International Journal of
Environmental Sciences & Natural Resources
ISSN: 2572-1119

Juniper PUBLISHERS
key to the Researchers

Research Article
Volume 32 Issue 5 - November 2023
DOI: 10.19080/IJESNR.2023.32.556352

Int J Environ Sci Nat Res

Evaluation of Air Pollution and Mitigation using Analysis Technological Factors: A Study of Apapa and Tincan Island Seaports of Nigeria

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Submission: September 22, 2023; **Published:** November 06, 2023

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Abstract

The International Maritime Organisation (IMO) on 26th October 2018 adopted an amendment to the Annex of the protocol of 1997 to amend the international convention for the prevention of pollution from ships, Annex VI regulations provides regulations for the prevention of air pollutions from ships, to comply with this requirement in Nigerian seaports, this research estimated the substances which constitutes ambient air in Apapa and Tincan Island seaports' areas in Lagos, Nigeria. Pollutants such as CO, NO2, CO2, HC and SO2 were critically monitored with air sample analyser monitors, at source, receptor and the control. We found the mean concentrations of the pollutants in wet and dry seasons; the result exceeds the safe acceptable limit when compared with both the Nigerian and international standards of World Health Organization's (WHO) for gaseous pollutants. Further, the research analysed the factors for mitigating air pollution in both seaports. The results from the Factor Analysis and Principal Component Analysis showed that there are air pollution mitigation factors for ocean going and harbour vessels in both seaports, alternative fuel or the use of LNG on locomotives significantly impact on air pollution mitigation in Apapa seaport and that alternative marine power or cold ironing does not exist in Apapa seaport. Recommendations were made towards adopting appropriate mitigation technologies in all the seaports in Nigeria.

Keywords: Air; Pollution; Mitigation; Technologies; Seaport

Introduction

Seaports all over the world are main focal points of activities as well as main sources of pollution. There are massive ships with engines operating on the dirtiest fuel and a daily visit of thousands of diesel truck, diesel locomotives of many miles hauling cargo and other polluting equipment, and activities at marine ports contributing to a lot of environmental impacts that can dangerously affect local communities as well as the environment (Badejo & Solaja 2014).

In the past, there was significant environmental oversight by shipping companies and port operators; [1]. High volume of Nitrogen and Sulphur Oxides (NOx and SOx) emissions is due to the global shipping activity. Emissions of Nitrogen Oxide represents a share of 13% while Sulphur Oxides represents a share of 12% of global emissions respectively [2] also in 2012, IMO estimated greenhouse gas (GHG) emissions from shipping totaled 2.2% of anthropogenic carbon dioxide (CO_2) emissions. Furthermore, burning of the Sulphur content of marine fuels in international shipping leads to emissions which contribute to air pollution in the form of SOx and particulate matter (Sys, Vanelslander, Adriaenssens, Van, 2015).

During port operation, several quantities of diesel emission take place when transport and cargo handling equipment's use diesel fuel. For the period of the burning process in diesel engines, these fuels are capable of producing major quantities of particulate matter (PM), nitrogen oxides (NO_x), black smoke, sulfur oxides (SO_x), carbon monoxide (CO), carbon dioxide (CO_2), unburned hydro carbons (UHC) and many others.

The pollutants are capable of depleting the ozone layer, add to the green-house effect as well as producing acid rain which could be a source of detriment to human health as well as other living being (IMO 2019). Under the support of IMO, appropriate regulations have received considerations, this includes the 2011 acceptance of the technical and operational actions to cut emissions from global shipping [3].

The International Maritime Organisation's (IMO's) MARPOL ANNEX VI, which is an international regulation, was developed to address emissions from vessels. Nevertheless, there is low effectiveness of this regulation in curbing air pollutant emissions from vessels to address local air quality concerns especially in vital port cities where port-related emissions (both within and outside the port) add to the air challenges for these regions [4]. Similarly, a lot of ports and maritime operational functions rely on how durable and strengthened diesel engines in trucks, cargo handling equipment, locomotives, harbor craft and ocean-going vessels manifest. Evidently, these transportation and cargo handling machineries use diesel fuel and as such releasing significant and serious amounts pollutants like SOx, NOx and many other pollutants from diesel emission occurs from port operations. A visit to Apapa and Tincan ports shows that there are inadequate air pollution mitigation technologies in these seaports; therefore, to reduce air pollution in our seaports, mitigation technologies must be present in our seaports, this brings to the fore the following questions;

a) Could it be that the level of pollutants emission in Nigeria seaport are not in line with the National and international standards?

b) Are there available air pollution reduction technologies in our seaports?

Han [5] took a case study on clean air strategies of the global key ports which include six USA ports (port of Los Angeles and Long Beach, York and New Jersey seaports as well as the port of Seattle and Tacoma seaport), two European ports (the port of Rotterdam and the port of Gothenburg) including the Busan Port. According to him, seaport emission reductions are sector driven and category based. The various sectors include ocean going vessels sector, cargo handling equipment's sector, as well as truck and rail sector, while category based include reduction control technologies, operational changes and market-based measures. He noted that the effect of port-related emission reduction can be maximized when various measures are conducted on a regional basis including neighboring ports and that regional or global-based approach is useful to guarantee the level playing field among ports. Also, Beza, Kitsantas & Mitselos (2014) studied ship waste management and its impact on ports of Igoumenitsa while Nitonye & Uyi (2018) analysed marine pollution on Onne and Port Harcourt ports as well as the Okrika jetty alone. Furthermore, Bailey et al. [4] merely carried a study on Harboring pollution; strategies to clean up the U.S. ports.

There are numerous problems associated with seaport pollution in relation to seaport performance indicators. When the lives of port workers are threatened due to air pollution, it affects staff performance which impacts on the overall service quality of seaports. This scenario increases port idle time; reduce cargo throughput, ship turnaround time as well as high berth occupancy rate.

Against this background of gaps and the above stated problems, this research work is aimed at analyzing air pollution mitigation technologies in Nigerian seaports, specifically in Apapa and Tincan Island.

Methodology

Plate 1: Map showing the study area.

Area of study

The Apapa and Tincan seaports are located at the Western coast of the Nigeria in Lagos State which is on Latitude 6.6080° N, Longitude 3.6218° E, while port is the busiest port in Nigeria and in the West African region, Tincan Island port is the second busiest port in Nigeria (Plate 1).

Equipment and field materials

The equipments or air analyser that was used to obtain data for this study was sourced by the researchers 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 -20°C to 60°C 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. Cell phone with in-built GPRS for monitoring the speed of the wind at the seaport site.

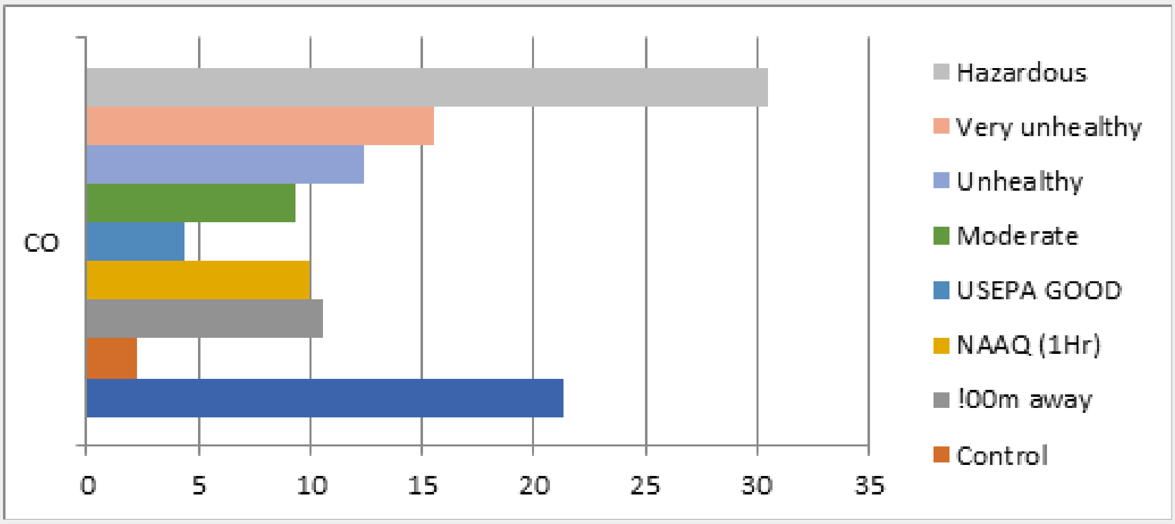

Figure 1: Comparing average CO during wet season in Apapa with respect to National and international Standards (Authors computation).

Domain of inquiry and definitions

In this research work, the variables studied are SO_2, NO_2, CO, HC and CO_2 at the ground level relative 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 used as it characterizes the height for breathing of human beings, for situations of seating or standing.

High traffic spots" in this work are connections in the port with more movement of vehicles. The "background" (about 100 metres away from traffic), estimation of air quality at "background" was determined and at a "control site" was carried out. Control site(s) is the area without much or high traffic emission in the port area.

Spatial and temporal coverage

The areas covered include vessels habour areas, trucks movement areas, cargo handling equipments working areas of the specific ports of Apapa and Tincan. "Background" measurement was carried out. A Residential Area was selected as "control site".

Determination of traffic levels

The number and types of vehicles or vessels in the port were determined. The motive power category was counted and recorded which includes the vessels, CHE, Off-site trucks, locomotives based on their traffic movement. Traffic density determination was carried out by 800am – 900am, 12.00noon

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-1.00pm and by 4.00pm – 5.00pm daily in the sites in Tincan and Apapa, 100m away and control location.

Correlation between traffic levels and air quality

To establish a relationship between air pollution and traffic emissions, measured data was analysed using traffic level information. By establishing a connection between traffic counts and air pollution, the relationship between high traffic and pollutants concentration was explored.

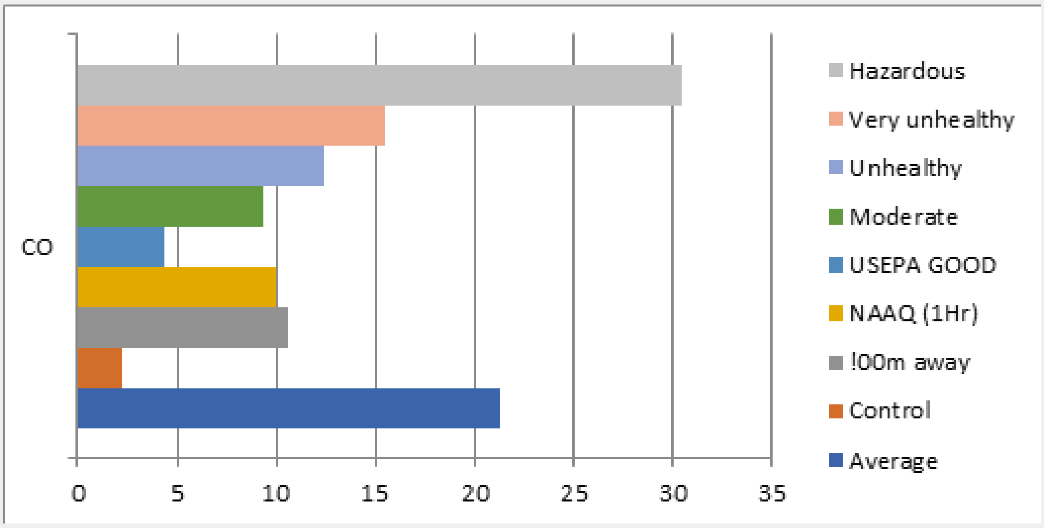

Figure 2: Comparing average NO2 during wet season in Apapa with respect to National and international Standards (Authors computation).

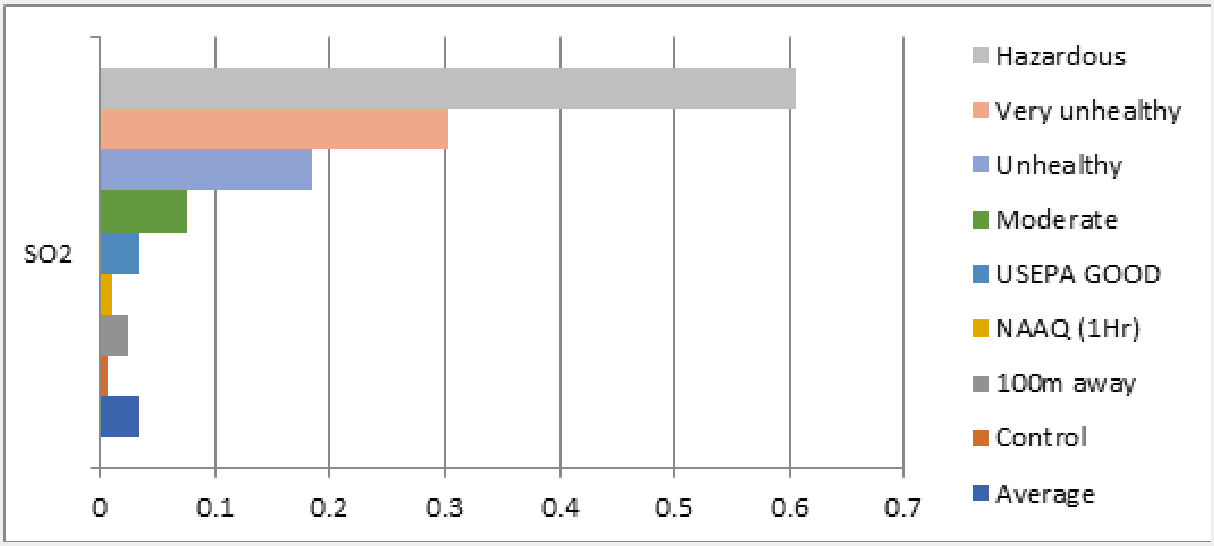

Figure 3: Comparing average CO during wet season in Apapa with respect to National and international Standards (Authors computation).

Establishing the relationship between Concentration of Emission at Source (CS), the Receptor (CR), as well as the Distance (D) from the point of Emission or the Source.

Hence, this is due to the reality that pollutant concentration decreases with increase in distance from the point of release of the pollutant. Therefore, more concentration of pollutant emission at a receptor location is in direct proportion to the concentration emitted at source with inverse proportion to the distance from the source with the mathematical relationship below;

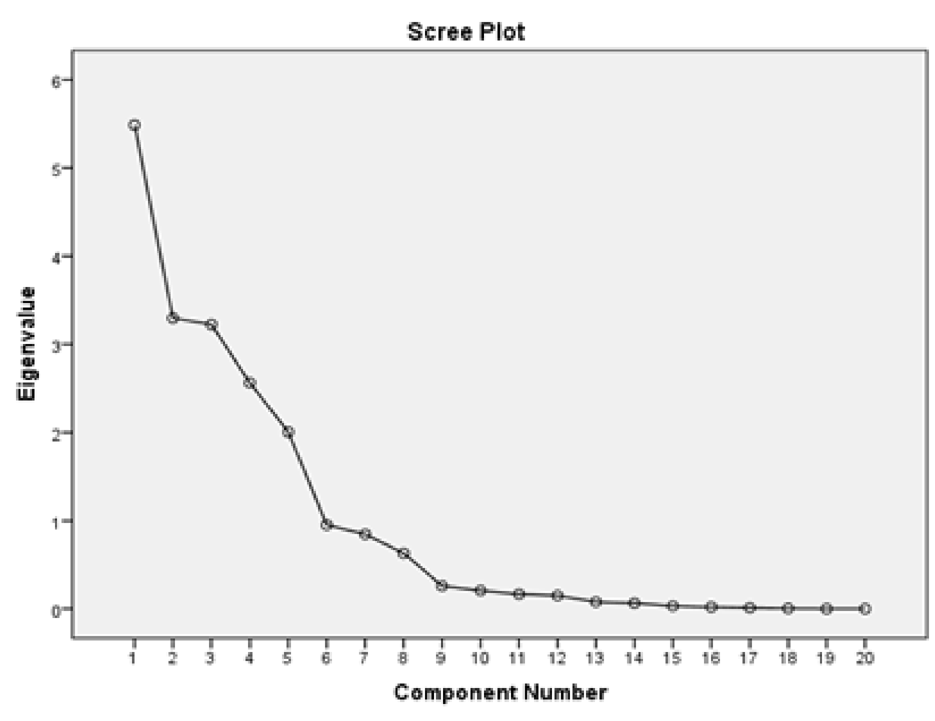

Figure 4: A Scree Plot of Total Variance of mitigation factors.

Source: SPSS Iterations.

$$CR \ \alpha \ {}^{Cs}\!/_{D}$$

$$CR \ = k \, {}^{Cs}\!/_{D}$$

CR = pollutant's concentration at reception location in ppm.

CS = pollutant's concentration *t* the source in ppm.

D = reception distance from the emission source in metres.

K = constant.

Logarithm of both sides shows:

$$Log \ CR = Log \ K + Log \, {}^{Cs}\!/_{D}$$

Where Log K is the gradient of the graph when plotted on a straight line and the antilog will give the value of K as the constant of proportionality.

Analytical method used

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

EFA was used to explain the pattern of relationships within the data set and to compare them against the hypothesized 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 represent 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 are 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.

Results and Discussion

The summary of the description of the entire variables posed in the study is presented in the Table 7, with the mean and standard deviations of the variables resulting from the survey on technological mitigation strategies of air pollution in Apapa and Tincan seaports. 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 Component Matrix^{a} table)

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Table 1: Average traffic volumes per hour in selected points in Apapa and Tincan Island Port.

Sampling Site	Average Traffic Volume per Hour			
	Locomotives/Trucks	Cargo Handling Equipments	Vessels	Total
Terminal A Apapa	1032 ± 16	1126 ± 12	106 ± 2	2264 ± 30
Terminal B Apapa	1206 ± 19	1612 ± 14	4 ± 1	2820 ± 34
Fivestar Logistics Tincan	911 ± 18	735 ± 16	103 ± 2	2649 ± 33
Tincan container terminal	481 ± 8	903 ± 10	116 ± 4	1813 ± 22

Source: Field work.

Table 2: Field location and GPS values.

Location	GPS Values	Elevation Above Sea Level (Metre)
Terminal A	06° 44‟ 55.8” N 03° 21‟ 49.1” E	4
Terminal B	06° 44‟ 28” N 03° 21‟ 49” E	9
Fivestar Logistics Tincan	062 44‟ 17” N 03° 23‟ 04” E	9
Tincan container terminal	062 45‟ 35.0” N 03° 23‟ 15.1” E	7

Source: Field work.

Table 3: Average concentration of air pollutants during the morning, afternoon and evening hours in dry season in Apapa.

Location	Air Quality Parameter					
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temperature (°C)
Apapa port traffic point	30.23±2.23	0.039±0.007	0.038±0.002	380.00±25.00	0.027±0.093	31.0 ±3.5
100m away	11.44	0.038	0.033	352.78	0.027	
Control	3	0.001	0.006	348	0.001	28

Source: researchers' field work.

Table 4: Average concentration of air pollutants during the morning, afternoon and evening hours in wet season in Apapa

Location	Air Quality Parameter					
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temperature (°c)
Apapa port traffic point	21.3±0.80	0.033±0.002	0.035±0.002	354.33±21.00	0.029±0.012	
100m away	10.57	0.019	0.025	357.78	0.019	
Control	2.2	0.001	0.006	341	0.001	27.24

Source: Field work.

Table 5: Average concentration of air pollutants during the morning, afternoon and evening hours in dry season in Tincan port.

Location	Air Quality Parameter					
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temperature (°C)
Tincan port traffic point	29.23±2.23	0.036±0.005	0.028±0.005	350.00±23.00	0.024±0.094	30.5 ±3.5
100m away	10.48	0.035	0.031	342.7	0.025	
Control	2.8	0.001	0.005	325	0.001	27

Source: researchers' field work.

Table 6: Average concentration of air pollutants during the morning, afternoon and evening hours in wet season in Tincan port.

Location	Air Quality Parameter					
	CO (ppm)	NO_2 (ppm)	SO_2 (ppm)	CO_2 (ppm)	HC (ppm)	Air Temperature (°c)
Tincan port traffic point	20.52±0.80	0.032±0.003	0.027±0.003	340.30±20.00	0.021±0.010	
100m away	9.8	0.029	0.024	330.7	0.019	
Control	2.2	0.001	0.004	341	0.001	27.24

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Table 7: List of air mitigation technology for ocean vessels and harbour vessels in Apapa and Tincan seaports.

	N	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
Application of other shoreside power like generators	300	4	5	2351	4.7	0.458	0.21
Use of automatic idling control device	300	2	5	1880	3.76	0.936	0.876
Adoption of cleaner marine fuels such as LNG in the vessels to reduce Sulphur	300	1	4	1011	2.02	1.103	1.216
Use of Alternative Marine power or cold ironing	300	2	5	1936	3.87	1.023	1.046
Engine temperatures reduction through direct water injection to reduce NOx	300	2	5	2184	4.37	0.733	0.538
The use of humid air motors to reduce NOx	300	3	5	2321	4.64	0.488	0.238
Facilitating alternative fueling infrastructure by port for hydrogen	300	2	5	1928	3.86	1.057	1.117
Repower equipment’s more than ten years old with alternative-fuel engines	300	1	4	1288	2.58	1.246	1.551
Retrofit equipment’s less than 10years with the best available control technology.	300	1	4	806	1.61	0.889	0.791
Existing equipment should be switched to cleaner diesel fuels.	300	1	5	2116	4.23	0.753	0.567
Purchase new equipment that uses alternative fuels	300	1	5	2116	4.23	0.753	0.567
Automated gate systems to reduce queue times and emissions	300	1	5	982	1.96	1.175	1.381
Use of electrification technology	300	3	5	2438	4.88	0.348	0.121
Use of Liquefied Natural Gas on Locomotives	300	1	5	2000	4	0.566	0.321
Locomotives and trains engines must be service regularly	300	1	4	806	1.61	0.889	0.791
Conversion of existing engines to LNG engines	300	4	5	2421	4.84	0.365	0.133
Need for sufficient infrastructures for the projects such as land and power	300	4	5	2304	4.61	0.489	0.239
Requirement of sufficient infrastructures fueling terminal	300	4	5	2444	4.89	0.316	0.1
Application of scrubber	300	2	5	2133	4.27	0.79	0.624
Use of other idling control device	300	2	5	1681	3.36	0.957	0.917
Valid N (listwise)	300						

Descriptive Statistics.

Source: SPSS Iterations.

Table 8: Component Matrix^{a}.

	Component				
	1	2	3	4	5
Application of other shoreside power like generators			0.741		
Use of automatic idling control device	0.701				
Adoption of cleaner marine fuels such as LNG in the vessels to reduce Sulphur	0.631				
Use of Alternative Marine power or cold ironing					-0.618
Engine temperatures reduction through direct water injection to reduce NOx				0.633	0.541
The use of humid air motors to reduce NOx	0.787				
Facilitating alternative fueling infrastructure by port for hydrogen	0.562		0.618		
Repower equipment’s more than ten years old with alternative-fuel engines					-0.676
Retrofit equipment’s less than 10years with the best available control technology.	0.659				

Existing equipment should be switched to cleaner diesel fuels.	0.87				
Purchase new equipment that uses alternative fuels	0.87				
Automated gate systems to reduce queue times and emissions		0.555	-0.614		
Use of electrification technology		-0.521	0.52		
Use of Liquefied Natural Gas on Locomotives		-0.768			
Locomotives and trains engines must be service regularly	0.659				
Conversion of existing engines to LNG engines				0.75	
Need for sufficient infrastructures for the projects such as land and power	-0.634	0.513			
Requirement of sufficient infrastructures fueling terminal		0.568	0.522		
Application of scrubber				-0.713	
Use of other idling control device	0.718		-0.594		

Extraction Method: Principal Component Analysis.

a. 5 components extracted.

Source: SPSS Iterations.

Table 9: KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.791
Bartlett's Test of Sphericity	Approx. Chi-Square	1206.821
	Df	18
	Sig.	.000

Source: *SPSS Iterations.*

Table 10: Total Variance Explained.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
Application of other shoreside power like generators	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	60.03	3.224	16.121	60.03
Use of Alternative Marine power or cold ironing	2.562	12.812	72.842	2.562	12.812	72.842
Engine temperatures reduction reduces NOx	2.005	10.027	82.87	2.005	10.027	82.87
The use of humid air motors to reduce NOx	0.952	4.761	87.63			
Facilitating alternative fueling infrastructure by port for hydrogen	0.846	4.231	91.861			
Repower equipment's more than ten years old with alternative-fuel engines	0.631	3.154	95.015			
Retrofit equipment's less than 10years with the best available control technology.	0.261	1.305	96.32			
Existing equipment should be switched to cleaner diesel fuels.	0.209	1.043	97.363			
Purchase new equipment that uses alternative fuels	0.167	0.836	98.198			
Automated gate systems to reduce queue times and emissions	0.151	0.753	98.951			
Use of electrification technology	0.079	0.394	99.345			
Use of Liquefied Natural Gas on Locomotives	0.064	0.32	99.665			
Locomotives and trains engines must be service regularly	0.031	0.157	99.822			

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Conversion of existing engines to LNG engines	0.02	0.101	99.923			
Need for sufficient infrastructures for the projects such as land and power	0.011	0.056	99.98			
Requirement of sufficient infrastructures fueling terminal	0.004	0.02	100			
Application of scrubber	2.78E-16	1.39E-15	100			
Use of other idling control device	-3.83E-16	-1.92E-15	100			

Extraction Method: Principal Component Analysis.

Source: SPSS Iteration.

Table 11: Rotated Component Matrix

	Component				
	1	2	3	4	5
Purchase new equipment that uses alternative fuels	0.87				
Existing equipment should be switched to cleaner diesel fuels.	0.87				
The use of humid air motors to reduce NOx	0.787				-0.304
Requirement of sufficient infrastructures fueling terminal	0.718		-0.594		
Use of automatic idling control device	0.701	-0.315			
Retrofit equipment's less than 10years with the best available control technology.	0.659	0.409	-0.398		
Use of electrification technology	0.659	0.409	-0.398		
Locomotives and trains engines must be service regularly	-0.634	0.513		-0.433	
Conversion of existing engines to LNG engines	0.631	-0.452	0.429		
Use of Liquefied Natural Gas on Locomotives		-0.768			
Rebuilding existing engines to LNG engines		0.568	0.522	-0.418	
Use of electrification technology		-0.521	0.52		
Application of scrubber		0.463	0.741		
Facilitating alternative fueling infrastructure by port for hydrogen	0.562	0.303	0.618		
Automated gate systems to reduce queue times and emissions	0.313	0.555	-0.614		
Conversion of existing engines to LNG engines				0.75	0.411
Use of other idling device	0.342			-0.713	0.488
Engine temperatures reduction through direct water injection to reduce NOx				0.633	0.541
Repower equipment's more than ten years old with alternative-fuel engines		0.436	0.38	0.336	-0.676
Use of Alternative Marine power or cold ironing	0.359	-0.49		0.402	-0.618

Rotated Component Matrix[a].

Extraction Method: Principal Component Analysis.

a. 5 components extracted.

Bartlett's Tests of sphericity

Bartlett's test is used to test if *k* samples are from populations with equal variances. Equal variances across populations are called homoscedasticity or homogeneity of variances. Some statistical tests, for example the analysis of variance, assume that variances are equal across groups or samples. The Bartlett test can be used to verify that assumption. Bartlett's test is sensitive to departures from normality. That is, if the samples come from non-normal distributions, then Bartlett's test may simply be testing for non-normality.

The Bartlett's test conducted proved to be statistically significant (Sig-value=0.000< 0.001). The Kaiser-Meyer-Olkin (KMO) measure was approximately 0.80, indicating the data were sufficient for principal component analysis (PCA). The Bartlett's test of sphericity X^2 = 1206.821 (Chi-square), P < 0.001 showed that there were patterned relationships between the variables. Because the chi-square of 1206.821 for Apapa and Tincan seaport studied with 18 degrees of freedom are unlikely to have arisen by chance, the 300 staff of the seaports interviewed do not have equal opinion on technological mitigation strategies of air pollution.

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Exploratory factor analysis of air pollution mitigation strategies in Apapa and Tincan seaport

The factors which describe the critical variables that impinge on technological mitigation strategies of ocean-going 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 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 4) 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.

From Table 10, 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 the total variance explained table of Table 10, PCA has assisted us to identify five underlying components explaining 82.9% of the common variance.

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 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's 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

Purchase new equipment that uses alternative fuels and Existing equipment switched to cleaner diesel fuels 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 Liquefied Natural Gas on Locomotives 0.768

Use of Liquefied Natural Gas on Locomotives variable has the highest factor loading of 76.8%. Thus, component two can be identified as use of **Alternative fuel or Liquefied Natural Gas 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

How to cite this article: Okechukwu Julius A, Charles Odeyovwi O, Nwoloziri Chinyeaka N, Nwagu Chibueze O, Asionye Ezenwa I, et al. Evaluation of Air Pollution and Mitigation using Analysis Technological Factors: A Study of Apapa and Tincan Island Seaports of Nigeria. Int J Environ Sci Nat Res. 2023; 32(5): 556352. DOI: 10.19080/IJESNR.2023.32.556352

Rebuilding existing engines to LNG engines
0.522

Use of electrification technology
0.520

Therefore, component 3 can be identified as **scrubber factor** because 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 Factor** because of the variable has the highest factor loading of 54.1%.

Test of Hypotheses

HO_1: There are no significant air pollution mitigation factors for ocean going and harbour vessels in Apapa and Tincan seaports.

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

This implies that the variables are significant mitigation technologies for 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 Apapa and Tincan seaport.

$HO_{2:}$ Alternative fuel like LNG for locomotives does not significantly impact on air pollution mitigation in Apapa and Tincan seaports.

From Table 5, use of alternative marine fuel variable has a factor loading of (0.768) > (0.50) on factor 2. This implies that the variable is significantly important in air pollution mitigation for locomotives in Apapa and Tincan seaport. Thus, the null hypothesis was rejected and the alternate accepted. Hence the researchers conclude that Alternative fuel like LNG for locomotives significantly impact on air pollution mitigation in Apapa and Tincan seaports.

Discussion

Comparison of the air quality for both wet and dry seasons of Apapa seaport alone showed that the air quality during the wet season was relatively better when compared to that of the dry season. This was so because during the wet season, the atmosphere is bound to be humid and saturated with water vapour for this reason, a significant quantity of the pollutants would have been absorbed in the atmosphere unlike in the dry season. When compared to that of Tincan Island seaport, there is a sharp difference of pollutant emission in Apapa seaport environment than the Tincan. The situation is the same when compared to both seasons of dry and wet periods.

Above all, the excess in all these pollutants against the National and USEPA international standards could signify ecological hazards to residents, Flora and Fauna as elevated levels of these gaseous pollutants have been associated with chronic obstructive pulmonary diseases, asthma, tuberculosis [6], increased risk of liver failure, respiratory problems, skin disorders, neonatal deformities and other health risks ([7]. The observed high concentration of the pollutants can be attributed to the presence of several transport modes and equipments. Ships, cargo trucks, cranes, cargo handling equipment, and all rail locomotives contribute to maritime related emission of air pollutants [8]. Emissions from maritime shipping have increased considerably, causing depletion of the ozone layer and most importantly posing a threat to lives and coastal environment through air pollution [9]. These pollutants are majorly from the conventional fuel and can be reduced by adopting liquefied natural gas as marine fuel, use other less pollutant content marine fuels or application of scrubbers for air pollution mitigation (Anyanwu and Onyemechi 2016).

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The results of hypotheses showed that there are significant mitigation technologies for air pollution from ocean-going and harbour vessels and that there are significant mitigation

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technologies for CHE and locomotive in Apapa and Tincan seaport. It was found that the mitigation technology for vessels and locomotives in Apapa and Tincan seaports are the use of alternative marine fuel like LNG. The study also found that mitigation technology adopted in Apapa and Tincan Island ports for cargo handling equipments and locomotives include maintenance, servicing and replacement of CHE and use of electric CHE as well as water injection for locomotives. 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 SA et al. [10] 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 ocean going vessels and CHEs. The finding is also consistent with the work of Anyanwu [11] who maintained in his work that abatement technologies and LNG fuel are major technological mitigation factors for air pollution from shipping. A Jerzy [12], 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 (SOx) 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 are comparable to heavy fuel oil (HFO), according to him, this technology totally reduces SOx (1ppm), PM emissions, NOx ~90% and CO_2 emissions by ~20%. This is one of the ways in which operators in the maritime industry can meet the low sulfur limits of IMO, Jerzy [12-14].

Conclusion

When compared the concentrations of pollutants in both seaports with National Ambient Air Quality Standards, and the World Health Organization'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 equipments that contributes to air pollutants.

However, this study has noted and identified the air pollution mitigation technology factors for vessels and locomotives in both seaports. The technology for reducing emission from ships in both seaports 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. In conclusion, the study concluded that there are air pollution mitigation factors for ocean going and harbour vessels in Apapa and Tincan seaport, alternative fuel significantly impact on air pollution mitigation in Apapa and Tincan seaport and that alternative marine power or cold ironing does not mitigate air pollution in Apapa and Tincan seaport.

Recommendations

The following recommendations based on the objectives and findings of this study were highlighted as follows:

a) Ports should analyse and adopt the best operational air pollution mitigation strategies for ocean going vessels, harbour vessels, locomotives and cargo handling equipments so as to meet the global emission limit and IMO regulation.

b) There is absolute need for Nigerian Ports to give incentives to 'green' ships to encourage them to invest in other effective port-based emission reduction techniques.

c) The port operators and ship operators should yearly examine the available air pollution mitigation technologies in Nigeria seaport with respect to global standard and IMO regulation.

d) There is absolute need for Nigerian Ports to give incentives to 'green' ships to encourage them to invest in other effective port-based emission reduction techniques.

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.

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