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Driver Education and Awareness of In-Vehicle Air Pollutants and Health

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ABSTRACT

Background: The confined space of vehicle cabins 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). Rising levels of in-vehicle air pollutants in public transport are of public health concern in sub-Saharan Africa**.** This study explores the educational levels of commercial vehicle drivers and their association with in-vehicle pollution. **Methods:** Employing a mixed-method approach, the study utilized a self-administered questionnaire and air pollutant exposure monitors. Purposive sampling selected 89 drivers and corresponding 89 passengers of vehicles that travel an average of 1 hour per trip. Logistic models and non-parametric tests were used for statistical analyses. **Results:** Findings show that CO and PM are common in-vehicular air pollutants at different levels across diverse compartments in a vehicle. In addition, 64% of drivers had formal education up to the senior high school level. Breathlessness and coughing were respiratory symptoms common among drivers with a low level of education compared to their highly educated counterparts. Moreover, drivers had limited knowledge of the negative impact of in-vehicular air pollutants on respiratory health. Drivers predominantly associated pollution with exhaust emissions. **Conclusion:** The pivotal role of formal education in mitigating in-vehicle air pollution is emphasized by the study. It advocates for intensified driver education initiatives that result in the protection of both drivers and passengers from the health risk of pollution.

Keywords: Air Pollutants; Commercial Drivers; Respiratory Symptoms; Vehicles

Background

In-vehicle air pollution has become a mounting public health concern in sub-Saharan Africa. Drivers and passengers are exposed to a great deal of air pollutants inside the cabins of motor vehicles. This exposure poses respiratory and non-respiratory health risks, contributing to reported mortality from cardiovascular diseases and acute respiratory infections (Mohd Firdaus & Juliana, 2014). One of the top ten leading causes of death and hospitalization in sub-Saharan Africa is acute respiratory infections. Common in-vehicle air pollutants include carbon monoxide (CO), particulate matter ($PM_{2.5}$), and volatile organic compounds (VOCS).

Contributing Factors to In-vehicle Air-pollution

The increasing urbanization in sub-Saharan Africa has led to a surge in population within urban areas (WHO, 2016). This has fostered a parallel rise in demand for transportation for both commercial and private purposes. With road transport being the predominant mode of commuting in sub-Saharan Africa, there has been a notable increase in the number of motor vehicles. Contributing to the elevated pollution levels is the burning of fossil fuels on the roads by motor vehicles. The rate of road traffic density results in excessive amounts of air pollution inside and outside of vehicles. Vehicular and mechanical factors, coupled with socio-demographic considerations, collectively contribute to the emission of air pollutants inside vehicle cabins.

The factors include fuel type, vehicle age, maintenance practices, engine type, daily usage duration, and emissions from surrounding vehicles (Perez, Rapp & Kuenzli, 2010; Gorham, 2002). An important socio-demographic factor is the level of formal education of the driver, which can influence awareness of exposure to air pollutants and their health effects. In addition, it affects his knowledge and understanding of existing environmental laws on air pollution and preventive measures. Inhalation exposure renders drivers and passengers susceptible to a spectrum of respiratory symptoms, including cough, wheezing, sputum production, and breathlessness, alongside non-respiratory manifestations such as dizziness, palpitations, easy fatigability, and loss of concentration. Understanding these multifaceted contributors is crucial for devising effective strategies to mitigate vehicle air pollution and safeguard the health and well-being of occupants in sub-Saharan Africa.

Problem Statement

Air pollution is the largest single environmental health risk, resulting in three million premature deaths a year in the world (WHO, 2016). In Sub-Saharan Africa, one hundred and seventy thousand people die prematurely annually from acute respiratory infections (ibid.). The situation is aggravated by the increase in urbanization and its resulting increase in population. Consequently, demand for vehicular transportation is on the rise. High levels of pollution inside vehicles arise and pose a great health concern.

While existing literature correlates drivers' education with road safety (Akbari *et al*., 2021; Sami *et al*., 2013; Raftery & Wundersitz, 2011), the current study addresses a notable gap by exploring the insufficiently studied relationship between the educational levels of commercial drivers and in-vehicle pollution awareness and health risk perception. Recent studies on public perceptions of air pollution (Odonkor & Mahami, 2020) suggest a significant link between socio-demographic factors and general air pollution awareness. However, empirical evidence supporting the association between the educational levels of commercial drivers and awareness of in-vehicular pollution and associated health risks remains inadequate. This study seeks to fill this crucial research gap, offering valuable insights into the complex interplay between drivers' education, in-vehicle pollution, and health risk awareness in the unique context of Sub-Saharan Africa. The assessment of drivers’ educational level and knowledge will offer useful insight that will serve as an effective tool in curtailing air pollution and its health effects, especially in sub-Saharan Africa.

The objectives of the study are to determine:

- Levels of personal carbon monoxide (CO) exposure
- Vehicular levels of CO exposure
- Vehicular levels of particulate matter ($PM_{2.5}$) exposure

- Prevalence of respiratory health symptoms among commercial drivers and passengers
- Educational level of drivers and their awareness of the health risks of pollutants.

Empirical/Theoretical Background

A comprehensive search on studies pertaining to in-vehicle air pollution and driver awareness was carried out. The search was carried out from different sources: Google Scholar, Web of Science, and Science Direct. Key words used include in-vehicle air pollution, drivers, and educational level. Articles without these key words were excluded. Publications of the last ten years were considered, and publications beyond ten years were excluded.

Air-pollutant Exposure and Ventilation

Lim *et al*., (2021) studied evidence for reduction strategies from in-vehicle personal air pollutant exposure monitoring. They characterized professional drivers' exposure to traffic-related air pollution (Sharmilaa, G., & Ilango, 2022). Employing a mixed method with a cross-sectional design they had an important outcome. They stated that driver's exposure to air pollutants is significantly reduced when vehicle windows are closed. This assertion is contradicted by Campagnolo *et al*., (2023), who argued that ventilation is the most effective response to in-vehicle exposures to air pollutants. They reviewed factors affecting in-vehicle exposure to traffic-related air pollutants. This was a qualitative study with a multi-cross-sectional design. Other major arguments were that traffic and time-related variables are associated with each other and they affect in-vehicle exposure to air pollutants.

Similar studies had earlier been carried out by Kadiyala & Kumar (2013), who corroborated the argument on ventilation. They reiterated that automobile pollutant levels are affected by ventilation inside vehicles. They also added that general weather conditions also affect in-vehicular pollutant levels. Their study sought to quantify in-vehicle gaseous contaminants of $CO2$ and CO under different climate conditions. Very important older studies sought to make similar assertions. In the study by Hsu & Huang (2009), they argued that infiltrations from other particulate matter and emissions from the exhaust of a vehicle can result in high exposure to pollutants. They studied the concentrations of air pollutants in buses on highways. Their assertion may be related to the subject of ventilation. If concentrations inside vehicles build up because of infiltrations, adequate ventilation can reduce it. They employed a mixed-method approach in a multi-cross-sectional design, much like Kadiyala & Kumar (2013).

Driver Knowledge on Air Pollutants and Health Effects

In assessing drivers' knowledge regarding the effects of air pollution on health, Gany *et al*., (2017) carried out an empirical study among taxi drivers in New York City. He employed a cross-sectional design in a mixed-methods approach. The key arguments were that drivers' awareness of air pollutants was limited. Therefore, this has a negative influence on reducing air pollutant exposure. A related study by Dhanvijay & Pohekar (2021) stated that drivers had good knowledge about air pollution and respiratory health implications. This argument emphasizes that through drivers' knowledge, they can support prevention strategies of in-vehicle air pollutants. They undertook a qualitative study using a cross-sectional design to arrive at such a conclusion. There is therefore empirical evidence to the fact that drivers' knowledge can influence the extent of exposure to air pollutants. Consequently, drivers' knowledge becomes an effective tool in curtailing air pollution and its health effects.

Duration and Concentration of Air-Pollutants Exposure and Health Risks

Research on the important considerations on the amount of exposure and levels of air pollutant exposure has been studied in the literature (Etim, 2016; Mohd Firdaus & Juliana, 2014). Employing a mixed-methods approach, Mohd Firdaus & Juliana (2014) studied exposure to indoor air pollutants such as particulate matter (PM10), carbon dioxide ($CO2$), and carbon monoxide (CO). They further researched the respiratory health effects of these pollutants among long-distance express bus drivers. In a cross-sectional design, they concluded that continuous exposure to air pollutants while driving is potentially causing ill effects to drivers' respiratory health. While they stressed on length of exposure, Etim (2016) focused on amount of exposure in the study on emission inventory along major traffic routes in Ibadan. The key arguments were that levels of ambient CO are high on high traffic density roads. They concluded that respiratory health risks increase with increased air pollution exposure.

Methods

Study Design and Study Setting

The current study used a cross-sectional design in a mixed-methods approach. The study setting was commercial motor vehicles that travel to selected destinations in an average of one hour from a particular lorry station in Madina-Ghana, where commercial activities are rife.

Study Population and Sample Size

The target population was drivers with registered vehicles at Madina Lorry station. There were one hundred (100) drivers that ply the selected route in an average of one (1) hour. They were all male drivers. The study sought to include all drivers purposefully, but eighty-nine (89) drivers acceded to participate in the study. In addition, a corresponding passenger on board of each of the 89 vehicles was randomly selected for comparison in the study. Consequently, personal levels of CO and PM were measured on the driver and the selected passenger.

Data Collection Process

There were three phases in the data collection:

1. Stakeholder Meeting

A meeting was held with leaders of the driver union to explain the rationale behind the research among drivers. It was also to seek their consent for the research.

2. Selection and Enrolment of Study Participants.

The station masters of the selected routes introduced the researcher to drivers and thereby sought their consent. For comparative analysis, a passenger on board of each of the vehicles that was monitored was included in the study. The corresponding number of passengers for the commercial vehicle drivers was 89. Vehicular levels of pollutants and personal levels of pollutants were done on drivers and passengers for each of the vehicles.

3. Data Collection

Data collection tools were a self-administered questionnaire and monitors for measuring air pollutant exposure. The personal CO monitoring was carried out with a SidePak Personal Aerosol model AM 510 (TSI, Shorevie, MN, USA). The vehicular levels of CO and PM were monitored with a LASCAR CO/PM monitor (MicroDAQ, Contoocook, NH, USA). Both devices were standardized tools that had been factory-calibrated and have been used in related studies in Ghana (Quinn *et al*., 2016).

A 24-hour monitoring was done at the departure posts to check ambient levels of exposure prior to monitoring in the vehicles. The LASCAR CO/PM monitor was mounted on a height at the stations and allowed to remain for 24 hours. Security of the monitors was ensured by hiring a watchman. A Lascar CO/PM monitor was mounted at the driver compartment of the vehicle and another at the passenger compartment in the third row. The time of mounting monitors was immediately recorded, and monitoring of vehicular levels of CO and PM was started. A detailed description of human activities at the station was done. While still at the station, a questionnaire is administered to the driver as his 'mate' keeps getting passengers on board. Once the vehicle is full, the data logger of the personal CO monitor is started on a personal computer and fixed on the driver's shirt before he sets off. The researcher takes his seat on the second or third row of the passenger compartment, and by convenient sampling technique, the next person to him is selected, and the second personal CO monitor is fixed to his dress after its data logger has also been started. The ventilation setting is at the different compartments in the commercial buses. 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 the truck station is recorded, and a detailed description of human and traffic activities are noted based on the researcher's observations. These activities included human trading activities along the roads, and light and heavy vehicles in adjacent or corresponding positions to the commercial buses. The routes selected are standard dual-direction asphalt urban roads that have 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 has the personal CO monitor while enroute. Time of arrival is noted at destination, and the process restarts with another vehicle going back. Measurements were done for an average one-hour continuous journey duration (Egondi *et al*., 2016). Data collected on the devices were downloaded to a computer with a USB cable. The SidePak Personal Aerosol monitor model AM 510 (TSI, Shoreview, MN, USA) came with air quality report software; therefore, data was 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. Respiratory and non-respiratory symptoms experienced by respondents due to exposure to vehicle air pollutants were also obtained using the same questionnaires. Data was collected from Monday to Saturday during both the peak hours of the day from 7:00am to 9:30am and then from 3:00pm to 7:30pm, as well as off-peak hours. Mainly, hours between 10:00am and 3:00pm, as well as after 7:30pm.

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 average (mean) and the level 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 and non-respiratory health symptoms among both drivers and passengers were also examined.

A logistic model was used in the inferential statistics to determine associations and the level of significance between the independent and dependent variables. A nonparametric test, Mann-Whitney, was also used to determine a significant difference in median concentration levels of personal carbon monoxide. Conclusions were drawn based on the strength and direction of the association between the independent and the dependent variables.

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 the previous day's activities was done so that challenges could be addressed.

Results

Table 1: Socio-Demographic Characteristics of Participants

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)
*Basic education represents JHS, and below, **Secondary represents SHS, ***Others represents Middle school and no formal education		

A total of one hundred and seventy-eight participants participated in the study. 59.6% of the drivers were between the ages of 31 and 40 years 55.1% of passengers were between 18 and 30 years 64% of the drivers had attained secondary education, and 28.1% had attained basic education. (See Table 1) 44.9% of the passengers had attained tertiary education, and 55.1% of the passengers had other forms of educational level.

Table 2: Prevalence of Respiratory Symptoms

Self-Reported Respiratory Symptoms	Drivers, *n* (%)	Passengers, *n* (%)
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)

Prevalence of Respiratory and Non-Respiratory Symptoms among Commercial Drivers and Passengers

The study identified prevalent self-reported respiratory symptoms among drivers, with cough (35.9%) and phlegm production (34.8%) being predominant. Passengers exhibited a higher prevalence of phlegm production (44.9%) and coughing (28.1%) (See Table 2). The non-respiratory symptoms reported were palpitation, numbness, easy fatigability, and loss of concentration.

Drivers' Knowledge on Air Pollution

All (100%) of the drivers claimed knowledge of pollution but emphasized emissions from vehicle exhausts. All (100%) could not relate non-respiratory symptoms reported to air pollutants.

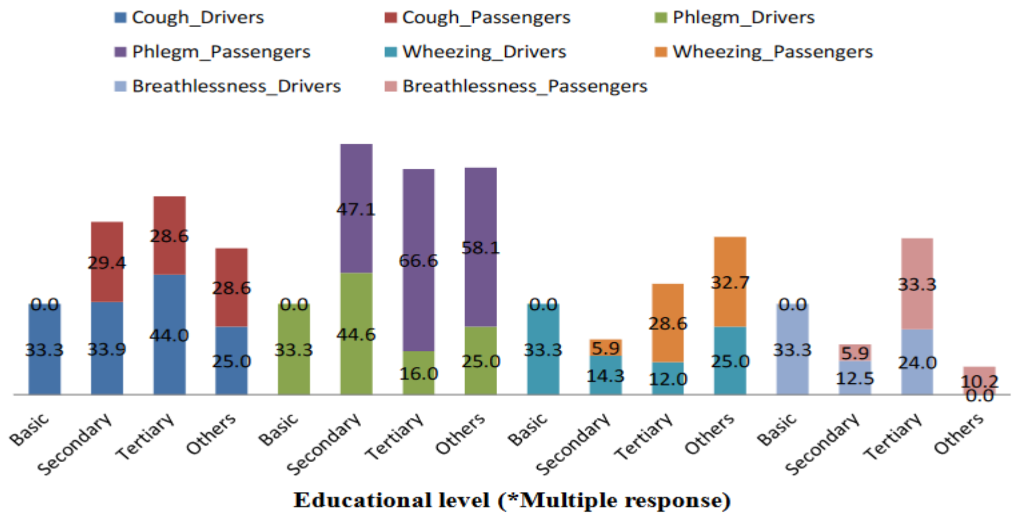

Fig. 1: Distribution of Respiratory Symptoms by Educational Level of Study Participants

On the distribution of respiratory symptoms by educational level of study participants, the combined reported symptoms of respondents with basic and other levels of education were the highest (see figure 1).

Table 3: Personal Level and In-Vehicle Air Pollutant Concentrations

Categories	Mean	SD	Geometric Mean	Min	Q_1	Median	Q_3	Max
Personal level of exposure CO(ppm)								
Drivers	9.2	11.1	7	3	4.5	6.7	9.0	88.5
Passengers	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

Personal Level and In-Vehicle Air Pollutant Concentrations

Table 3 details personal and vehicular carbon monoxide (CO) and particulate matter ($PM_{2.5}$) levels. Drivers' median personal CO was 6.7 ppm (range: 3-88.5), while passengers had 10.2 ppm (range: 3.5-178.5). Vehicular CO medians were 10.5 ppm (range: 7.5-12.2) and 21 ppm (range: 19.9-22.5) for drivers and passengers, respectively. $PM_{2.5}$ medians were 43 ppm (range: 16.5-71.1) and 46.7 ppm (range: 22-108.5) for both sides.

Table 4: Output of Wilcoxon Rank-Sum Test $\alpha = 0.05$

Categories	Obs	Rank Sum	Expected	Test statistics	*P*-value
Passengers	89	9700.5	7921	5.222	0.000
Drivers	89	6052.5	7832		
Combined	178	15753	15753		

A significant correlation (p = 0.356) existed between vehicular CO concentrations in driver and passenger compartments, while the Wilcoxon rank-sum test revealed that passengers had significantly higher CO concentrations than drivers (see Table 4).

Discussion

The result of the study highlights the importance of ventilation in managing in-vehicle air pollution exposure. It also underscores the significant relationship between air pollutants and respiratory symptoms. The higher the exposure levels of pollutants, the more prevalent the respiratory health symptoms among participants. This is consistent with previous research (Etim, 2016; Mohd Firdaus & Juliana, 2014). The high concentration of air pollutants is proportional to the health risks that are increased by exposure. The average personal CO concentration levels among drivers were less than those of passengers. This is understandable because commercial drivers had their windows lowered. In contrast, passengers' windows were regulated by preference. The literature stressed the importance of ventilation in the management of in-vehicle air pollutant exposure (Campagnolo *et al*., 2022; Lim *et al*., 2021; Kadiyala, A., & Kumar, A. 2013). The air pollutants are dispersed to reduce concentration when the ventilation is adequate. When drivers and passengers are exposed to in-vehicle air pollutants, the predominant respiratory symptoms reported were coughing and phlegm production. However, breathlessness and coughing were higher among drivers with low levels of education and equally higher among their passengers. There is a clear understanding that the higher the educational level, the more health conscious there is. When the health consciousness is high, various levels of efforts are made to reduce health risks.

Limitations of the Study

The present study was restricted to urban roads that had asphalt-constructed lanes. It may be recommended that future studies examine exposure levels on untarred roads and driver knowledge on road conditions and health.

Conclusion

The common air pollutants in the cabin of motor vehicles are CO and $PM_{2.5}$. The common respiratory symptom deemed to be influenced by levels of personal CO exposure is cough.

One clear implication of the study is the potential impact of drivers' educational levels on their health awareness. Higher education could lead to increased health consciousness and efforts to reduce health risks. Reduction of health risks is necessary for the prevention of diseases among both drivers and their passengers.

Declarations

Ethics Approval and Consent to Participate: Ethical approval was obtained from the Ghana Health Service Ethics Review Committee with approval number GHS-ERC: 45/02/17 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.

Conflict of Interest: The study has no competing interests. Research was funded by principal investigator. There were no external sponsorships.

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