Original Research Article

ASSESSMENT OF EXHAUST EMISSIONS FROM HAULAGE TRUCKS AT ONNE PORT IN RIVERSSTATE, NIGERIA

ABSTRACT

Haulage trucks are among the primary causes of air pollution in urban areas. The effect of air pollution caused by transportation, especially freight transportation, on public health is a major concern globally.In this study, exhaust emissions from haulage trucks at Onne Port in Nigeriawere assessed.Real-time measurements of air pollutants were taken using a portable Testo 350 Analyzer and a portable IGRESS Intelligent Detector from seventy (70) haulage trucks at Onne Port grouped according to production years, region of origin, and truck length, and the data obtained were compared with the World Health Organization (WHO) air quality standards. The results revealed that the trucks'emissions exceeded WHO limits for six criteria pollutants, including NO_2, SO_2, CO, PM_1, $PM_{2.5}$, and PM_{10}, which are associated with adverse health effects such as respiratory and cardiovascular diseases. Other notable findings included higher concentrations of NO_2 and $PM_{2.5}$ from trucks produced between 2011 and 2021, while older trucks exhibited increased emissions of SO_2, CO, $PM_{1,}$ and PM_{10}. There were no significant variations in pollutant emission concentrations observed within the four categories across different production years. Trucks manufactured in Asia consistently emitted lower pollutant concentrations compared withthose from other regions, suggesting the influence of varying emission standards. Interestingly, truck length did not significantly impact emission levels. These findings underscore the urgency of addressing the air quality issues associated with haulage trucks in the region, highlighting the need for stringent emissions control measures.

Keywords: Truck emissions, Onne Port, Air pollution, Criteria pollutant, Freight transport, Emission Assessment

1.INTRODUCTION

Transportation-induced air pollution has become a significant public health concern, with numerous studies illustrating the detrimental effects of outdoor air pollution on human well-being (WHO, 2005). Freight transportationis made up of various sub-modes that operate collaboratively, instead of competing with each other. According to Rodrigue (2020), the market potential of a mode of transportation is determined by a combination of its technical, operational, andcommercialfeatures. Technical features refer to factors like speed, ability to carry passengers or goods, and the type of technology it uses for movement. On the other hand, operational features include elements such as safety regulations, speed limits, and the hours during which the mode of transportation can operate. Also, the demand for transportation and the ownership of different transportation mode plays a significant role in shaping the market. These commercial characteristics are crucial in determining the market potential of a particular mode of transportation. The technical, operational, and commercial features of trucks directly affect their emissions and overall environmental impact, as factors such as fuel efficiency, engine technology, load capacity, and operational practices influence the level of pollutants released into the environment, making it essential to consider these aspects when assessing the environmental effect of trucks and their market potential.

According to the World Health Organization (WHO, 2005), road transportation is a considerable originator of poisonous air pollutants, emitting various harmful substances into the air. These pollutants come from different parts of vehicles, including the exhaust of internal combustion engines, brake pads, clutch discs, tires, and fuel tanks, among others. The combined emissions from these sources create a complex mixture of air pollution that has been shown to negatively impact human health (Hoek et al., 2002). While transportation is often considered as a whole in discussions about energy use and greenhouse gas emissions, there is a lack of distinction between freight and passenger transport. This can result in the freight transport sector being overlooked, despite its faster growth rate compared to passenger transportation. Freight transport is predicted to persist in expanding at a rapid pace in the future (Eom et al., 2012). According to Okedere et al. (2021), the usage of diesel-powered haulage trucks in Nigeria has become essential for transporting large products throughout the country due to the deterioration of the rail system over the years. To meet domestic demand, a significant number of haulage trucks have been imported from international suppliers, with an estimated 70% of these being rebuilt or refurbished. Okedere et al. (2021) also noted that the issue of atmospheric pollution generated by air emissions is increasingly worrying various entities, including governments, NGOs, and scholars worldwide. The main reason for this concern is the harmful impacts of air pollution on air quality and the Earth's climate, which affects humans, animals, and the overall environment.

According to Rodrigue et al. (2006), seaports function asa transportationcentre that facilitates different types of transportation modes, with road transport being the most commonly used means of transportation for inland areas in the majority of international ports. As a result, there is a high volume of truck movement in port cities. In light of the detrimental effects of air pollution on both the well-being of individuals and the ecosystem, there is growing pressure on Governments globally to address this issue. Sornn-Friese et al. (2021) observed that ports are under growing pressure from various groups such as port users, regulatory bodies, and local communities to lower the air pollution caused by their operations. Moreover, the general public is greatly concerned about air quality, and ports are commonly linked to significant air emissions and expenses that affect the environment outside of the port. Liu et al. (2016) highlighted that ports play a crucial role in connecting land and sea transportation, and Gobbi et al. (2020) pointed out that since ports are built to last for a long time, their impact on the environment can be long-lasting, and that estimating the emissions should also take a long-term approach. Wiegmans and Louw (2011) and Pluciński (2017) observed that ports often act as city-forming entities and are located in the middle of urban areas, near city centres or housing developments.

The Onne port, like many other ports around the world, is essential to the economic value of the region and the country as a whole, by facilitating the movement of various cargo products.

However, due to the nature of land transportation in Nigeria, road transport has been predominantly utilized to serve the hinterland of many ports, despite efforts made by the Federal Government and Port Authorities of Nigeria to encourage modal transportation. Therefore, it is essential to conduct a more comprehensive assessment of truck emissions from ports to assist port authorities in knowing and controlling current emission levels and implementing measures to minimize truck emission discharge.

2 MATERIALS AND METHODS

2.1 Study Area

The Onne Port is located in the southern part of Nigeria's Niger Delta area,specifically in Eleme Local Government Area of Rivers State (Figure 1). The Port is located on the Bonny River Estuary which opens up into the Atlantic Ocean. It is bordered by the Alode, Ebubu, Ngololo Creek and a tributary of the Bonny River. The area is known for its flowing rivers, streams, and marshes, and it is home to a diverse array of plant and animal species. It is located at latitude 4.6981° N and longitude 7.1730° E. The Onne Port is also close to several industrial facilities which have had a considerable influence on the local economy and ecology. One such facilityis the Onne Port Free Trade Zone, which is a major part of the Port and is a large, industrial area with warehouses, factories, and other commercial and logistics facilities. The Free Trade Zone also has several residential and recreational areas for workers, including housing, schools, and parks.

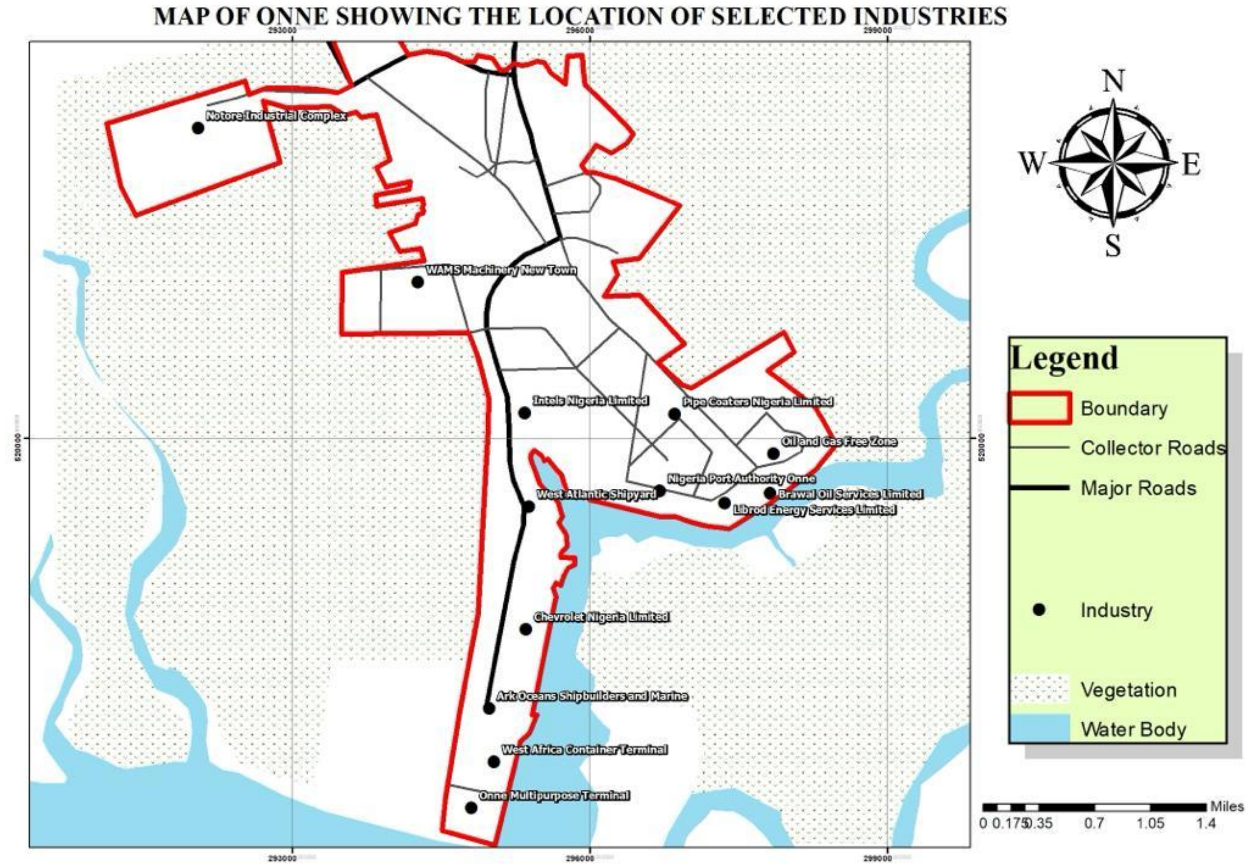

Figure 1: Map of the study area

2.2 Truck Emissions Measurements

A portable Testo 350 Analyzer (Plate 1)which adheres to ASTM D3249-95 (2000) standards and equipped with specific sensors, was utilized to measure exhaust emissions of the trucks, including Carbon Monoxide (CO), Nitrogen Oxides (NO_2), Sulphur Dioxide (SO_2), The Analyzer probe was inserted into the exhaust outlet of each truck, ensuring a secure and airtight connection within the exhaust pipe, and clamped in place for a continuous monitoring of gas emission in real time while the trucks were in operation. The readings were promptly displayed on an LCD screen, enabling immediate data capturing and analysis of the emission levels. Also, a portable IGRESS Intelligent Detector, which adhered to the ASTM D4096-91(1997) standard (Plate 2) was used to detect Particulate Matters (PM) of different sizes (PM_1, $PM_{2.5,}$ PM_{10}). By employing infrared spectroscopy technology, the IGRESS detector analysed the composition and concentration of particulate matter by passing an infrared beam through the air sample and measuring the particles' light absorption. The detector was positioned closer to the exhaust pipe of the trucks during their operations, enabling it to continuously sample the air and provide real-time measurements of particulate matter (PM_1, $PM_{2.5}$ and PM_{10}) concentrations. These readings were displayed on a digital screen, facilitating immediate assessment of the levels of particulate matter present in the truck emissions in micrograms per cubic meter ($\mu g/m^3$). The data collection phase encompassed the examination of emissions from 70 trucks grouped according to production years, region of origin, and truck length, with the purpose of evaluating them in relation to the standards set by the World Health Organization (WHO). Qualitative data was obtained through confidential oral interviews with truck drivers to determine the type of fuel used. Truck model names and manufacturing years were identified using various methods, including locating them on different parts of the trucks and utilizing the Vehicle Identification Number (VIN).

Plate 1: Testo 350 Analyzer

Plate 2: A portable IGRESS Intelligent Detector

2.3 Qualitative Assessment

To gather information on the type of fuel used by haulage truck drivers, confidential oral interviews were conducted, assuring drivers of anonymity. The drivers willingly shared details about their fuel usage without reservation. Truck model names were identified from various sources, including badges, emblems, and vehicle panels. The manufacture year of trucks was sourced from reliable Vehicle Identification Numbers (VINs). These steps ensured robust data collection and formed the basis for the presented decision analysis table, allowing for informed evaluations of factors such as minimal maintenance, use of illegal diesel (KPO), awareness of environmental and health impacts, and health problems due to KPO fires.

Table 1: Assessment of Truck Fuel Types and Recommended Actions

Statement	Strongly Agree	Agree	Disagree	Strongly Disagree	Weighted Mean	Decision
Minimal maintenance of the truck	20	40	10	0	3.14	Maintain regularly
Use of illegal diesel (KPO)	70	0	0	0	4	Investigate and address
Awareness of negative environmental impact	40	20	10	0	3.43	Raise awareness
Awareness of the negative health impact	36	10	10	14	2.97	Provide education
Health problems due to KPO fire	38	17	10	5	3.26	Improve safety measures

2.4 Statistical Analysis

The outcomes of the conducted one-way ANOVA analyses on emissions (NO_2, SO_2, CO, PM_1, $PM_{2.5}$, PM_{10}) from truck exhaust, grouped by production year, region of origin, and truck type, reveal p-values of 0.869, 0.620, 0.405 for NO_2; 0.46, 0.188, 0.223 for SO_2; 0.851, 0.176, 0.768 for CO; 0.886, 0.973, 0.203 for PM_1; 0.627, 0.823, 0.152 for $PM_{2.5}$; and 0.974, 0.662, 0.110 for PM_{10}. All these p-values surpass the predetermined significance threshold of 0.05, implying an absence of statistically significant discrepancies in emissions across the different categories for each pollutant type, production year, region of origin, and truck type.

3. Results and Discussion

3.1 Concentrations of air pollutants from trucks of different production years

Figure 2indicates that trucks produced between 2011 and 2021 exhibited the highest averageconcentrations of NO_2(35.48 ppm). Conversely, trucks manufactured between 1991 and 2000 demonstrated the lowest average NO_2concentration of 32.05 ppm. Sulphur dioxide (SO_2) emissions were found to be highest from trucks produced between 1991 and 2000, with an average concentration of 31.16 ppm, while trucks manufactured between 2011 and 2021 exhibited the lowest average SO_2 concentrations of 23.93 ppm. Carbon monoxide (CO) emissions peaked in trucks manufactured between 2001 and 2010 with an average concentration of 775.87 ppm. Conversely, trucks produced between 1980 and 1990 had the lowest average CO concentration of 699.00 ppm. Trucks manufactured between 1980 and 1990 displayed the highest average concentrations of PM_1(216.75µg/m^3), while trucks produced between 2001 and 2010 had the lowest average PM_1concentration of 188.30 µg/m^3. For $PM_{2.5}$, trucks manufactured between 2011 and 2021 exhibited the highest average concentrations of 300.73 µg/m^3, whereas trucks produced between 2001 and 2010 showed the lowest average $PM_{2.5}$ concentration of 250.87 µg/m^3. Regarding PM_{10}, trucks manufactured between 1980 and 1990 had the highest average concentrations of 341.75 µg/m^3, whereas trucks produced between 2001 and 2010 displayed the lowest average PM_{10}concentration of 322.23 µg/m^3.The findings related to the production year suggest that newer trucks tend to have higher emissions of NO_2 and $PM_{2.5}$, while older trucks tend to have higher emissions of SO_2, CO, PM_{10} and PM_1. One possible reason for this could be that newer trucks are equipped with advanced emission control technologies such as diesel particulate filters and selective catalytic reduction, which reduce emissions of particulate matter but may increase NO_2 emissions due to the way they work. On the other hand, older trucks may not have these technologies, resulting in higher emissions of SO_2, CO, and PM_1.

Statistical analyses were performed utilizing one-way ANOVA to explore the potential connection between the production years of the trucks. However, when examining the concentrations of NO_2, SO_2, CO, PM_1, $PM_{2.5}$, and PM_{10}, both individually and as a whole, the resulting p-values (0.869, 0.46, 0.851, 0.886, 0.627, 0.974 respectively) exceeded the threshold of 0.05, indicating that there was no statistically significant difference in pollutant concentrations among trucks of different production year categories.Although these findings suggest that the production year of trucks has no impact on emissions, however newer trucks, tend to generally emit higher levels of NO_2 and $PM_{2.5}$ than their older version. This observation can be attributed to the presence of advanced emission control mechanisms, such as diesel particulate filters and selective catalytic reduction (SCR) systems, in modern trucks. On the other hand, older trucks lacking these advanced technologies tend to have higher emissions of SO_2, CO, PM_1,andPM_{10}. This disparity highlights the importance of implementing emission control measures in older vehicles to mitigate their environmental impact and improve air quality.

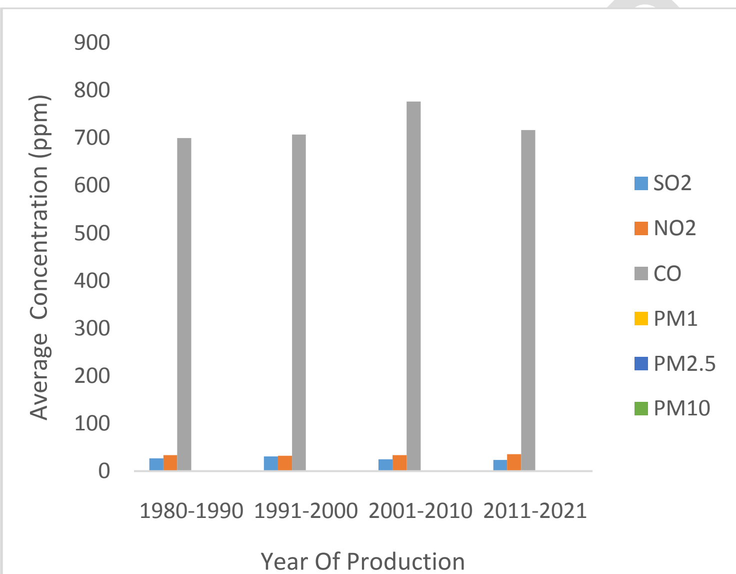

Figure 2: Truck emission according to production year

3.2Concentrations of air pollutants from trucks of different Region of Origin

Extensive analysis of the region of origin's influence on truck emissions reveals intriguing patterns and variations in pollutant concentrations. The data (Figure 3) indicate that trucks manufactured in Asia consistently exhibit lower concentrations of pollutants compared to those made in other regions. Specifically, trucks originating from Asia display the lowest average NO_2 concentration at 29.80 ppm, while trucks manufactured in Europe show the highest average NO_2 concentration at 34.74 ppm. Similarly, trucks produced in Asia exhibit the lowest average SO_2 concentration at 21.43 ppm, whereas trucks made in North America demonstrate the highest average SO_2 concentration at 28.82 ppm. In terms of carbon monoxide (CO) emissions, trucks originating from Asia display the lowest average concentration at 574 ppm, while trucks manufactured in North America exhibit the highest average CO concentration at 783.37 ppm. Moreover, trucks manufactured in Asia have the lowest average concentrations ofPM_1 at 190.86 µg/m3, while trucks made in Europe have the highest average PM_1 concentration at 197.69 µg/m3. Also, in the case of $PM_{2.5}$ emissions, trucks manufactured in North America display the lowest average concentration at 255.64 µg/m3, while trucks originating from Asia show the highest average $PM_{2.5}$ concentration at 282.00 µg/m3. Lastly, trucks manufactured in Asia exhibit the lowest average PM_{10} concentration at 291.00 µg/m3, while trucks made in Europe have the highest average PM_{10} concentration at 334.77 µg/m3.

Further analysis using one-way ANOVA testswas conducted to explore the statistical significance of the differences in pollutant concentrations based on the region of origin. The results indicate that for all pollutants (NO_2, SO_2, CO, PM_1, $PM_{2.5}$, and PM_{10}) bothindividually and collectively, the obtained p-values (0.62, 0.188, 0.176, 0.973, 0.823 and 0.662 respectively) were greater than the preset significance level of 0.05. This suggests that there is no statistically significant difference in pollutant concentrations among the different regional categories.

However, it is important to consider that emission standards and regulations may differ among regions, contributing to the variations observed. One possible reason for this could be the difference in emission standards set by different countries. For instance, Japan has some of the strictest emission standards for diesel engines in the world, which could explain why trucks manufactured in Asia have lower emissions (TransportPolicy.net, 2018).

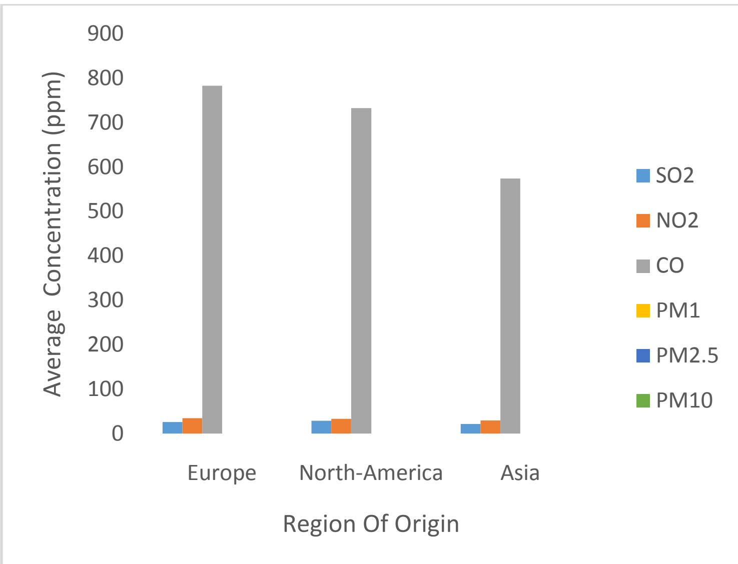

Figure 3: Truck emission according to Region of Origin

3.3 Concentrations of air pollutants from trucks of different Truck Length

Analysis of truck emissions based on their truck length shows the relationships between the pollutants and the truck type in length (Figure 4). Specifically, the NO_2 concentration in the 20ft trucks was 7.6% higher, the SO_2 concentration was 11.5% higher, the CO concentration was 2.7% higher, the PM_1 concentration was 12.9% higher, the $PM_{2.5}$ concentration was 16.8% higher, and the PM_{10} concentration was 14.4% higher than those in the 40ft trucks. To further analyze the statistical significance of these differences, a one-way analysis of variance

(ANOVA) (Table 3) was conducted for each pollutant category. The obtained individual P-values for NO_2, SO_2, CO, PM_1, $PM_{2.5}$, and PM_{10} were 0.405, 0.223, 0.768, 0.203, 0.152, and 0.110, respectively while that of the collective pollutant was 0.989. These P-values were compared to the preset alpha value of 0.05, which is commonly used to determine statistical significance. Since all the obtained P-values were greater than 0.05, it suggests that there is no statistically significant difference in pollutant concentrations among the different truck categories.

These findings indicate that the size of the haulage trucks, specifically 20ft and 40ft, does not have a significant impact on emissions from their exhaust. This aligns with a previous study conducted by Mansoori et al. in 2020, which also found no correlation between truck size and fuel consumption or emissions during cargo transportation. Therefore, it can be inferred that both truck types emit similar levels of air pollutants.

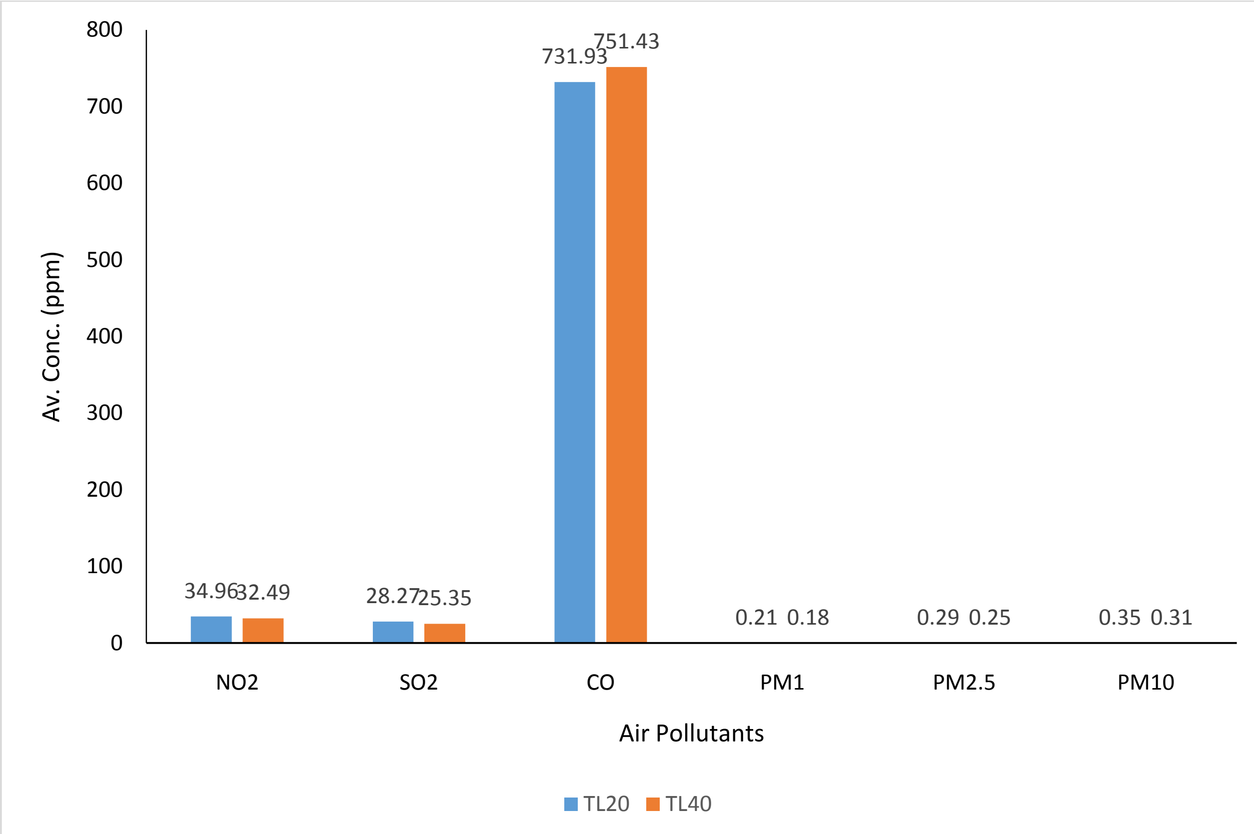

Figure 4: Average concentrations of air pollutants emitted from different truck type exhausts

The data(Table 4) also reveals that the concentration of all pollutants exceeded the permissible limit set by the World Health Organization (WHO). A study conducted by Onwuegbuchunam et al in 2021 looked into the air quality at Onne Port and found that the levels of ozone, carbon monoxide, nitrogen dioxide, Sulphur dioxide, and particulate matter were alarmingly high and exceeded the safe limits set by the World Health Organization (WHO). The researchers identified that the trucks transporting goods in and out of the Port could be a significant contributor to these emissions. Another study by Omoko and his team in the same year evaluated the air quality in the surrounding areas of Onne Port, choosing ten measurement stations, four of which were located within the Port. They discovered that carbon monoxide was the most prevalent pollutant in the Port area and although the air quality was better in other areas outside the Port, with lower mean values of other pollutants, one of the stations within the Port still recorded readings that exceeded the WHO standards.

Table 2: Quantitative comparison of criteria Pollutants with truck production year, the region of origin, and the truck types

Pollutant	Highest Concentrations (Production Year)	Lowest Concentrations (Production Year)	Lowest Concentrations (Region)	Highest Concentrations (Region)	20ft vs 40ft	WHO Permissible Limit Exceeded?
NO_2	Trucks: 2011-2021 (35.48 ppm)	Trucks: 1991-2000 (32.05 ppm)	Asia (29.80 ppm)	Europe (34.74 ppm)	20ft > 40ft 7.6%	Yes (0.012ppm)
SO_2	Trucks: 1991-2000 (31.16ppm)	Trucks: 2011-2021 (23.93ppm)	Asia (21.43ppm)	North America 28.82ppm)	20ft > 40ft 11.5%	Yes (0.014ppm)
CO	Trucks: 2001-2010 (775.87 ppm)	Trucks: 1980-1990 (699.00 ppm)	Asia (574ppm)	North America (783.37ppm)	40ft > 20ft 2.7%	Yes (0.003ppm)
PM_1	Trucks: 1980-1990 (216.75 μg/m^3)	Trucks: 2001-2010 (188.30 μg/m^3)	Asia (190.86 μg/m^3)	Europe (197.69 μg/m^3)	20ft > 40ft 12.9%	Yes (25 μg/m^3)
$PM_{2.5}$	Trucks: 2011-2021 (300 μg/m^3)	Trucks: 2001-2010 (250.87 μg/m^3)	North America (255.64 μg/m^3)	Asia (282.00 μg/m^3)	20ft > 40ft 16.8%	Yes (25 μg/m^3)
PM_{10}	Trucks: 1980-1990 (341.75 μg/m^3)	Trucks: 2001-2010 (322.23 μg/m^3)	Asia (291.00 μg/m^3)	Europe (334.77 μg/m^3)	20ft > 40ft 14.4%	Yes (50 μg/m^3)
Truck	Man Diesel Commander, Volvo, Mack, Howo, Man Sema, DAF, Iveco, Astra, Man Diesel GGR, Mercede,					

Brand	Sinotruck, Scania, Shacman, Man Commander, Renault, and Man TGS.

3.4 Qualitative Analysis

Following interviews with 70 haulage truck drivers, a qualitative analysis was conducted to identify recurring themes and patterns in their responses. The analysis revealed two primary themes: the prevalent use of adulterated locally refined diesel known as KPO fire and the drivers' awareness of its harmful effects. Despite its illegality, all drivers reported using KPO fire due to reasons such as cost and availability. Most drivers were conscious of the negative impact of KPO fire on their health and the environment, with some experiencing health issues and others expressing concerns about long-term environmental damage. The analysis emphasized the widespread usage of KPO fire among Onne haulage truck drivers and their awareness of its potential harm.

Qualitative data indicates that the utilization of adulterated diesel fuel, also known locally as KPO fire fuel, by all drivers, may contribute to increased emissions of pollutants. The use of low-quality fuel can result in incomplete combustion and higher emissions of pollutants such as NO_2, SO_2, CO, PM_1, $PM_{2.5}$, and PM_{10}. This finding aligns with a study by Tan et al. (2013) that discusses the impact of fuel characteristics on diesel engine emissions. The study emphasizes that low-quality fuel with higher sulfur and aromatic content leads to higher emissions of pollutants. Another study by Okedere et al. (2021) identifies petroleum production and the use of fossil fuels in thermal plants as significant sources of air pollution in Nigeria. They suggest implementing cleaner energy policies to reduce pollutant emissions. Therefore, although the one-way ANOVA analysis did not find significant differences in the various categories, the quality of fuel used by trucks appears to be a crucial factor in determining emission levels, which is supported by the studies conducted by Onwuegbuchunam et al. (2021), Omoko et al. (2021), Tan et al. (2013), and Okedere et al. (2021).

4. Conclusion

The assessment of exhaust emissions from haulage trucks at Onne Port in Rivers State, Nigeria was conducted. The result showed that diesel trucks use for freight transportation in Onne Port emit high levels of air pollutant. This comprehensive analysis of truck emissions, considering diverse factors such as production years, regional origins, and types, offers crucial insights into the intricate interplay between pollutants, specific truck characteristics, and the regional dynamics. The findings indicate that newer trucks tend to have higher emissions of NO_2 and $PM_{2.5}$, potentially due to the presence of advanced emission control technologies. On the other hand, older trucks without these technologies exhibit higher emissions of SO_2, CO, PM_1, and PM_{10}. Also trucks manufactured in Asia tend to have lower emissions of all pollutants, while trucks made in North America tend to have higher emissions of CO, $PM_{2.5}$, and PM_{10}. The variation in emission standards and regulations across regions may contribute to the observed disparities in pollutant levels. Moreover, the analysis revealed that the size of haulage trucks, whether 20ft or 40ft, does not significantly impact emissions. Additionally, qualitative data highlighted the prevalent use of adulterated diesel fuel and the drivers' awareness of its harmful effects, suggesting that the quality of fuel used in trucks plays a crucial role in emission levels. This study underscores the pressing need for emissions control and regulation in the context of haulage trucks at Onne Port. It emphasizes that emissions are influenced by a complex interplay of factors, including truck age, origin, and type of fuel used.Therefore, it is recommended to implement emission control measures in older vehicles, promote the use of cleaner fuel alternatives, and continue monitoring and enforcing emission standards to reduce the environmental impact of truck emissions and improve air quality.

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