2), hydrogen sulphide (H_2S) and ammonia (NH_3) were the air quality parameters, measured using handheld Crowcon Triple Plus+ and Crowcon Tetra-Portable Multi-Gas Detectors. The average concentration of CO range between 3.25 and 50.8 ppm with highest concentration observed during the morning and evening peak hours. Results showed strong correlation ($p=0.05$) between ambient CO levels and traffic density. Relatively low levels of H_2S, and NH_3 were detected while NO_2 levels were relatively constant (<0.1 ppm). Sulphur dioxide was generally not detected within the study locations. Findings suggest the need for constant monitoring of vehicular emissions to forestall possible air pollution.

Reviewed literature (e.g. Ekpenyong et al., 2012; Pindus et al. 2016, Baccarelli et al. (2014)) found that long exposure to vehicular induced pollutants are associated with higher levels of respiratory disease or function impairment .

Kadiyala and Kumar (2013) quantified the monitored indoor (or in-vehicular) contaminants of carbon dioxide (CO_2) and carbon monoxide (CO) under varying climatic conditions using advanced statistical methods of regression trees and analysis of variance (ANOVA). The determinant variables affecting in-vehicular CO_2 and CO were first identified by using regression trees after considering meteorology, monitoring periods, indoor sources, on-road vehicles, and ventilation. Analysis of Variance was then used to determine the statistical significance of the identified independent variables and to prioritize the statistically significant variables based on the F value. Passenger ridership and month were observed to have a predominant influence on in-vehicular CO_2, while month and sky conditions significantly influenced CO levels. High passenger ridership on a warm/hot day with good ventilation resulted in high CO_2 build-up inside the vehicle. High levels of CO were observed inside the vehicle during fall, spring, and summer months on overcast days, with low to medium indoor temperatures, moderate to good ventilating conditions, low indoor relative humidity, and low wind speeds. The present study would measure CO and author would gather the data in the month of May to July, which is within the rainy season. Thus, it would give appropriate measure for in-vehicle CO.

The aim of the study by Mohd and Juliana (2014) was to determine the exposure of in-vehicular air pollutants (PM_{10}, CO_2 and CO) and respiratory health problem among long distance express bus drivers in Malaysia. All parameters were measured along the routes where the average duration was four hours. Using purposive sampling, respondents selected were between 20 to 56 years old, with at least one year working experience, no history of chronic lung diseases, and non-smokers. Questionnaire adapted from American

Thoracic Society (ATS) was used to collect information on respondents' socio-economic status, working history, and respiratory symptoms. Moreover, monitors were used to measure PM_{10}, CO_2 and CO emissions in the vehicles and lung function tests were performed after the participants arrived at their destinations. Data collected showed that the mean concentration of PM_{10} (220.00±120.00µg/m3), CO_2 (1085.50±460.98ppm), and CO (2.79±0.95ppm) were still below the permissible level according to indoor air guidelines by WHO. Chronic respiratory symptoms, which were reported among drivers, were phlegm (23.3%), cough (20.0%), wheezing (13.3%) and chest tightness (10.0%). Lung function result showed that there were 50% respondents who had abnormality of FVC% value and FEV1% value. The conclusion deduced from the study was that continuous exposure to air pollutants over a long period while driving has potentially causing ill effects to drivers' respiratory health. Exposure to PM_{10} in air-conditioned buses such as long distance express buses can increase the risk of respiratory illness and the reduction of lung function among bus drivers. Although the study was on drivers, Mohd and Juliana (2014) found that the number of passengers on the bus also influenced the concentrations of elevated CO_2 inside buses. The present study builds on the study by Mohd and Juliana (2014) by investigating the exposure levels (both personal and vehicular levels) associated with commercial drivers and passengers respiratory health symptoms. It can be postulated that passengers' level of exposure to in-vehicular air pollutants may differ significantly from drivers.

Based on the reviewed studies the following were proposed as the research hypotheses;

H_0: There is no significant difference in the median concentration of personal levels of CO among drivers and passengers.

H_1: There is significant difference in the median concentration of personal levels of CO among drivers and passengers.

2.4 Summary of Literature Review

In concluding this section, several of studies have revealed similar results indicating that motor vehicular emissions from within and without contribute significantly to air pollution. Moreover, levels of exposure differ among drivers, workers and passengers or commuters who travel long distances as compared to those that travel short journeys (Hsu& Huang, 2009; Tramuto et al., 2011; Hoek et al., 2002; Kadiyala & Kumar (2013). In addition, exposures to air pollutants such as PM and CO emissions are higher when motor vehicles stay longer in heavy traffic jam. Studies in which concentrations of CO was measured, revealed that the concentrations were higher inside motor vehicles than those measured in ambient air (Nielsen et al., 2011).

Finally, all of the factors that contribute to excessive exposure of motor vehicle use to pollutants results in different levels of health risks. The health risks include respiratory as well as cardiovascular and neurological health risks. These lead to increase in morbidity and mortality due to the harmful effects of the most common air pollutants present in vehicles such as PM and CO (Ferm & Sjoberg, 2015; Kheirbek et al., 2016).

CHAPTER 3

METHODOLOGY

3.1 Study Design

This cross sectional study was conducted from May to July, 2017 in commercial 'trotro' vehicles, that travel from Madina lorry station to selected destinations in Accra and the Central Region (Kasoa).

3.1.1 Study Setting

Madina is largely (84%) an urban area of a population of about 94000 with a sex ratio of 94.1 (Ghana Statistical Service, 2014). It is under the jurisdiction of La Nkwantanang-Madina Municipality of the Greater Accra Region. Economic activities are mainly commerce and manufacturing with its central point being the Madina market. The municipality is linked by road to other parts of Accra. Commercial transportation by vehicles and taxis provide employment for drivers. There are several business associations such as market women's associations, drivers associations, farmer groups and dressmakers. The extensive commerce that goes on at the market is what gives much prominence to the Madina lorry station.

The lorry station is a busy noisy environment populated with numerous vehicles packed at various departure points awaiting commuters. Most common buses include the mini-urvan buses that have a 15-passenger capacity, the 207 Benz buses and the Benz sprinter that have a 23-passenger capacity. There are over a thousand drivers travelling different routes in and outside the municipality and the Greater Accra Region. The lorry space is an untarred one that gets dusty in the dry season and muddy during the rainy seasons.

Other trading activities also go on and so there are several other people present trading their wares. This is where transportation of goods and services take place. Drivers who use the routes from Madina to Kasoa, Dansoman and Accra are approximately one hundred, according to information from the Madina-Adenta Drivers Welfare Office.

3.2 The Commercial driver in Madina

Motorized transport in Ghana is dominated by commercial transport. Commercial drivers in Madina and other lorry stations in Greater Accra Region operate from lorry stations to different short and long distance destinations with the aid of a conductor popularly known as 'driver's mate' in Ghana. The 'driver's mate' does the travelling fare collection whiles the vehicle is running on the routes. Drivers work from morning to evening by doing return journeys between the stations of departure and arrival. Madina drivers work for a minimum of 14 hours a day beginning from 4:30am and closing after 8:00pm in the evening (Source: Personal communication members of the Driver's Union at Madina). Vehicles at lorry stations that travel the same routes move in turns and are normally filled with passengers who alight at different points on the road. When this occurs, other waiting passengers are also picked to fill in vacant seats in the vehicles.

3.3 Study Population

The study population included all 100 registered 'trotro' drivers operating from Madina lorry station to Dansoman, Accra and Kasoa as well as passengers on board the vehicle at the time of the data collection. The three roadway or routes were selected because (i) they represent typical urban commuting routes in the La Nkwantanang-Madina Municipality; (ii) the traffic density on the roads are the highest in the La Nkwantanang-Madina Municipality ; and (iii) of convenience to the researcher.

3.4 Study Variables

3.4.1 Independent variables

The independent variables included (i) vehicular levels of CO, and $PM_{2.5}$: at driver and passenger compartments; and personal CO levels of driver and passenger.

3.4.2 Dependent variables

The outcome variables of interest were self-reported respiratory symptoms. Respiratory symptoms were defined as cough, wheezing, phlegm production and breathlessness.

3.4.3 Covariates

The covariates were formal educational levels of drivers, income level, type of fuel used, duration of daily vehicle use, vehicle age and frequency of maintenance (Gorham, 2002).

3.5 Data Collection Procedure

The field work was done in three phases: (1) Stakeholder meeting (2) Selection and enrolment of study participants (3) Data collection and CO monitoring.

3.5.1 Phase 1: Stakeholder meeting

Meeting was held with leaders and drivers of the Madina Drivers' Union to explain the objectives of the study and the benefits of the study, so as to seek their consent and participation.

3.5.2 Phase 2: Selection and enrolment of study participants

Selection and enrolment of study participants started on the 18th of May, 2017. First, the station masters at various lorry stations introduced the Principal Investigator (PI) to drivers, after which the purpose of the study was explained to the drivers. Of the 100 drivers, 11 declined to take part in the study. With respect to the passengers, the researcher took his seat on the third row (i.e. the middle seat) in the passenger compartment which represents the centre of the passenger compartment. A passenger who sat next to the researcher and agreed to be part of the study was recruited. If none of the passengers on the row agreed to participate, a passenger in the next row was selected. In the end, 89 drivers and 89 passengers were studied.

3.5.3 Phase 3: Data collection

The data collection tools included a self-administered questionnaire and monitors for measuring levels of air pollutant exposure. Both equipment are standardized tools which have been factory calibrated and have been used in related studies in Ghana, specifically in Kintampo in the Brong Ahafo Region (Quinn et al., 2016;Vliet et al., 2013).

Monitoring in vehicles begun as passengers got on board a vehicle at the station. A SidePak Personal Aerosol monitor was mounted at the driver compartment of the vehicle and another at the passenger compartment in the third row. Time of mounting monitors was immediately recorded and monitoring of vehicular levels of CO and PM were started. Detailed description of human activities at the station was done. Whiles still at the station, questionnaire was administered to the driver as his 'mate' kept getting passengers on board. Once the vehicle was full, the data logger of the LASCAR CO (MicroDAQ, Contoocook, NH, USA) personal CO monitor was started on a personal computer and fixed on the driver's shirt before he set off. The researcher took his seat on the third row of the passenger compartment which is representative of the central part of the vehicle and the second personal CO monitor was fixed unto the dress of the passenger selected after its data logger had also been started. Of significant mention in the 'trotro' bus was the ventilation setting at the different compartments. While the driver compartment always had the windows down, the passenger compartment had windows either slightly down or closed based on passengers' convenience.

Time of departure from lorry station was recorded and a detailed description of human and traffic activities were noted based on the researcher's observations. These activities included human trading activities along the roads, light and heavy vehicles in adjacent or corresponding positions to the commercial 'trotro' bus.

The routes selected were standard dual direction asphalt urban roads plied by stop-and go traffic that results from the combination of heavy traffic. Traffic was noticeably heavier in the mornings and evenings but was lighter in the afternoons. A questionnaire was administered to the passenger that had the personal CO monitor whiles en route. Time of arrival was noted at destination and the process restarted with another vehicle going back to the Madina station. Measurements were done for an average of one-hour continuous journey duration (Egondi et al., 2016; Amaral et al., 2015).

Data collected on the devices were downloaded to a computer with USB cable. The SidePak Personal Aerosol monitor model AM 510 (TSI, Shoreview, MN, USA) and the LASCAR CO (MicroDAQ, Contoocook, NH, USA) came with air quality report software, therefore data were processed and reports generated after each journey.

The questionnaire served as an interview guide and was used to obtain data on socio-demography such as age, level of education, average income and place of residence. Further questions which were answered by only drivers included years of working experience, type of fuel use, daily duration of driving, and frequency of maintenance.

Respiratory symptoms experienced by respondents due to exposure to in-vehicle air pollutants were also obtained using the same questionnaires. Data were collected from Monday to Saturday during both the peak and off-peak hours of the day. The peak hours were from 7:00am to 9:30am and then from 3:00pm to 7:30pm; whereas the off-peak hours were the periods between 10:00am and 3:00pm; as well as after 7:30pm.

3.6 Data Processing and Analysis

Data entry was done using Microsoft Excel 10 and transferred into Stata 14 for analysis. Analysis included both descriptive and explanatory (inferential) statistical analysis. The descriptive statistics calculated the median and other levels of variations (dispersion) for continuous variables and proportions for categorical variables. Analysis provided information about the socio-demographic information as well as air pollutant exposure levels (both personal and vehicular) among commercial drivers in Madina and their passengers. The key factors that influence the prevalence of respiratory symptoms among both drivers and passengers were also examined.

Logistic model was used in the inferential statistics to determine associations and the level of significance between the independent and dependent variable (outcome). A non-parametric (Mann-Whitney) test was also used to determine significant difference in median concentration levels of personal carbon monoxide among drivers and passengers. Conclusions were drawn based on the strength and the direction of the association between the independent and the dependent variables.

3.7 Quality Control

Extreme care was employed during monitoring personal and vehicular air pollutant levels. Daily recordings of data were done to avoid oversight. In addition, daily evaluation of previous day's activities was done so that challenges could be addressed.

3.8 Ethical approval

Ethical approval was obtained from the Ghana Health Service Ethical Review Board before the study started. Approval was obtained from the leaders of the Madina Drivers' Union and informed consent was also received from each respondent before data were collected.

3.9 Record Storage and Protection

Research records and data were protected against inappropriate use or disclosure, accidental loss or destruction in order to protect the confidentiality of subject data. However, missing values were mainly as a result of hard disk and battery problems on the monitor used for the passenger compartment. This reduced the total data of 89 to 63.

Data would be appropriately and safely disposed off, by shredding paper documents and secure erasure of electronic media.

CHAPTER FOUR

RESULTS

4.1 Socio-demographic characteristics of study participants

A total of 178 participants including 89 drivers and 89 passengers were considered for this study. Table 4.1 presents socio-demographic characteristics of study participants, vehicle information and information on reported respiratory health diseases. More than half (59.6%) of the drivers were between 31 and 40 years whiles most of the passengers (55.1%) were between 18 and 30 years. 64.0% of the drivers had attained secondary (SHS) education. On the other hand, 44.9% of the passengers had attained at most tertiary education. 43.8% of the drivers had income level between GH₵200.00 and GH₵400.00 as compared to 39.3% of the passengers whose income level were greater than GH₵400.00 on average. Approximately, 60.7% of the drivers had more than 10 years of driving experience. Most of the vehicles (84.3%) were Sprinter Benz buses and 95.1% of the drivers had vehicles whose model was before the year 2006; whereas three-quarters of them (75.6%) were using 310 engine capacity types. 84.3% confirmed that they service their vehicles monthly. Most of the drivers (93.3%) work for more than 5 hours daily and majority of them (80.9%) had used their respective vehicles for at most 2 years. In addition, 96.6% of the drivers use diesel as a fuel.

Moreover, asthma and pneumonia were relatively more predominant among passengers. 78.6% of pneumonia cases reported by passengers were actually confirmed by a doctor. On the other hand, approximately 77.8% of asthma cases reported by passengers were confirmed by a doctor.

Table 4.1 Demographic characteristics of study population, vehicle information and information on reported respiratory health diseases

Characteristics	Drivers, *n* (%)	Passengers, *n* (%)
Age of participants		
18-30yrs	17(19.1)	49(55.1)
31-40yrs	53(59.6)	25(28.1)
>40yrs	19(21.3)	15(16.8)
Educational level		
Basic	25(28.1)	2(2.2)
Secondary	57(64.0)	17(19.1)
Tertiary	3(3.4)	21(23.6)
Others	4(4.5)	49(55.1)
Income level		
<₵200	26(29.2)	33(37.1)
₵200-₵400	39(43.8)	21(23.6)
>₵400	24(27.0)	35(39.3)
Vehicle Information		
Brand of vehicle		
Sprinter	75(84.3)	
207 Benz	13(11.2)	
Urvan bus	1(4.5)	
Year model of vehicle		
Before 2006	85(95.1)	
2006	3(3.4)	
2012	1(1.1)	
Engine type		
210	10(12.2)	
212	3(3.7)	
308	3(3.7)	
310	62(75.6)	
312	4(4.9)	
Driving hours a day		
2hours	1(1.1)	
3hours	2(2.2)	
4hours	1(1.1)	
5hours	2(2.2)	
>5hours	83(93.3)	
Fuel use		
Diesel	86(96.6)	
Petrol	3(3.4)	

Table 4.1 continued:

Characteristics	Drivers, *n* (%)	Passengers, *n* (%)
Frequency of servicing car		
Monthly	75(84.3)	
Bi-monthly	12(13.5)	
Quarterly	2(2.2)	
Reported Respiratory Diseases		
Self-reported disease		
Pneumonia		3(21.4)
Asthma	6(6.7)	2(22.2)
Doctor diagnosed disease		
Pneumonia	6(6.7)	11(78.6)
Asthma		7(77.8)

4.2 Personal carbon monoxide and vehicular carbon monoxide /Particulate Matter levels

Table 4.2 shows personal CO and vehicular CO and $PM_{2.5}$ levels. The median personal CO among the drivers was 6.7 ppm (range: 3-88.5); whereas, the median personal CO concentration among passengers was 10.2ppm (range: 3.5-178.5).

The table also shows that the median concentration of vehicular levels of CO was estimated at 10.5 ppm (range: 7.5-12.2) and 21ppm (range: 19.9-22.5) at both the driver's and passenger's compartments respectively; whiles the median concentration of vehicular levels of $PM_{2.5}$ was found to be 43 ppm (range: 16.5-71.1) and 46.7ppm (range: 22-108.5) at both sides respectively.

It was found that there was significant correlation (p=0.356) between vehicular concentration of CO at the driver's compartment and that of the passenger's compartment. Moreover, two-sample Wilcoxon rank-sum (Mann-Whitney) for non-parametric test observed a significant difference in the median concentration of personal CO level among drivers and passengers. Hence, it can be inferred further that the concentration of personal level of CO among passengers is significantly greater than that of the drivers.

Table 4.2 Personal CO levels and vehicular air pollutant concentrations ($CO/PM_{2.5}$)

Categories	Mean	SD	Geometric Mean	Min	Q_1	Median	Q_3	Max
Personal level of exposure CO(ppm)								
Driver	9.2	11.1	7	3	4.5	6.7	9.0	88.5
Passenger	21.8	30.3	13.3	3.5	7.5	10.2	22.0	178.5
Vehicular level of CO(ppm) and ($PM_{2.5}$) (μ / m^3)								
Driver's compartment (CO)	9.7	4.2	8.1	0.8	7.5	10.5	12.2	21.0
Passenger's compartment (CO)	21.1	30.3	20.5	3.5	19.9	21.0	22.5	178.5
Driver's compartment ($PM_{2.5}$)	77.9	110.3	42.4	8.3	16.5	43.0	71.1	524.0
Passenger's compartment($PM_{2.5}$)	97.4	128.7	52.2	5.5	22.0	46.7	108.5	577.2

SD: Standard deviation Q_1: Lower quartile Q_3: Upper quartile

4.3 Prevalence of respiratory symptoms among commercial drivers and passengers

The predominant self-reported respiratory symptoms among drivers were found to be cough (35.9%) and phlegm production (34.8%). Also, phlegm production (44.9%) was the leading respiratory symptom among passengers followed by coughing problem (28.1%).

Figure 3 and Figure 4 show the distribution of respiratory symptoms by age for both drivers and passengers.

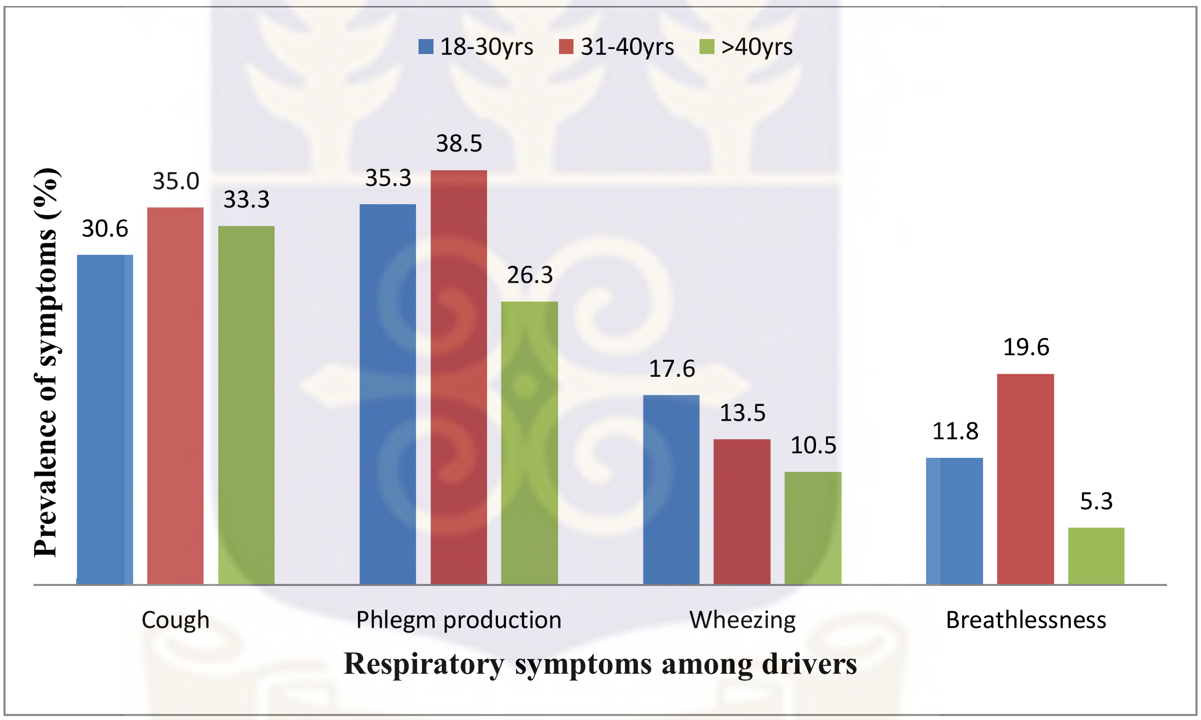

Figure2: Distribution of respiratory symptoms among drivers by age

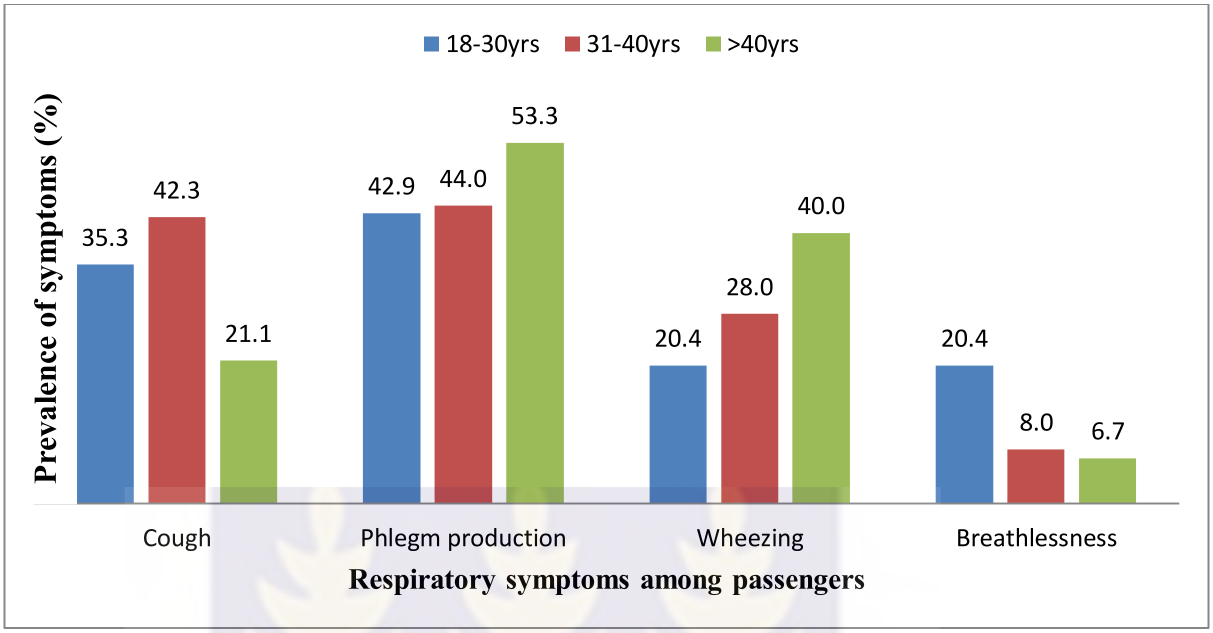

Figure3: Distribution of respiratory symptoms among passengers by age

Table 4.3 Prevalence of respiratory symptoms (n=178)

Symptoms	**Drivers, *n*(%)**	**Passengers, *n*(%)**
Self-reported respiratory symptoms		
Coughing problem	32(35.9)	25(28.1)
Phlegm production	31(34.8)	40(44.9)
Wheezing problem	12(13.5)	23(25.8)
Breathlessness	14(15.7)	13(14.6)

4.4 Association between personal CO level and respiratory symptoms

Table 4.4 presents the results of the logistic regression indicating the association between personal CO level and respiratory symptoms. The personal CO concentrations for both drivers and passengers were dichotomized respectively using median split. Personal CO concentration of drivers above 7 ppm was considered as high exposure; whereas personal CO concentration of passengers above 10ppm was considered high exposure. Both continuous and categorized personal CO concentration levels were used in determining the association between personal exposure level of CO and respiratory health symptoms using a logistic regression model. It was found that the personal CO concentration levels had no significant effect on the respiratory symptoms of both drivers and passengers respectively.

It was discovered from the logistic analysis that in the presence of all other factors that could contribute to coughing among drivers, personal CO exposure (AOR=1.11, 95% CI=1.00-1.24) will increase the prevalence of coughing by 1.11 times. In other words, the odds of coughing among drivers increased by 11% upon exposure to CO when all other contributory factors were present.

Table 4.4 Association between personal CO concentration and respiratory symptoms for both drivers and passengers (n=178)

Exposure variables	Cough		Phlegm Production	
	Crude OR(95% CI)	Adjusted OR(95% CI)	Crude OR(95% CI)	Adjusted OR(95% CI)
Drivers				
CO (continuous)	1.02(0.98-1.06)	1.11(1.00-1.24)	0.98(0.92-1.03)	1.01(0.96-1.06)
CO (category)				
Low(≤7ppm)	1.00	1.00	1.00	1.00
High(>7ppm)	1.43(0.60-3.44)	3.01(0.95-9.49)	0.70(0.29-1.71)	1.16(0.37-3.67)
Passengers				
CO (continuous)	0.99(0.97-1.01)	0.99(0.97-1.01)	0.99(0.97-1.01)	0.99(0.97-1.01)
CO (category)				
Low(≤10ppm)	1.00	1.00	1.00	1.00
High(>10ppm)	0.84(0.33-2.12)	0.82(0.31-2.13)	1.11(0.48-2.56)	1.02(0.42-2.52)

Table 4.4 continued:

Exposure variables	Breathlessness		Wheezing problem	
	Crude OR(95% CI)	Adjusted OR(95% CI)	Crude OR(95% CI)	Adjusted OR(95% CI)
Drivers				
CO (continuous)	1.14(0.93-1.40)	1.14(0.93-1.40)	0.98(0.90-1.07)	1.00(0.92-1.08)
CO (category) Low(≤7ppm)	1.00	1.00	1.00	1.00
High(>7ppm)	1.85(0.58-5.87)	2.86(0.51-15.95)	1.30(0.39-4.41)	1.99(0.38-10.24)
Passengers				
CO (continuous)	0.96(0.91-1.02)	0.96(0.91-1.02)	1.00(0.99-1.02)	1.00(0.98-1.01)
CO (category) Low(≤10ppm)	1.00	1.00	1.00	1.00
High(>10ppm)	0.55(0.16-1.83)	0.43(0.12-1.62)	0.84(0.32-2.17)	0.68(0.24-1.95)

4.5 Association between vehicular CO and $PM_{2.5}$ concentration and respiratory symptoms

Tables 4.5 and 4.6 present results of the logistic regression indicating the association between vehicular CO and $PM_{2.5}$ concentration and respiratory symptoms.

The vehicular CO and $PM_{2.5}$ concentration were both categorized using median splits respectively for both driver's and passenger's compartments. Vehicular CO concentration above 10ppm and 21ppm respectively at both driver's and passenger's compartment was considered high. On the other hand, vehicular $PM_{2.5}$ concentration above $43\mu/m^3$ and $47\mu/m^3$ respectively at both driver's and passenger's compartment was considered high.

It was revealed that vehicular CO concentration was not associated with respiratory symptoms among the drivers. Among the passengers an increase in vehicular CO level by 1 ppm resulted in about 22% increase in the risk of breathlessness. However, vehicular CO treated as a categorical variable was not associated with respiratory symptoms among the passengers. No significant association was found between vehicular $PM_{2.5}$ concentration and any respiratory symptom among drivers and passengers.

Table 4.5 Association between vehicular CO concentration and respiratory symptoms for both driver's and passenger's compartments (n=178)

Exposure variables	**Cough**		**Phlegm Production**	
Driver's compartment	**Crude OR (95% CI)**	**Adjusted OR(95% CI)**	**Crude OR (95% CI)**	**Adjusted OR(95% CI)**
CO ppm (continuous)	0.91(0.82-1.02)	0.88 (0.86-1.06)	0.96(0.86-1.06)	0.92 (0.82-1.03)
CO (category) Low(≤10ppm)	1.00	1.00	1.00	1.00
High(>10ppm)	0.24(0.08-0.72)	0.19 (0.05-0.63)	0.78(0.27-2.21)	0.51 (0.14-1.84)
Passenger's compartments				
CO ppm (continuous)	0.93(0.81-1.05)	0.91(0.76-1.04)	0.92(0.82-1.04)	0.94 (0.82-1.07)
CO (category) Low(≤21ppm)	1.00	1.00	1.00	1.00
High(>21ppm)	0.40(0.13-1.25)	0.38 (0.12-1.23)	0.71(0.26-1.95)	0.83 (0.28-2.39)

Table 4.5 continued:

Exposure variables	Breathlessness		Wheezing problem	
	Crude OR(95% CI)	**Adjusted OR(95% CI)**	**Crude OR (95% CI)**	**Adjusted OR(95% CI)**
Driver's compartment				
CO ppm (continuous)	0.89(0.78-1.02)	0.78(0.61-1.01)	0.95(0.82-1.09)	0.95(0.81-1.10)
CO (category) Low(≤10ppm)	1.00	1.00	1.00	1.00
High(>10ppm)	0.08(0.02-0.43)	0.07 (0.01-0.42)	0.40(0.10-1.67)	0.38 (0.07-2.08)
Passenger's compartment				
CO ppm (continuous)	1.09 (0.93-1.28)	1.22 (0.99-1.49)	0.93 (0.81-1.06)	0.93 (0.81-1.08)
CO (category) Low(≤21ppm)	1.00	1.00	1.00	1.00
High(>21ppm)	2.43(0.65-9.12)	4.36(0.87-21.97)	0.72(0.22-2.38)	0.67(0.19-2.35)

Confounders: socio-demographic characteristics of participants, vehicular information; fuel use, year model, brand of vehicle

Table 4.6 Association between vehicular $PM_{2.5}$ (μ/m^3) concentration and respiratory symptoms (n=178)

Exposure variables	Cough		Phlegm Production	
	Crude OR(95% CI)	**Adjusted OR(95% CI)**	**Crude OR(95% CI)**	**Adjusted OR(95% CI)**
Driver's compartment				
$PM_{2.5}$(μ/m^3) (continuous)	1.00(0.99-1.01)	1.00(0.99-1.01)	1.00(0.99-1.01)	1.00(0.99-1.01)
$PM_{2.5}$ (category) Low(≤43 μ/m^3)	1.00	1.00	1.00	1.00
High(>43 μ/m^3)	1.67(0.60-4.30)	1.83(0.62-5.35)	1.27(0.46-3.51)	2.31(0.69-7.74)
Passenger's compartment **$PM_{2.5}$(μ/m^3) (continuous)**	0.99(0.98-1.00)	0.99(0.98-1.00)	0.99(0.98-1.00)	1.00(0.99-1.01)
$PM_{2.5}$ (category) Low(≤47 μ/m^3)	1.00	1.00	1.00	1.00
High(>47 μ/m^3)	0.56(0.18-1.70)	0.60(0.18-1.98)	1.57(0.57-4.34)	1.75(0.56-5.48)

Table 4.6 continued: Association between vehicular $PM_{2.5}$ (μ/m^3) concentration and respiratory symptoms for both driver's and passenger's compartments

Exposure variables	Breathlessness		Wheezing problem	
	Crude OR (95% CI)	**Adjusted OR (95% CI)**	**Crude OR (95% CI)**	**Adjusted OR(95% CI)**
Driver's compartment **$PM_{2.5}$(μ/m^3) (continuous)**	1.00(0.99-1.01)	1.00(0.99-1.01)	1.00(0.99-1.01)	1.00(0.99-1.01)
$PM_{2.5}$ (category) Low(≤43 μ/m^3)	1.00	1.00	1.00	1.00
High(>43 μ/m^3)	1.11(0.30-4.10)	1.03(0.24-4.39)	1.16(0.28-4.79)	1.54(0.33-7.13)
Passenger's compartment **$PM_{2.5}$(μ/m^3) (continuous)**	1.00(0.99-1.01)	1.00(0.99-1.01)	0.99(0.98-1.00)	0.99(0.98-1.01)
$PM_{2.5}$ (category) Low(≤47 μ/m^3)	1.00	1.00	1.00	1.00
High(>47μ/m^3)	1.58(0.44-5.62)	1.16(0.24-5.52)	1.51(0.45-4.99)	0.98(0.26-3.65)

CHAPTER FIVE

DISCUSSION

5.1 Summary of main findings

This work was a cross-sectional study that has researched into vehicular air pollutants exposure; namely CO and $PM_{2.5}$ and respiratory health symptoms among commercial 'trotro' drivers and passengers who travel on three different routes from Madina to Accra, Dansoman and Kasoa.

The vehicular levels of CO and $PM_{2.5}$ were relatively lower at the driver compartment compared to levels at the passenger compartment. Similarly, the median personal CO levels were found to be relatively lower at the driver compartment than at the passenger compartment.

It was concluded that there is significant difference in the median concentration of personal levels of CO among drivers and passengers. Moreover, prevalence of respiratory symptoms was higher among passengers compared to drivers. The predominant respiratory symptoms reported among both drivers and passengers were coughing and phlegm production.

5.2 Methodological validity

The study has a number of strengths. It happens to be the first time such a study has been conducted in Ghana in which in-vehicle air pollutant exposure levels and respiratory symptoms among commercial 'trotro' drivers and passengers are compared. The research reported here studied the exposures of air pollutants in a complex microenvironment such as vehicle cabin which has a multitude of factors that contribute to levels of air pollutants such as CO and PM. Being the first of its kind the choice of a purposive sampling technique in the routes were very relevant to the outcome of the study and the study participants were most appropriate. The source population included all registered drivers that use the routes; hereby implying drivers that were regular on those routes. This eliminated occasions of engaging drivers that rarely use the routes selected. The use of questionnaire helped to collect information that was measurable within specific durations. Prior to the data collection, a thorough orientation on the need for accuracy in data collection was carried out. These measures notwithstanding, it is important to note that there were few limitations to the study. First and foremost, geographical location of the study area in relation to the geographic coordinate system was not indicated and this does not allow for easy location of study sites. Also, the study is a cross-sectional design and it is not possible to establish any temporality. However, exposure-response relations were observed and this suggests that exposure to in-vehicle air pollutants might be an important determinant of self-reported symptoms. Moreover, it is likely that reported symptoms might be due to exposures other than in-vehicle air pollutants which this study did not consider. Though this point is arguable, not until future studies have proven otherwise repeated exposures to in-vehicle pollutants would result in symptoms that were prevalent among participants. In addition, the sample size of participants was small and the study was limited to specific routes. These do not allow for generalizing the results of the research work. The monitoring period was very short and a 4-hr monitoring would have been better. Also, the study was limited by use of only commercial 'trotro' drivers and their passengers. In addition, this study was carried out during the rainy season where vehicle ventilation systems were poor due to fear of wetness of the cabin as well as of passengers. In this way, trapped pollutants would concentrate and exposure levels may thereby increase. The study was expensive to conduct because it was financially draining and that contributed to the sample size considered. Vehicular monitors could not be checked for strength of battery until study was terminated at the end of the day. These created errors in recording exposures resulting in missing values.

5.3 Comparison of the findings with previous studies

Vehicular air pollution is an important public health concern due to the associated health symptoms that result from exposure to the pollutants (Liu et al., 2014). An extensive search on the subject revealed important studies that have been done across the world on motor vehicle drivers. Whiles one study is as old as 1997, there are a few recent ones. Though a brief review on the study on drivers' exposure to carbon monoxide in Nottingham by Clifford et al, 1997 would be relevant due to its closer similarity to the current study, much focus would be on the more recent works. This study was to assess the exposure of carbon monoxide to drivers that use busy routes and to understand the medical effects of the exposure. It also sought to measure levels of CO inside a moving car and to compare measurements done at fixed locations. The survey was conducted for a period of seven weeks, using sensors to measure the flow of air, CO and road speed. The results were divided into sections that recorded the average external CO, internal exposure, effect of vehicle speed on CO exposure, effect of individual vehicles on exposure as well as meteorological effects.

The results of the study showed that average CO exposure to drivers ranged from 3 and 22 ppm indicating exposures within WHO standards for an average one hour period.

In the current study, though there were daily variations to the CO exposure levels, the average CO exposure was within recommended limits for the driver compartment of the vehicle. Moreover, a similar approach of selecting busy routes was done but the exposure was only done in the cabin of the vehicles and not on the outside.

In the study undertaken at the US (Kadiyala & Kumar, 2013), in-vehicle contaminants of carbon dioxide (CO_2) and carbon monoxide (CO) were quantified under varying climatic conditions. The results in this study proved that in-vehicle levels of CO are dependent on daily to monthly variations. Moreover, factors such as those prevailing on the routes such as on road light and heavy vehicles are important. Other significant factors included the weather. Poor ventilation inside the vehicles was also cited as a factor that increases pollutant level.

In the current study, the levels of air pollutant (CO, $PM_{2.5}$) at passenger compartments were consistently higher than that of the driver compartment. This means that, passengers would often be exposed to higher levels of pollutants compared to drivers. In the same vein, prevalence of associated respiratory symptoms would result from these levels of exposure. Thus this study clearly indicates that respiratory symptoms are more prevalent with passengers in the study than drivers. Similar to the study carried out in the US, poor ventilation setting of passenger compartments of 'trotro' vehicles are big factors in the vehicular concentration levels of CO. The windows of the driver compartment were often lowered and allowed for inflow and outflow of air thereby limiting the concentration of pollutants at this compartment. On the other hand, windows of the passenger compartment were either slightly opened or closed based on passenger's convenience. In this way, concentration of pollutants increase as the vehicle moves because of the poor ventilation the closure of windows creates.

Whiles low levels of CO was observed in the study undertaken in the US during summer, low levels were also observed in the current study on sunny days. This is because, windows were opened at both drivers' and passengers' compartments to allow for flow of fresh air during the hot periods of the day and that would result in the easy diffusion of any trapped pollutant

Adjacent light and heavy vehicles contribute to exposure levels within the cabin of the 'trotro' vehicle. Moreover, the two previous studies have proven that CO levels always increase in heavy-traffic. Various studies (Hoek et al., 2002; Huang & Hsu, 2009; Tramuto et al., 2011) indicated that when vehicles stay in heavy traffic jammed environment, concentration of pollutants increase and thereby increasing exposure levels. In addition, there is infiltration of pollutants from emissions that come from vehicles in adjacent and corresponding positions.

The study by Firdaus and Juliana was a cross-sectional study that looked at exposure to air pollutants such as PM_{10}, CO_2 and CO and respiratory health problems among 30 long distance express drivers. This study was conducted in Malaysia (Firdaus & Juliana, 2014). In the study, chronic respiratory symptoms were reported and included phlegm, cough, wheezing and chest tightness among drivers. Exposure to air pollutants over a long period while driving was found to be harmful to driver's respiratory health. Factors such as fuel type, ventilation setting, and maintenance of buses as well as length of bus routes influenced exposure to $PM_{10.}$ CO levels were found to be lower than those found in urban buses. This is probably because these buses have a constant speed and do not stop and drive as frequent as intracity buses.

In the current study, the use of busy urban routes was influenced by heavy traffics and intermittent stops and drive that accumulate exposure levels. Also, respiratory symptoms that were reported among participants included phlegm production, wheezing, cough and chest pain. The current study also looked at non-respiratory symptoms which were not studied in previous studies alongside the respiratory symptoms. The non-respiratory symptoms included numbness and dizziness.

In summary, the results of the current study have much similarity with previous works considering similar factors and their outcomes though there are variations in protocols. The major distinction is that the current study compared exposure levels among drivers and passengers and this was not done in previous studies. Exposure to air pollutants over long periods while driving was found to be harmful to both drivers' and passengers' respiratory health at varying levels of prevalence.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

In conclusion, this study has shown vehicular levels of CO and prevalence of respiratory symptoms among drivers of commercial 'trotro' vehicles and passengers. The median personal CO concentration levels among drivers were less than that of passengers. It was concluded that there is significant difference in the median concentration of personal levels of CO among drivers and passengers. Moreover, the predominant respiratory symptoms reported among both drivers and passengers were coughing and phlegm production.

In summary, concentrations of personal CO, vehicular CO and vehicular $PM_{2.5}$ had relatively higher levels at the passenger compartment compared with the driver compartment. This could be a reason why the level of exposure and prevalence of respiratory symptoms was higher among passengers as compared to drivers. However, there was no association of levels of vehicular CO concentration with drivers' compartment. Furthermore, it was found that there was significant correlation of 0.356 between vehicular concentration of CO at the driver's compartment and that of the passenger's compartment; and the odds of coughing among drivers increased by 11% upon exposure to CO when all other contributory factors were present.

6.2 Recommendations

Based on the evidence derived from the study and the conclusion drawn, the following recommendations have been made.

i. The government of Ghana must roll out and enforce national emission reduction strategies to control levels of emissions from vehicles.

ii. The Ministry of Roads and Highway, should improve transport systems build strong urban transportation institutions so as to allow more people to use the public transport and thereby decongest the vehicle population on urban roads

iii. Driver unions and transport owners should enforce regular maintenance of vehicles so as to reduce emission levels

iv. Driver unions should organise regular respiratory health screening for their members

v. Further studies should extend work to other routes in Ghana and involve a larger sample to allow for generalization of study.

vi. In addition, further studies should consider private vehicles as well as air-conditioned vehicles

vii. Future studies must mainly emphasize on the use of standard protocols to allow for accurate and defensible results and to allow for inter comparisons among various studies done in the same country at different periods or with other countries

REFERENCES

Abi-Esber, M. E.-F. L. (2009). *In-vehicle Exposure to Carbon Monoxide Emissions from Vehicular Exhaust : A Critical Review In-vehicle Exposure to Carbon Monoxide Emissions from Vehicular Exhaust : A Critical* (Vol. 3389). http://doi.org/10.1080/10643380701798264

Akimoto, H., Keating, T., & Dentener, F. (2010). *Hemispheric Transport of Air Pollution 2010, Part A, Ozone and particulate matter*. New York : United Nations Publications. 2010.

Akumu, J. (2014). Air Quality in African Cities , UNEP. Retrieved from http://unep.org/transport/

Amaral, S., de Carvalho, J., Costa, M., & Pinheiro, C. (2015). An Overview of Particulate Matter Measurement Instruments. *Atmosphere*, *6*(9), 1327–1345. http://doi.org/10.3390/atmos6091327

Arku, R. E., Vallarino, J., Dionisio, K. L., Willis, R., Choi, H., Wilson, J. G., … Ezzati, M. (2008). Characterizing air pollution in two low-income neighborhoods in Accra, Ghana. *Science of the Total Environment*, *402*(2–3), 217–231. http://doi.org/10.1016/j.scitotenv.2008.04.042

Azizi, M. H. (2011). Impact of Traffic-Related Air Pollution on Public, *14*(2), 2011.

Baccarelli, A. A., Zheng, Y., Zhang, X., Chang, D., Liu, L., Wolf, K. R., … Koutrakis, P. (2014). Air pollution exposure and lung function in highly exposed subjects in Beijing , China : a repeated-measure study. *Particle and Fibre Toxicology*, 1–10. http://doi.org/10.1186/s12989-014-0051-7

Chang, Y., Lee, H., & Huang, J. (2016). Risk Factors and Outcome Analysis in Children with Carbon Monoxide Poisoning. *Pediatrics and Neonatology*, 1–7. http://doi.org/10.1016/j.pedneo.2016.03.007

Cheng, Y., Lee, S., Gu, Z., Ho, K., Zhang, Y., Huang, Y., … Zhang, R. (2015). PM2.5 and PM10-2.5 chemical composition and source apportionment near a Hong Kong roadway. *Particuology*, *18*, 96–104. http://doi.org/10.1016/j.partic.2013.10.003

Clifford, M. J., Clarke, R., & Riffat, S. B. (1997). Drivers' Exposure to Carbon Monoxide in Nothingham. *Atmospheric Environment*, *31*(7), 1003–1009.

Corcoran, I., & DiLoreto, D. (2012). *Carbon Monoxide: Sources, Uses, Hazards*. New York. Nova Science Publishers,Inc.2012.

Dionisio, K. L., Rooney, M. S., Arku, R. E., Friedman, A. B., Hughes, A. F., Vallarino, J., … Ezzati, M. (2010). Within-neighborhood patterns and sources of particle pollution: Mobile monitoring and geographic information system analysis in four communities in Accra, Ghana. *Environmental Health Perspectives*, *118*(5), 607–613. http://doi.org/10.1289/ehp.0901365

Effiong, U. E. (2016). Air pollution emission inventory along a major traffic route within Ibadan Metropolis, southwestern Nigeria. *African Journal of Environmental Science and Technology*, *10*(11), 432–438. http://doi.org/10.5897/AJEST2016.2107

Egondi, T., Muindi, K., Kyobutungi, C., Gatari, M., & Rocklöv, J. (2016). Measuring exposure levels of inhalable airborne particles (PM2.5) in two socially deprived areas of Nairobi, Kenya. *Environmental Research*, *148*, 500–506. http://doi.org/10.1016/j.envres.2016.03.018

Ekpenyong, C. E., Ettebong, E. O., Akpan, E. E., Samson, T. K., & Daniel, N. E. (2012). Urban city transportation mode and respiratory health effect of air pollution : a cross-sectional study among transit and non-transit workers in Nigeria. *BMJOpen*. http://doi.org/10.1136/bmjopen-2012-001253

Ferm, M., & Sjoberg, K. (2015). Concentrations and emission factors for PM2.5 and PM10 from road traffic in Sweden. *Atmospheric Environment*, *119*, 211–219. http://doi.org/10.1016/j.atmosenv.2015.08.037

Firdaus, M.O;Juliana, J. (2014). Exposure to Indoor Air Pollutants (PM 10 , CO 2 And CO) and Respiratory Health Effects among Long Distance Express Bus Drivers. *Health and the Environment Journal*, *5*(3), 66–85.

Ghana Statistical Service. (2014). 2010 Population & Housing Census: La Nkwantanang-Madina Municipality District Analytical Report, 91.

Gorham, R. (2002). Air Pollution From Ground Transportation an Assessment of Causes , Strategies and Tactics , and Proposed Actions for the International Community. *Strategies*, 1–194.

Hoek, G., Brunekreef, B., Goldbohm, S., Fischer, P., & Van Den Brandt, P. A. (2002). Association between mortality and indicators of traffic-related air pollution in the Netherlands: A cohort study. *Lancet*, *360*(9341), 1203–1209. http://doi.org/10.1016/S0140-6736(02)11280-3

Houston, D., Li, W., & Wu, J. (2014). Disparities in exposure to automobile and truck traffic and vehicle emissions near the Los Angeles-long beach port complex. *American Journal of Public Health*, *104*(1), 156–164. http://doi.org/10.2105/AJPH.2012.301120

Hsu, D.J., & Huang, H. . (2009). Concentrations of Volatile Organic Compounds, Carbon Monoxide, Carbon Dioxide and Particulate Matter in Buses on Highways in Taiwan.

Atmospheric Environment, *43(36)*, 5723–5730.

Huang, H. L., & Hsu, D. J. (2009). Exposure levels of particulate matter in long-distance buses in Taiwan. *Indoor Air*, *19*(3), 234–242. http://doi.org/10.1111/j.1600-0668.2009.00587.x

Jones, S., Tefe, M., Zephaniah, S., Tedla, E., Appiah-Opoku, S., & Walsh, J. (2016). Public transport and health outcomes in rural sub-Saharan Africa - A synthesis of professional opinion. *Journal of Transport and Health*, *3*(2), 211–219. http://doi.org/10.1016/j.jth.2015.12.005

Kadiyala, A., & Kumar, A. (2013). Quantification of in-vehicle gaseous contaminants of carbon dioxide and carbon monoxide under varying climatic conditions. *Air Quality, Atmosphere and Health*, *6*(1), 215–224. http://doi.org/10.1007/s11869-011-0163-2

Kheirbek, I., Haney, J., Douglas, S., Ito, K., & Matte, T. (2016). The contribution of motor vehicle emissions to ambient fine particulate matter public health impacts in New York City: a health burden assessment. *Environmental Health*, *15*(1), 89. http://doi.org/10.1186/s12940-016-0172-6

Krzyzanowski, M., & Cohen, A. (2008). Update of WHO air quality guidelines. *Air Quality, Atmosphere and Health*, *1*(1), 7–13. http://doi.org/10.1007/s11869-008-0008-9

Lamoureux, D. P., Diaz, E. A., Chung, Y., Coull, B. A., Papapostolou, V., Lawrence, J., … Godleski, J. J. (2013). Effects of fresh and aged vehicular particulate emissions on blood pressure in normal adult male rats. *Air Quality, Atmosphere and Health*, *6*(2), 407–418. http://doi.org/10.1007/s11869-012-0177-4

Liu, Z., Pagoulatos, A., Hu, W., & Schieffer, J. (2014). Valuing the Benefit of Reducing

Adverse Effects from Polluting Heating Fuels ∗. *Scoial Science Quarterly*, *95*(3), 868–881. http://doi.org/10.1111/ssqu.12072

Luke, D. (2011). Review paper A review of commuter exposure to ultrafine particles and its health effects International Laboratory for Air Quality and Health , Queensland University of Technology , Brisbane , QLD , 4001 , Australia . Institute of Health and Biomedical Inn, *45*, 2611–2622.

McAlister, A. L., Huang, P., Ramirez, A. G., Harrist, R. B., & Fonseca, V. P. (2010). Potential Health Impact of Switching From Car to Public Transportation When...: EBSCOhost. *American Journal of Public Health*, *100*(12), 2388–2391. Retrieved from http://web.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=4746ae09-7e74-42d2-83eb-7b6c67e1cc01@sessionmgr111&vid=20&hid=122

Middleton, N., Yiallouros, P., Nicolaou, N., Kleanthous, S., Pipis, S., Zeniou, M., … Koutrakis, P. (2010). Residential exposure to motor vehicle emissions and the risk of wheezing among 7-8 year-old schoolchildren : a city-wide cross-sectional study in Nicosia , Cyprus. *Environmental Health*, *9*(28), 1–18.

Mohd, F. . O., & Juliana, J. (2014). Exposure to Indoor Air Pollutants (PM10 , CO2 And CO) and Respiratory Health Effects among Long Distance Express Bus Drivers. *Health and the Environment Journal*, *5*(3), 66–85.

Nielsen, V. G., Chawla, N., Mangla, D., Gomes, S. B., Arkebauer, M. R., Wasko, K., Vosseller, K. (2011). Carbon monoxide-releasing molecule-2 enhances coagulation in rabbit plasma and decreases bleeding time in clopidogrel/aspirin-treated rabbits. *Blood Coagulation & Fibrinolysis*, *22*(8), 756–759. http://doi.org/10.1097/MBC.0b013e32834c7412

Perez, L., Rapp, R., & Kunzli, N. (2010). The Year of the Lung : outdoor air pollution and lung health. *European Journal of Medical Sciences*, (November), 1–6. http://doi.org/10.4414/smw.2010.13129

Pindus, M., Orru, H., Maasikmets, M., Kaasik, M., & Jõgi, R. (2016). Association Between Health Symptoms and Particulate Matter from Traffic and Residential Heating − Results from RHINE III in Tartu. *The Open Respiratory Medicine Journal*, *10*, 58–69. http://doi.org/10.2174/1874306401610010058

Quinn, A. K., Ae-ngibise, K. A., Jack, D. W., Abrafi, E., Enuameh, Y., Nuhu, M., … Kinney, P. L. (2016). International Journal of Hygiene and Association of Carbon Monoxide exposure with blood pressure among pregnant women in rural Ghana : Evidence from GRAPHS. *International Journal of Hygiene and Environmental Health*, *219*(2), 176–183. http://doi.org/10.1016/j.ijheh.2015.10.004

Rasmussen, N., & Knudsen, H. (2012). *Particulate Matter : Sources, Emission Rates, and Health Effects. New York : Nova Science Publishers, Inc.*

Smith, K. R. (2002). Indoor air pollution in developing countries : recommendations for research. *Indoor Air*, *12*, 198–207. Retrieved from http://ehsdiv.sph.berkeley.edu/krsmith/publications/02_smith_1.pdf

Taylor, J., Mavrogianni, A., Davies, M., Das, P., Shrubsole, C., Biddulph, P., & Oikonomou, E. (2015). Understanding and mitigating overheating and indoor PM 2 . 5 risks using coupled temperature and indoor air quality models. *Building Serv. Eng. Res. Technol.*, *36*(2), 275–289. http://doi.org/10.1177/0143624414566474

Tramuto, F., Cusimano, R., Cerame, G., Vultaggio, M., Calamusa, G., Maida, C. M., & Vitale, F. (2011). Urban air pollution and emergency room admissions for respiratory symptoms: a case-crossover study in Palermo, Italy. *Environmental Health : A Global Access Science Source*, *10*, 31. http://doi.org/10.1186/1476-069X-10-31

Vliet, E. D. S. Van, Asante, K., Jack, D. W., Kinney, P. L., Whyatt, R. M., Chillrud, S. N., … Owusu-agyei, S. (2013). Personal exposures to fi ne particulate matter and black carbon in households cooking with biomass fuels in rural Ghana. *Environmental Research*, *127*, 40–48. http://doi.org/10.1016/j.envres.2013.08.009

WHO. (2004). Environmental health criteria 213: Carbon monoxide. *Who*, (November), 492. http://doi.org/10.1016/0160-4120(80)90163-4

WHO. (2016a). Ambient (outdoor) air quality and health. Retrieved from www.who.int/mediacentre/factsheets/en

WHO. (2016b). Ghana: Life Expectancy. *Ghana: WHO Statistical Profile*, 1–3. Retrieved from http://www.who.int/countries/gha/en/

World Health Organization. (2006). Air Quality & Health Questions and Answer, 1–3. Retrieved from http://www.who.int/phe/air_quality_q&a.pdf

APPENDICES

Appendix 1: Informed Consent

Institutional Affiliation

Department of Biological Environmental and Occupational Health Sciences (BEOHS): School of Public Health, College of Health Sciences, University of Ghana-Legon.

Background

Dear participant, I am **Owusu Yankyera Benedict**, a student of the School of Public Health, University of Ghana, Legon. I am undertaking a study on air pollutant exposure and respiratory health symptoms among 'trotro drivers' using the Madina-Kasoa, Madina-Accra and Madina-Dansoman routes.

The study hopes to measure exposure levels of carbon monoxide and particulate matter among 'trotro' drivers; and the relationship between exposure and respiratory symptoms.

Procedures

The study will involve answering questions from a structured questionnaire, an average 2- hour personal CO, vehicular levels of CO and PM monitoring. This is purely an academic research, which forms part of my work for the award of a master of public health degree.I would be very grateful to have you as part of this study.

Risks and Benefits

The study will not cause any discomfort to participants. The results of the study will be shared with your driver's union. It is hoped that results obtained from this study will be used by policy makers and the driver union association in particular to either improve upon existing safety measures or to enforce existing ones with the objective of protecting drivers from incidences of respiratory symptoms and other possible diseases.

Right to refuse

Participation in this study is voluntary and drivers can choose not to answer any particular question or all questions. You are at liberty to withdraw from the study at any time. However, it is encouraged that you participate since your opinion is important in determining the outcome of the study.

Anonymity and Confidentiality

I would like to assure you that whatever information provided will be handled with strict confidentiality and will be used purely for the research purposes. Your responses will not be shared with anybody who is not part of the research team. Data analysis will be done at the aggregate level to ensure anonymity.

Dissemination of results

The result of this study will be sent to you if you provide your address below.

Before taking the consent, do you have any question you wish to ask about the study?

Yes (if yes, questions to be noted below)

No

………………………………………………………………………………………………

………………………………………………………………………………………………

If you have questions later, you may contact on 0233826685.This study is to seek Ethical Clearance from the Ghana Health Service Ethical Review Board. If you have questions about your rights as a research participant, please contact the administrator of the Ghana Health Service Ethical Review Board at: **GHS-ERC Administrator: Hannah Crimping (0507041223).**

Consent

I……………………………………., declare that the purpose of the study have been thoroughly explained to me and I have understood. I hereby agree to answer the questions

Signature…………………………. Date………………………………

Thumb print

Interviewer's Statement

I, the undersigned, have explained this consent form to the subject and that he understands the purpose of the study, procedures to be followed as well as risks and benefits involved. The subject has freely agreed to participate in the study.

Interviewer's signature…………………………

Date……………………………..

Address……………………………

Appendix 2: Questionnaire

SCHOOL OF PUBLIC HEALTH

UNIVERSITY OF GHANA

DEPARTMENT OF BIOLOGICAL, ENVIRONMENTAL AND OCCUPATIONAL HEALTH (BEOH)

QUESTIONNAIRE

This research instrument is designed to collect data from 'motor' drivers who use the following routes: Madina-Kasoa, Madina-Dansoman, Madina-Accra.

INTERVIEWER:
Your participation in the study as said earlier is completely voluntary. *I would also like to assure you that all information collected in the course of the study will remain confidential.* *Thanks a lot for your participation. In case you have any questions, please let us know.* *Please also ask when you have a problem understanding the meaning of any of the questions*

1-QUESTIONNAIRE FOR DRIVERS

SECTION 1: SOCIO-DEMOGRAPHIC PROFILE OF RESPONDENTS

Date: Date _____/_____/ 2016 **INTERVIEWEE N° /__________/**

1	How old are you?	Record as mentioned:	
2	What is your highest level of educational attainment?	No formal education	0
		Primary	1
		JHS	2
		SHS	3
		Tertiary	4
		Other (specify)………………………	7
3	Would you mind if I ask you about your average income per month (in GHS)? Income per month	Record as mentioned:	
4	Place of residence.	Record as mentioned:	
5	How many years have you lived in this community?	Record as mentioned:	
6	How many years of experience do you have in your occupation (driving)	Record as mentioned:	

SECTION 2: ABOUT YOUR VEHICLE AND AIR POLLUTION (CO/PM EMISSION)

7	What is the year model of your vehicle?	2006	1
		2007	2
		2008	3
		2009	4
		2010	5
		2011	6
		2012	7
		2013	8
		2014	9
		2015	10
		Other(specify)	11
8	Which of the following types of fuel do you use in your vehicle?	Petrol	1
		Diesel	2
		LPG	3
9	Which is the engine capacity of your vehicle?	Record as mentioned:	
10	What type of car do you use?	Record as mentioned:	
11	How long do you drive in a day?	2hour	1
		3 hours	2
		5 hours	3

		6 or more continuous hours	4
12	How long have you used your car?	1 year	1
		2 years	2
		3 years	3
		4years	4
		5 or more years	5
13	How often do you service your car?	Monthly	1
		Bi-monthly	2
		Quarterly	3
		Yearly	4

SECTION 3: RESPIRATORY SYMPTOMS

14	**COUGH** Do you usually have a cough? If No, please skip to question 20	No	0
		Yes	1
15	Do you usually cough as much as 4 to 6 times a day, 4 or more days out of the week?	No	0
		Yes	1
16	Do you usually cough at all on getting up, or first thing in the morning?	No	0
		Yes	1

17	Do you usually cough at all during the rest of the day or at night?	No	0
		Yes	1
18	Do you usually cough like this on most days for 3 consecutive months or more during the year?	No	0
		Yes	1
		Does not apply	2
19	For how many y**ears have you had this cough?**	Record as mentioned:	
20	**PHLEGM** Do you usually bring out phlegm from your chest?If No, please skip to question 27	No	0
		Yes	1
21	Do you usually bring up phlegm as much as 4 to 6 times a day, 4 or more days out of the week?	No	0
		Yes	1
22	Do you usually bring up phlegm at all on getting up, or first thing in the morning?	No	0
		Yes	1
23	Do you usually bring up phlegm at all during the rest of the day or at night? IF NO TO ALL, SKIP TO THE NEXT SECTION (WHEEZING)	No	0
		Yes	1
24	Do you bring up phlegm like this on most days	No	0

	for 3 consecutive months or more during the year?	Yes	1
25	For how many years have you had trouble with phlegm?	Record as mentioned:	
26	Have you had periods or episodes of (increased) cough and phlegm lasting for 3 weeks or more each year?	No	0
		Yes	1
27	**WHEEZING**Does your chest ever sound wheezy or whistling when you have a cold? If No, please skip to question 35	No	0
		Yes	1
28	Does your chest ever sound wheezy or whistling occasionally apart from cold?	No	0
		Yes	1
29	Does your chest ever sound wheezy or whistling most days and nights?	No	0
		Yes	1
30	If you answered YES to questions 27, 28 or 29, how many years has this condition been present?	Record as mentioned:	
31	Have you ever had an attack of wheezing that had made you short of breath?	No	0
		Yes	1
32	If you answered YES to question 31, how many	Record as mentioned:	

	times have you had this experience in the past 1 year?		
33	How many years has this condition been present?	Record as mentioned:	
34	How old were you when you had your first such attack?	Record as mentioned:	
35	**BREATHLESSNESS** Are you troubled by shortness of breath when hurrying on the level or walking up a slight hill?	No	0
		Yes	1
36	If yes to 35, do you have to walk slower than people of your age on level because breathlessness?	No	0
		Yes	1
37	Do you ever have to stop for a breath when walking at your own pace on level?	No	0
		Yes	1
38	Are you too breathless to leave the house or on dressing?	No	0
		Yes	1
39	**CHEST COLDS AND CHEST ILLNESS** If you get a cold, does it usually go to your chest?	No	0
		Yes	1
40	During the past 3 years, have you had any chest	No	0

	illnesses that have kept you off work, in doors at home, or in bed? If No, please skip to question 43	Yes	1
41	Did you produce phlegm with any of these chest illnesses?	No	0
		Yes	1
42	In the last 3 years, how many such illnesses, with (increased) phlegm, did you have which lasted a week or more?	Record as mentioned:	
43	**PAST ILLNESSES** Have you had any lung trouble in the past?	No	0
		Yes	1
44	Have you ever had any attacks of bronchitis?	No	0
		Yes	1
45	If you answered yes to question 44, did a doctor diagnose it?	No	0
		Yes	1
46	At what age (in years) did you first experience it?	Record as mentioned:	
47	Have you ever had any attacks of Hay fever?	No	0
		Yes	1
48	If you answered yes to question 47, did a doctor diagnose it?	No	0
		Yes	1
49	At what age (in years) did you first experience it?	Record as mentioned:	

50	Have you ever had chronic bronchitis?	No	0
		Yes	1
51	If you answered yes to question 50, did a doctor diagnose it?	No	0
		Yes	1
52	At what age (in years) did you first experience it?	Record as mentioned:	
53	Do you still experience it?	No	0
		Yes	1
54	Have you ever had pneumonia?	No	0
		Yes	1
55	If you answered yes to question 54, did a doctor diagnose it?	No	0
		Yes	1
56	Have you ever had asthma?	No	0
		Yes	1
57	If you answered yes to question 56, did a doctor diagnose it?	No	0
		Yes	1
58	If you answered yes to question 56, do you still experience the asthma?	No	0
		Yes	1
59	Do you experience any other chest illness?	No	0
		Yes	1
60	If you answered yes to question 59, please specify	Record as mentioned:	

2-QUESTIONNAIRE FOR PASSENGERS

SECTION 1: SOCIO-DEMOGRAPHIC PROFILE OF RESPONDENTS

Date: Date _____/_____/ 2017   INTERVIEWEE N° /__________/

1	How old are you?	Record as mentioned:	
2	What is your highest level of educational attainment?	No formal education	0
		Primary	1
		JHS	2
		SHS	3
		Tertiary	4
		Other (specify)……………………….	7
3	Would you mind if I ask you about your average income per month (in GHS)? Income per month	Record as mentioned:	
4	Place of residence.	Record as mentioned:	
5	How many years have you lived in this community?	Record as mentioned:	

SECTION 2: ABOUT YOUR DAILY TRAVELS

10	What type of car do you normally use in your travels?	Record as mentioned:	
11	How long do you stay in a vehicle daily?	2hour	1
		3 hours	2
		5 hours	3
		6 or more continuous hours	4

SECTION 3: RESPIRATORY SYMPTOMS

14	**COUGH** Do you usually have a cough? If No, please skip to question 19	No	0
		Yes	1
15	Do you usually cough at all on getting up, or first thing in the morning?	No	0
		Yes	1
16	Do you usually cough at all during the rest of the day or at night?	No	0
		Yes	1
17	Do you usually cough like this on most days for 3 consecutive months or more during the year?	No	0
		Yes	1
		Does not apply	2
18	For how many years have you had this cough?	Record as mentioned:	
19	PHLEGM Do you usually bring out phlegm from your	No	0
		Yes	1

	chest?If No, please skip to question 27		
20	Do you usually bring up phlegm at all on getting up, or first thing in the morning?	No	0
		Yes	1
21	Do you usually bring up phlegm at all during the rest of the day or at night? IF NO TO ALL, SKIP TO THE NEXT SECTION (WHEEZING)	No	0
		Yes	1
22	Do you bring up phlegm like this on most days for 3 consecutive months or more during the year?	No	0
		Yes	1
23	For how many years have you had trouble with phlegm?	Record as mentioned:	
24	Have you had periods or episodes of (increased) cough and phlegm lasting for 3 weeks or more each year?	No	0
		Yes	1
25	WHEEZING Does your chest ever sound wheezy or whistling when you have a cold? If No, please skip to question 35	No	0
		Yes	1
27	Does your chest ever sound wheezy or whistling most days and nights?	No	0
		Yes	1
28	If you answered YES to questions 25, or 27,	Record as mentioned:	

	how many years has this condition been present?		
31	How many years has this condition been present?	Record as mentioned:	
32	How old were you when you had your first such attack?	Record as mentioned:	
33	BREATHLESSNESS Are you troubled by shortness of breath when hurrying on the level or walking up a slight hill?	No	0
		Yes	1
34	If yes to 33, do you have to walk slower than people of your age on level because of breathlessness?	No	0
		Yes	1
37	PAST ILLNESSES Have you had any lung trouble in the past?	No	0
		Yes	1
39	If you answered yes to question 37, did a doctor diagnose it?	No	0
		Yes	1
40	At what age (in years) did you first experience it?	Record as mentioned:	
44	Do you still experience it?	No	0
		Yes	1
45	Have you ever had pneumonia?	No	0
		Yes	1

46	If you answered yes to question 45, did a doctor diagnose it?	No	0
		Yes	1
56	Have you ever had asthma?	No	0
		Yes	1
57	If you answered yes to question 56, did a doctor diagnose it?	No	0
		Yes	1
58	If you answered yes to question 56, do you still experience the asthma?	No	0
		Yes	1
59	Do you experience any other chest illness?	No	0
		Yes	1
60	If you answered yes to question 59, please specify	Record as mentioned:	