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Evaluation of Air Pollution and Mitigation Using Analysis Technological Approach Factors; A Study of Warri Seaport

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Abstract

The transportation sector is one of the largest energy end users, leading to more than 26.6% of all the energy use worldwide and thirty third in Europe, hence among the principal air polluters with an unbroken increase as projected by the European Commission. The researchers carried a research work on air pollution and mitigation technologies in Nigeria Seaport with Warri seaport as a focus. To establish pollution in the area, pollutants such as CO, NO_2, CO_2, HC and SO_2 were critically monitored with air sample analyser monitors, at source, receptor and Airport Junction Warri as control. The researchers found that the values in wet season was CO (17.30±0.80ppm), NO_2 (0.025±0.002ppm), SO_2 (0.028±0.002 ppm), CO_2 (370.50±21.00 ppm) and HC (0.015±0.012 ppm) while the values of the concentration during the dry season was CO(20.20±2.23ppm), NO_2(0.019±0.007ppm), SO_2(0.025±0.002ppm), CO_2(370.50±25.00ppm) and HC (0.015±0.093ppm) were significantly high. The observed values were found to be significantly different between the two seasons and higher than those observed in the control group across the seasons as well exceeded the safe allowable limits for gaseous pollutants when compared with both the Nigerian and international standards. This increase is a concern to Nigeria's commitments to implementations of (Annex VI) International Maritime Organization's (IMO) Convention for the Prevention of Marine Pollution (MARPOL 73/78) from Ships. However, survey data obtained were analyzed using both descriptive and inferential statistics. The results from the Factor Anaysis and Principal Component Analysis show that there are air pollution mitigation factors for ocean going and harbour vessels in Warri seaport, alternative fuel significantly impact on air pollution mitigation in Warri seaport. Recommendations were made towards adopting appropriate mitigation technologies in Warri seaport

Keywords: *Technological; Factors; air; pollution; mitigation; Warri Seaport*

1.0 Introduction

Ships' daily activities and accidents are some of the causes of marine environmental pollution (Ozdemir, Yılmaz & Basar, 2015). However, there are no substantial empirical evidences whatsoever that has scrutinized this assertion in the Nigeria marine transport domain (Anyanwu, 2022). There are several ways the transportation system have an effect on the natural environment. Some of these are construction facilities for moving people as well as goods and services like highways, airport and seaport facilities like the runways has its impacts on land, vegetation, and natural habitats. Another impact on the immediate environment is the vehicles which are used for transportation system **(Meyer, 2010).**

There is an increasing need to ensure efficient mitigation strategies for seaport pollution sources in Nigeria as seen in most ports in advance countries of the world. Several studies on human epidemiology established that diesel exhaust raises cancer risks. A study in 2000 at California found out that 70 percent of the cancer risk from air pollution is due to diesel exhaust, (California Air Resources Board, 2000). According to Pandya, Solomon, Kinner, & Balmes, (2002), Asthma has been associated with diesel exhaust in many current studies. Particulate matter (PM), volatile organic compounds (VOCs), nitrogen oxides (NOx), and sulfur oxides (SOx) are key air pollutants from diesel engines at ports that can have adverse effect on human health.

Onwuegbuchunam, Egelu, Aponjolosun and Okeke (2021) investigated the constituents of ambient air in Onne port's environment in Rivers State of Nigeria and found that mean concentrations (μg·m3) of the following pollutants: O_3 (71.776 ± 0.726), CO, (19.145 ± 0.275) NO_2 (28.145 ± 0.965) and SO2 (36.913 ± 0.378) were significantly high. The particulates (PM_{10}, $PM_{2.5}$) also showed higher mean concentrations of 48.400 ± 0.197 and 29.676 ± 0.352 respectively. Olayimka, Adedeji, and Ajibola, (2015) empirically researched on air pollutants CO_2, NO_2, CO, NO_2, H_2S and suspended Particulate Matter arising from vehicular emissions in Abeokuta metropolis. Also Anyanwu (2017) looked at the cost benefit of espousing liquefied Natural Gas as marine propulsion fuel with respect to other marine fuels of MGO and MDO in meeting the Annex IV of IMO 2020 requirement. The researchers therefore examine the pollutants present in Warri port environment. Against the background of information on empirical evidences of pollution on some of the Nigerian seaports and research gap still existing on empirical evidence from Warri seaport, this study will estimate the level of concentration of SO_X, NO_X, CO, CO_X and Particulate Matters in Warri port and compare same with the concentration of the control environment, this will enable the research to entirely establish the evidence of pollution in Warri seaports before further research process on the mitigation technologies in the ports.

Warri seaport is in Delta state, it belongs to one of the low traffic ports in Nigeria after Onne and Rivers seaports. A visit to Warri seaports shows that there are inadequate air pollution mitigation technologies in the seaport; therefore, to reduce air pollution in our seaports, mitigation technologies must be present, this brings to the fore the following questions;

- Could it be that the level of pollutants emission in Nigeria seaport are not in line with the National and international standards?
- Are there available air pollution reduction technologies in our seaports?
- Are there other mitigation strategies used to curb emissions in our ports?

Methodology

The study was carried out in Warri port, Nigeria.

Location: Warri is situated on the Warri River, 126km from the Bight of Benin. Warri has two ports with 8 berths at the old port, which includes Ogunu Wharf and 6 berths at the new port. A significant increase in traffic has resulted from the recent extensions to the quays and dredging programmes. The major exports are crude oil, LPG and steel, the main imports being food products, machinery and general cargo. Traffic figures: Approx 382,000t of cargo and 1,000TEU are handled annually. Load line zone: Tropical. Max size: Dry Cargo: LOA 250m, max draught at Escravos Bar 6.4m, up to 7.2m at HW. Tankers: LOA 156m, draught 6.4m, 15,000DWT.

Figure 1. The map of the study area showing the sampling locations.

2.0 Equipment and Field Materials

The equipment or air analyser that was used to obtain data for this study was sourced from the department of Environmental Technology, School of Engineering. FUTO. The equipment are as follows:

1. **Air samplers** (CROWNCON GASMAN TO MODEL CE89/336/EEC) for CO, NO_2, SO_2 and HC measurement: this instrument is an automatic ambient air measuring instrument which uses infrared sensing technology.

2. **CO_2 meter** (MODEL EE80): This instrument works on the principle of infrared sensing technology. The instrument was used for temperature and relative humidity measurements in the course of the survey. It has the capacity of measuring carbon dioxide within the range of 0 - 4000ppm, with resolution boast of 1ppm and an accuracy of +/- 40ppm. It can measure temperature in the range of -20oC to 60oC and relative humidity range of 10-95%RH

3. **Global Positioning System (GPS) Receiver** (Garmin model 60 CSx): This was used to determine the exact coordinates of the sampling sites in the seaports. The elevation of the sites above sea level was determined with the aid of this GPS receiver.

4. Mobile handset with in-built GPRS was used for monitoring wind speed at the seaport sites. The wind direction was determined by visual observation of the smoke particles released from the tailpipe of moving vehicles (trucks, cargo handling equipment etc). The direction of the particles emitted determined the position assumed when taking emission readings.

3.0 Inquiry and Definitions

In this research work, the variables that were studied specifically are the Sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), hydrocarbon (HC) and carbon dioxide (CO_2) at ground level in relation to traffic in the port. In this research work, ground level was defined as five (5) feet above the ground at intersections within the port. The height of five feet has been chosen because it characterizes the height of breathing of human beings, both standing and seating.

Traffic "hot spots" in this work are intersections in the port with high vehicular levels. The "background" (about 100 metres away from traffic), air quality measurements from "background" were equally carried out. Measurement at a "control site" was carried out. A control site in this context is an area adjudged free from significant impact of traffic/vehicular emission.

Results and Discussions

Level of Ambient Air Quality air pollutants, CO, CO_2, NO_2, HC, and SO_2 were critically monitored. The descriptive statistics of these pollutants in ambient air measured across sample locations within port and the control are presented in Table 7 and table8 below, much variability was observed among these pollutants across the sampling period and locations.

Table 1: Average traffic volumes per hour in selected points in Warri Port

Sampling Site	Average traffic volume per hour			
	Locomotives/Trucks	Cargo Handling Equipment	Vessels	Total
Warri seaport	56 ± 5	114 ± 2	6 ± 1	176 ± 8

Source: Field work

Principle Components Analysis (PCA) & Exploratory Factor Analysis (EFA)

Principal components analysis and Factor analysis are related techniques that can be used to replace one group of variables with another. One reason a researcher may want to do this is to reduce the number variables being studied.

EFA was used to explain the pattern of relationships within the data set and to compare them against the hypothesized Air pollution Mitigation Technologies) APOMITECH dimensions. EFA has three basic decision points (1) decide the number of factors, (2) Choosing an extraction method and (3) choosing a rotation method.

The most common approach to deciding the number of factors is to generate a scree plot. The scree plot is a two-dimensional graph with factors on the x-axis and *Eigeenvalues* on the y-axis. The eigenvalues are produced by the process of PCA and represents the variance accounted for each underlying factor.

Given the expectation that the APOMITECH dimensions might be correlated, an iterated EFA was performed on all the data sets using PCA rotated by orthogonal Promax algorithm (assumes that the factors are correlated. The eigenvalues greater than one and above is selected as a principal component to be analysed with the highest eigenvalue explaining the percentage of variance in the data analysed. The factor loading greater than 0.4 in absolute value was suppressed to sharpen the clarity of the relationships.

What is the major mitigation technology for ocean vessels and harbour vessels, CHEs and locomotive in Warri seaport?

Table 2 Descriptive Statistics

	N	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
Application of shoreside power or cold ironing technology	87	4	5	2351	4.70	.458	.210
Use of automatic idling control device	87	2	5	1880	3.76	.936	.876
Adoption of cleaner marine fuels such as LNG in the vessels to reduce sulphur	87	1	4	1011	2.02	1.103	1.216
Installation of emission reduction equipment such as scrubbers	87	2	5	1936	3.87	1.023	1.046

Engine temperatures reduction through direct water injection to reduce NOx	87	2	5	2184	4.37	.733	.538
The use of humid air motors to reduce NOx	87	3	5	2321	4.64	.488	.238
Facilitating alternative fueling infrastructure by port for hydrogen	87	2	5	1928	3.86	1.057	1.117
Repower equipment more than ten years old with alternative-fuel engines	87	1	4	1288	2.58	1.246	1.551
Retrofit equipment less than 10years with the best available control technology.	87	1	4	806	1.61	.889	.791
Existing equipment should be switched to cleaner diesel fuels.	87	1	5	2116	4.23	.753	.567
Purchase new equipment that uses alternative fuels	87	1	5	2116	4.23	.753	.567
Automated gate systems to reduce queue times and emissions	87	1	5	982	1.96	1.175	1.381
Use of electrification technology	87	3	5	2438	4.88	.348	.121
Use of Liquefied Natural Gas on Locomotives	87	1	5	2000	4.00	.566	.321
Locomotives and trains engines must be service regularly	87	1	4	806	1.61	.889	.791
Conversion of existing engines to LNG engines	87	4	5	2421	4.84	.365	.133
Need for sufficient infrastructures for the projects such as land and power	87	4	5	2304	4.61	.489	.239
Requirement of sufficient infrastructures fueling terminal	87	4	5	2444	4.89	.316	.100
Application of srubber not shore side power or CI technology	87	2	5	2133	4.27	.790	.624
Use of automatic idling control device	87	2	5	1681	3.36	.957	.917
Valid N (listwise)	87						

Source: SPSS Iterations

The summary of the description of the entire variables posed in the study is presented in the table 2 with the mean and standard deviations of the variables resulting from the survey on technological mitigation strategies of air pollution in Warri Seaport. On the whole, about 15 of the variables recorded mean values greater than 3.0 corresponding approximately to the 15 variables with highest scores in the factor analysis along with associated factors which scored in excess of 0.500 (see table 3).

Table 3. Component Matrix[a]

	Component				
	1	2	3	4	5
Application of shoreside power or cold ironing technology			.741		
Use of automatic idling control device	.701				
Adoption of cleaner marine fuels such as LNG in the vessels to reduce Sulphur	.631				
Installation of emission reduction equipment such as scrubbers					-.618
Engine temperatures reduction through direct water injection to reduce NOx				.633	.541
The use of humid air motors to reduce NOx	.787				
Facilitating alternative fueling infrastructure by port for hydrogen	.562		.618		
Repower equipment more than ten years old with alternative-fuel engines					-.676
Retrofit equipment less than 10years with the best available control technology.	.659				
Existing equipment should be switched to cleaner diesel fuels.	.870				
Purchase new equipment that uses alternative fuels	.870				
Automated gate systems to reduce queue times and emissions		.555	-.614		
Use of electrification technology		-.521	.520		
Use of Liquefied Natural Gas on Locomotives		-.768			
Locomotives and trains engines must be service regularly	.659				
Conversion of existing engines to LNG engines				.750	
Need for sufficient infrastructures for the projects such as land and power	-.634	.513			
Requirement of sufficient infrastructures fueling terminal		.568	.522		
Application of scrubber not horeside power or CI technology				-.713	
Use of automatic idling control device	.718		-.594		

Extraction Method: Principal Component Analysis.

a. 5 components extracted.

Source: SPSS Iterations

Exploratory Factor Analysis of air pollution mitigation strategies in Warri Seaports

The factors which describe the critical variables that impinges on technological mitigation strategies of oceangoing vessels and harbour vessels. To achieve some reduction in the categorical data points to deal with, while also investigating the structure of the data, an exploratory factor analysis was carried out. It was hoped that the analysis would also serve the purpose of streamlining the study by removing highly correlated variables from the data set. The Principal Component Analysis (PCA) was the extraction method used under the IBM SPSS 20.0 system.

As it turned out, the result of the PCA (principal component analysis) seemed somewhat reasonable in the absence of a clear idea of the nature of the distribution of Warri seaport personnel interviewed in the study. The numbers of components retained following the analysis were five.

The data structure suggests that there are twenty principal components of the factors in the analysis. These factors were retained for rotation following the varimax (orthogonal) rotation function of the PCA which selects for all factors with Eigen values greater than 1.0. Although, this may not be the most accurate method for selecting the number of factors to retain, a careful inspection of the Scree plot (see figure 1.) shows that some confidence can be place on the number of factors selected and that there is probably no over extraction or under-extraction of factors retained.

It seems clear then that the five components represent the underlying structure of the factors used in the study with 82.9 per cent of the total variance in the original variables, with only 17.1 per cent loss of information.

Table 4: Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
Application of technology for both harbour and OGV ships	5.486	27.431	27.431	5.486	27.431	27.431
Use of automatic idling control device	3.296	16.478	43.909	3.296	16.478	43.909
Adoption of cleaner marine fuels such as LNG in locomotives and CHE vessels to reduce Sulphur	3.224	16.121	60.030	3.224	16.121	60.030
Installation of emission reduction equipment such as scrubbers	2.562	12.812	72.842	2.562	12.812	72.842
Engine temperatures reduction reduces NOx	2.005	10.027	82.870	2.005	10.027	82.870
The use of humid air motors to reduce NOx	.952	4.761	87.630			

Facilitating alternative fueling infrastructure by port for hydrogen	.846	4.231	91.861			
Repower equipment more than ten years old with alternative-fuel engines	.631	3.154	95.015			
Retrofit equipment less than 10years with the best available control technology.	.261	1.305	96.320			
Existing equipment should be switched to cleaner diesel fuels.	.209	1.043	97.363			
Purchase new equipment that uses alternative fuels	.167	.836	98.198			
Automated gate systems to reduce queue times and emissions	.151	.753	98.951			
Use of electrification technology	.079	.394	99.345			
Use of Liquefied Natural Gas on Locomotives	.064	.320	99.665			
Locomotives and trains engines must be service regularly	.031	.157	99.822			
Conversion of existing engines to LNG engines	.020	.101	99.923			
Need for sufficient infrastructures for the projects such as land and power	.011	.056	99.980			
Requirement of sufficient infrastructures fueling terminal	.004	.020	100.000			
Application of scruber not cold ironing technology	2.775E-016	1.388E-015	100.000			
Use of automatic idling control device	-3.833E-016	-1.917E-015	100.000			

Extraction Method: Principal Component Analysis.

Source: SPSS Iteration

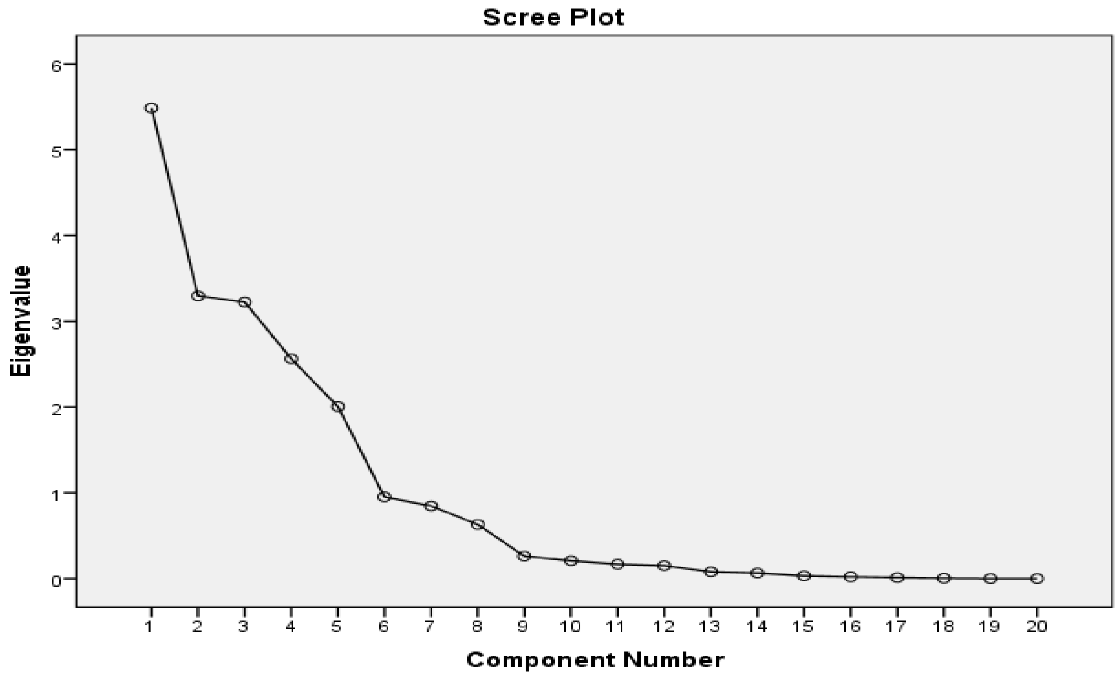

Fig 1: A Scree Plot of Total Variance of technological mitigation of pollutants

Source: SPSS Iterations

From the table 4, 20-item variables optimally weighted and summed based on the Kaiser criterion of Eigen value cut-off of 1.0, there were 5 components that explained a cumulative variance of 82.9%. The Scree plot confirmed the findings of retaining 5 components. The Scree plot is a visual representation of how much the Eigen value explained the components identified. The last point of inflexion at component 6, signifies that only 5 components should be retained.

As shown in total variance explained table of table 4.3, PCA has assisted us to identify five underlying components explaining 82.9% of the common variance.

Table 5: Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
Purchase new equipment that uses alternative fuels	.870				
Existing equipment should be switched to cleaner diesel fuels.	.870				
The use of humid air motors to reduce NOx	.787				-.304
Requirement of sufficient infrastructures fueling terminal	.718		-.594		
Use of automatic idling control device	.701	-.315			
Retrofit equipment less than 10years with the best available control technology.	.659	.409	-.398		
Use of electrification technology	.659	.409	-.398		
Locomotives and trains engines must be service regularly	-.634	.513		-.433	
Conversion of existing engines to LNG engines	.631	-.452	.429		

Use of Liquefied Natural Gas on Locomotives		-.768			
Rebuilding existing engines to LNG engines		.568	.522	-.418	
Use of electrification technology		-.521	.520		
Application of scrubber		.463	.741		
Facilitating alternative fueling infrastructure by port for hydrogen	.562	.303	.618		
Automated gate systems to reduce queue times and emissions	.313	.555	-.614		
Conversion of existing engines to LNG engines				.750	.411
Trains engines must be service regularly	.342			-.713	.488
Engine temperatures reduction through direct water injection to reduce NOx				.633	.541
Repower equipment more than ten years old with alternative-fuel engines		.436	.380	.336	-.676
Installation of emission reduction equipment such as scrubbers	.359	-.490		.402	-.618

Extraction Method: Principal Component Analysis.

a. 5 components extracted.

Component 1: explained 27.40% of the total variance in the data analysed and has Eigen value of (5.486). Component 1 is the major mitigation technology for OGVs and Harbour ships in the Warri port. Among the variables that correlated positively with component one and greater than 0.50 are;

Purchase new equipment that uses alternative fuels	0.870
Existing equipment switched to cleaner diesel fuels.	0.870
The use of humid air motors to reduce NOx	0.787
Requirement of sufficient infrastructures fueling terminal	0.718
Use of automatic idling control device	0.701
Retrofit equipment less than 10years with the best available control technology	0.659
Use of electrification technology	0.659
Conversion of existing engines to LNG engines	0.631
Facilitating alternative fueling infrastructure by port for hydrogen	0.562

Application of technology on ships variable has the highest factor loading of 87.0%. Thus, component one can be identified as **alternative fuel and new equipment Factor**.

Component 2: explained 16.480% of the total variance in the data analysed and has Eigen value of (3.296). Among the variables that correlated positively with component 2 and greater than 0.50 are;

Rebuilding existing engines to LNG engines	0.568

Automated gate systems to reduce queue times and emissions 0.555

Locomotives and trains engines must be service regularly 0.513

Use of automatic idling control device variable has the highest factor loading of 56.8%. Thus, component two can be identified as **Rebuilding existing engines Factor**.

Component 3: explained 16.12% of the total variance in the data analysed and has an Eigen value of (3.224). Among the variables that correlated positively with component 3 and are significant (greater than 0.50%) are;

Application of scruber 0.741

Facilitating alternative fueling infrastructure by port for hydrogen 0.618

Rebuilding existing engines to LNG engines 0.522

Use of electrification technology 0.520

Therefore, component 3 can be identified as **scrubber factor** because of the variable has the highest factor loading of 74.1% among the other variables.

Component 4: explained 12.8% of the total variance in the data analysed and has an Eigen value of (2.562). Among the variables that correlated positively with component 4 and are significant (greater than 0.50%) are;

Conversion of existing engines to LNG engines 0.750

Engine temperatures reduction through direct water injection to reduce NOx 0.633

Therefore, component 4 can be identified as **Conversion to LNG engines factor** because of the variable has the highest factor loading of 75% among the other variables

Component 5: explained 10% of the total variance in the data analysed and has an Eigen value of (2.005). Among the variables that correlated positively with component 5 and are significant (greater than 0.50%) are;

Engine temperatures reduction through direct water injection to reduce NO_x 0.541

Therefore, component 5 can be identified as **Water injection** F**actor** because of the variable has the highest factor loading of 54.1%.

Test of Hypotheses

There are no significant air pollution mitigation factors for CHE, Ocean Going and harbour vessels in Warri seaport.

From the total variance table 4 and the scree plot of figure 1, PCA identified five underlying components explaining (0.829) > (0.50) or 82.9% of the air pollution mitigation technology factors for CHE, ocean going and harbour vessels in Warri seaport.

This implies that the variables are significant mitigation technologies for CHE, ocean going and harbour vessels. Thus, the null hypothesis was rejected and the alternate accepted. The researchers conclude that there are significant mitigation factors for ocean-going and harbour vessels in Warri Seaport.

Table 6. Average concentration of air pollutants during the morning, afternoon and evening hours in dry season

Location	Air Quality Parameter						Meteorology	
	Afternoon							
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temperature (oc)	Relative Humidity (%)	Wind Speed (m/s)
Wari Seaport	20.00	0.036	0.036	366.00	0.027	26.7	85.4	3
100m away	10.57	0.019	0.025	357.78	0.019			
Control	2.20	0.001	0.006	341.00	0.001	27.24		

Source: Field work

Table 7. Average concentration of air pollutants during the morning, afternoon and evening hours in Wet season in Warri seaport

Location	Air Quality Parameter						Meteorology	
	Evening							
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temperature (oc)	Relative Humidity (%)	Wind Speed (m/s)
Warri seaport	17.30	0.025	0.028	370.50	0.015	27.3	80.2	1
100m away	10.57	0.019	0.025	361.78	0.019			
Control	2.10	0.001	0.005	320.00	0.001	27.25		

Source: Field work

Discussion of Findings

When compared the concentrations of pollutants in Warri seaport with National Ambient Air Quality Standards, and the World Health Organisation's critical values as well as the USEPA, CO pollutant concentration exceeded both the 1 hour limit of 10ppm and the 8 hours limit of 20ppm during dry. In wet season the site exceeded the 10ppm limit, for Sulphur dioxide (SO_2), both seasons experienced concentrations beyond the 1 hour standard of 0.01ppm, Hydrocarbon concentrations in both seasons were within the 0.6ppm limits. Carbon dioxide (CO_2) in both seasons was above the 314ppm obtainable in pure air. These values were quite different from the values at the control site and 100m away from the source; this could be linked to marine transport operations from Harbour Vessels, Ocean going vessels as well as operations of locomotives in the port environments the locomotives, trains and cargo handling equipment that contributes to air pollutants

The result of hypothesis showed that there are significant mitigation technologies for air pollution from ocean-going and harbour vessels and that there are significant mitigation technologies for CHE and locomotive in Warri seaport. It was found that the mitigation technology for vessels in Warri seaport is the use of scrubbers and the use of alternative marine fuel like LNG. The study also found that mitigation technology adopted in Warri seaport for cargo handling equipment include maintenance, servicing and replacement of CHE and use of electric CHE. Also, the technology adopted for locomotives is water injection. This implies that the variables are significant technological mitigation for ocean going, harbour vessels, CHE and locomotives. This finding is consistent with the works of Mohseni et al. (2019) who highlighted alternative technologies such as cold ironing, LNG fuel use for sulphur mitigation in a maritime container transport, according to their studies, emission in ports can be abated through different technological approaches in sectors of oceangoing vessels and CHEs. The finding is also consistent with the work of Anyanwu (2017) who maintained in his work that abatement technologies and LNG fuel are major technological mitigation factors for air pollution from shipping. A Jerzy (2011), who maintained that there are three drivers which make liquefied natural gas (LNG) more suitable in the shipping industry: First, LNG as ship fuel reduces Sulphur Oxide (SO_2) emissions by between 90 and 95 per cent and Nitrogen Oxide (NOx) emissions to comply with IMO Tier III limits. Second, LNG's lower carbon content leads to a reduction of Carbon dioxide (CO_2) emissions by 20 to 25 per cent. Third, current LNG prices in Europe and the USA is comparable to heavy fuel oil (HFO), according to him, this technology totally reduces SO_2 (1ppm), PM emissions, NOx ~90% and CO_2 emissions by ~20%.

3.0 Conclusion and Recommendations

It is pertinent to note that this study has evaluated the technology for reducing emission from Vessels in Warri seaport and they include: the use of scrubbers for ocean going vessels, the use of alternative marine fuel such as LNG and other low Sulphur fuels, while the technology for CHEs include maintenance, servicing and replacement of CHE. The study also revealed that for locomotives, water injection technology is used to reduce emission. The study also revealed the major sectors of air pollution which include, ocean going vessels, harbour vessels, cargo handling and locomotives as well as heavy duty trucks in the seaports.

- Incentives to 'green' ships to encourage them to invest in other effective port-based emission reduction techniques in necessary in Nigerian seaports.
- There should be an urgent call for Nigerian Ports to invest in AMP as a competitive tool whereby AMP ships could be granted priority to use terminals any time they arrive by so doing afford AMP ships a competitive advantage.

Other methods or strategies for emission reduction is necessary such as tree planting, use of electric vehicles among others.

- The NPA and other authorities should consider, as a matter of need, the reduction of taxes on electricity supplied to ships to serve as an incentive for ship operators to use shore power to pave way for ports to charge realistic fees to recover cost.

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