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Impact Of Shipping Activities On The Hydrochemistry And Macrobenthic Community Of The Lagos Lagoon

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***Abstract:** The impact of shipping activities on the hydrochemistry and macro invertebrate community of the Lagos Lagoon, Nigeria was investigated between 2013 and 2014. The study involved the assessment of physicochemical characteristics and heavy metal concentrations of surface water as well as macrobenthic community structure in shipping and non-shipping areas of the lagoon. The results showed that except for Iron which was higher in the surface water of the non- shipping areas, mean concentrations of other metals were either higher in the areas under influence of shipping activities or without significant difference (P<0.05). Also heavy metal concentrations were higher in the shipping zones in the rainy months. There was significantly higher (P<0.05) turbidity in the non-shipping areas of the lagoon. Macrobenthic species diversity was highest in the rainy season and in non-shipping activity impacted areas. Overall, Phylum mollusca were the most abundant and diverse taxa with 80% abundance and the least were the phylum chordata with 3% abundance. The bivalve, Gryphaea gazar was the most abundant species in zone 1 followed by Thais coronate while the gastropod, Neritina senegalensis was the most abundant species observed in zone 2, followed by Tympanotunus fuscatus indicating high dominance. Among all the species observed in all the sampled stations in both seasons and zones, Neritina senegalensis had the highest percentage for both zones in all seasons. The lower species abundance and diversity recorded in the areas associated with shipping activities were attributed to stress imposed by ship movements and continuous dredging to manage siltation.*

***Keywords:** Invertebrates, Maritime Industry, Community Structure Analysis, Harbour dredging*

I. INTRODUCTION

With more than 70 % of the surface covered by oceans, human interaction with and dependence on the sea in numerous aspects is obvious (Andersson et al., 2016). A key way by which humans have exploited the sea is with regards to shipping and related activities such as dredging and construction of harbours. Ship transport can be over any distance by boat, ship, sailboat or barge, over oceans and lakes, through canals or along rivers. Ships are vessels of considerable size that are intended for deep-water navigation (US Department of Transport, 2008).

Over 96% of the transportation of Nigeria's external trade is by maritime transport (Iheduru 1992). The import of this is particularly noticeable in Nigeria's commercial centre of Lagos, which hosts the busiest port in the Nation. The port of Lagos was developed under the British rule between 1908 and 1922 (Babafemi, 1976). Containerization of cargos revolutionized sea transport in the 1960's resulting in increased haulage of goods via oceans despite the advent of air transportation.

The Lagos ports are by far the busiest and most important port in Nigeria, receiving tonnes of cargo from large vessels annually. Apapa is the major port of the city of Lagos, Nigeria, and together with the Tin can port is located to the east of Lagos Island across Lagos harbour. It is a centre of exchange of goods and a hub for receipt of refined petroleum products. The high shipping traffic is a source of pollution pressure in the Lagos lagoon where much of the large vessels goes through. The Lagos lagoon has been reported to be a polluted water body (Ajao, 1996; Otitoloju 2007), with conditions around the shipping centres of Apapa port, Atlas cove and Iddo largely reported as worse off than most other areas, characterized of high polycyclic aromatic hydrocarbons (Amaeze et al., 2015a), polychlorinated biphenylys (PCBS), BTEX (benzene, toluene, ethyl benze and zylene), heavy metals and significantly lower diversity of macrobenthic fauna (Doherty, 2014).

Other shipping activities impacting the hydrochemistry and macrobenthic invetebrate in the lagos lagoon are the release of ballast water and continuous dredging. Dredging is conducted in some part of the lagos lagoon to keep sediments from building up, build-up of sediments may impede the nagivation of large ships, dredging can also be used to increase a channel's or river's water capacity to help relieve flooding in some areas. The constant dredging of the Lagos harbor by the Lagos Chanel Management Company to enhance ship navigation and to lesser extents other artisanal sand mining activities have the capacity to re-suspend heavy metals compounds from the sediments into the surface water, making them bioavailable for uptake by aquatic biota (Reible et al., 2002a&b). This subsequently pollutes the ecosystem, thereby endangering the life people and aquatic animal in the area.

There is therefore need to evaluate the Lagos lagoon to ascertain the current levels of impact on the hydrochemistry and macrobenthic communities resulting from shipping activities.

II. MATERIALS AND METHODS

DESCRIPTION OF STUDY SITE

This study was conducted in the Lagos Lagoon a tropical lagoon complex which stretches out from Cotonou in the Republic of Benin and extends to the fringes of Niger Delta in Nigeria. The lagoon is more than 50 km long and 3 to 13 km wide, separated from the Atlantic Ocean by long sand spit 2 to 5 km wide, which has swampy margins on the lagoon side. Its surface area is approximately 6,354.7 km². The Lagos Lagoon is shallow with an average of 1.5m except at the channels that are occasionally dredged (Webb, 1959;. Oyewo, 1998). The principal ocean port of Lagos is located at Apapa in a broad western branch off the main channel of the harbour with areas such as Atlas Cove and Iddo under the influence of shipping activities. For this study, areas associated with shipping activities are compared with those which are shallow and are not associated with shipping activities in the lagoon (Fig. 1)

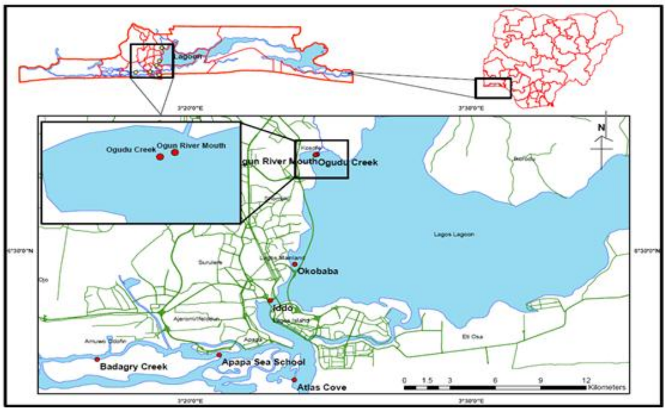

Figure 1: The Lagos Lagoon showing the study sites

SAMPLING DESIGN AND OPERATIONS

The sampling areas established for this study was divided into 2 major zones. The choice of the zones were based on the influence and degree of shipping activities, other anthropogenic activities, past studies (Dorherty,et al., 2014) and their suitability for the future survey base in the Lagos Lagoon Ecosystem. The first zone (Zone 1) is composed of areas under influence of shipping activities which consists of Atlas cove, Apapa and Iddo. The second zone (Zone 2) covers areas such as Imore, Ogun River and Okobaba, these areas not under intense influence of shipping activities. The field study was conducted along the western coastline of the Lagos Lagoon over a period of 2 years. Sampling stations were located with the aid of a handheld Global Position System (GPS) Device and visual notes of permanent and semi permanents structures. Each sampling zone comprised on three sampling stations, with sampling conducted in replicates. Sampling of surface water, sediment and macrobenthic species were conducted in all the sampling stations during the rainy (July) and dry (March) seasons from 2013-2014. Sediment and water were also collected during the *in situ* monitoring of caged organism in Apapa (representing zone 1) and Ogun river (representing zone 2) sampling locations.

ASSESSMENT OF SURFACE WATER PHYSICOCHEMICAL CHARACTERISTICS

The surface water samples were collected at a depth of 0.5cm with the aid of pre cleaned amber coloured glass tubes (500ml) to determine basic physicochemical properties which includes Acidity, Alkalinity, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Nitrates, Nitrites, Sulphate, Sulphide, Phosphate and Total Hydrocarbon. *In situ* physicochemical assessment was conducted to determine the levels of Electrical Conductivity, Dissolved Oxygen (DO), Hydrogen ion Concentration (pH), Salinity, Temperature, Total Dissolved solid (TDS) and Turbidity. The surface water samples were transported cool, using ice packs to the Ecotoxicology Laboratory, Department of Zoology in the University of Lagos where they were stored at 4°C prior to chemical analysis. To prevent adsorption of metals into the wall of the containers, the samples were acidified with 2 drops of concentrated HNO_3 (APHA-AWWA-WPF, 2005). Chemical analysis were conducted a the

Central Research Lab, University of Lagos using standard methods of volumetric analysis of various physico-chemical parameters and atomic absorption spectrophotometer (AAs) for heavy metals.

MACROBENTHIC INVERTEBRATE COLLECTION

Sediment samples were collected using hand deployed 0.1m^2 Van -Veen grab. Once grab have been retrieved, the macrobenthic fauna were sieved out from sampled sediments using various mesh sieves (0.1mm and 2 mm) and preserved in collection containers using 10% formalin prior to community structure assessment. Species identification was conducted at the Zoology Department laboratory, University of Lagos.

STATISTICAL ANALYSIS

Results from physicochemical analysis were represented as mean values and readings from three locations per zone were subjected to analysis of variance (ANOVA) using SPSS Software, Version 20 (IBM). Significant means were determined at *P*<0.05 and separated with LSD. Macrobenthic community structure was estimated using the Margalef's species richness index (d) (Margalef, 1951); Shannon-Weiner information function (AS) (Shannon and Weaver, 1949) and Equitability index or Evenness (Lloyd and Ghellardi, 1964).

III. RESULTS

PHYSIOCHEMICAL CHARACTERISTICS OF SURFACE WATER OF THE SHIPPING AND NON- SHIPPING ACTIVITY SECTIONS OF THE LAGOS LAGOON

Overall there was no significant difference (P>0.05) in the mean values of physiochemical parameters of the surface water during the two sampling seasons for both sampling zone. However, parameters varied significantly (P<0.05) amongst the two sampling zones. Physico-chemical properties of the water body were mostly within the WHO safe limits except for DO, Phosphate and Turbidity levels which were above the safe limit in both zones for both seasons. Alkalinity and sulphates were significantly higher (P<0.05) in the rainy season in zone 2 for both sampling years (Table 1). Sulphate was significantly (*P*<0.05) higher in zone 2 in the rainy season of both sampling years (33.50±67.22 mg/l and 19.15±32.2 mg/l) compared to zone 1 (2.77±3.90 mg/l and 0.89±0.46 mg/l) (Table 1). There was significant different (*P*>0.005) in the value of Nitrate during the wet season across the zones (table 1).

Also, Nitrites were significantly (*P*<0.05) higher in zone 2 during the dry season (12.0±4.48 mg/l) compared to zone 1 (6.79±1.36 mg/l) (Table 2). Nitrate was also significantly (*P*<0.05) higher in zone 2 (14.57±5.66 mg/l) compared to zone 1 (9.13± 0.44 mg/l) during the dry season (Table 2). Other Parameters such as Sulphite, total organic matter, Ammonia, total organic carbon and phosphate did not vary significantly (*P*>0.05) amongst the different zones in both seasons (Table 1 and 2).

Parameters	Year I		Year II		WHO limits
	zone 1	zone 2	zone 1	zone 2	
pH	7.97±0.31	7.43±0.37	7.97±0.31	7.63±0.51	6-9
Salinity (‰)	11.15±5.02*	6.43±5.22	10.15±5.31*	1.91±2.04	NS
Conductivity(mS/cm)	16.69±9.93	15.16±9.91	5.67±6.04	17.24±10.88	NS
Dissolved Oxygen (mg/l)	11.48±1.64	8.64±2.49	11.62±1.38	8.04±1.62	5.0
Total dissolved solids (mg/l)	13.65±3.22	12.6±3.49	11.51±4.36	13.04±7.38	2000
Surface Water Temperature(ºC)	28.47±1.72	29.08±1.55	28.30±2.64	28.50±2.15	<40
Turbidity (NTU)	12.28±14.05	31.88±27.27*	9.45±10	25.61±19.91*	10
Acidity (mg/l)	7.02±0.50	6.23±1.37	6.85±1.06	5.93±1.04	NS
Alkalinity (mg/l)	17.73±2.21	23.17±5.42*	17.40±2.10	24.62±4.25*	500
Chloride (mg/l)	2.3e3±1.7e3	3.4e3±2.3e3	2.6e3±1.7e3	3.75e3±1.92e3	600
Sulphite (mg/l)	0.00	0.00	0.00	0.00	400
Sulphate (mg/l)	2.77±3.90	33.5±67.22*	0.89±0.46	19.15±32.2*	400
Nitrite (mg/l)	0.00	0.00	0.00	0.00	0.2
Nitrate (mg/L)	3.95±1.17	3.51±1.56	3.89±1.23	4.19±1.57	30
Ammonia (mg/l)	0.02±0.02	0.007±0.10	0.02±0.02	0.02±0.06	0.5
Total Organic Matter (mg/l)	0.15±0.28	0.15±0.28	0.15±0.02	0.22±0.15	NS
Total Organic Carbon (mg/l)	0.54±0.46*	0.11±0.40	0.54±0.44	0.12±0.06*	5
Phosphate (mg/l)	0.60±0.71	0.82±0.89	0.6±0.71	0.67±0.88	0.03
Biological Oxygen Demand (mg/l)	18.88±1.96*	14.33±1.73	17.77±3.49*	13.77±2.22	100
Chemical Oxygen Demand(mg/l)	31.0±13.90	32.88±2.42	31.44±13.03	32.88±2.42	250

** implies significant differences; Zone 1: Apapa, Atlas cove and Iddo; Zone 2: Ogun River, Okobaba and Imore*

Table 1: Mean Physiochemical properties of Lagos Lagoon Surface water in the rainy season of 2013/2014 measured in the shipping (zone 1) and non-shipping (zone 2) sections

Parameters	Year I		Year II		WHO limits
	zone I	zone 2	zone I	zone 2	
pH	7.68±0.57*	7.08±0.32	8.15±0.19	15.85±23.4*	6-9
Salinity (‰)	27.03±4.41*	15.82±9.20	23.34±1.76*	14.15±8.28	NS
Conductivity(mS/cm)	41.16±5.73*	24.91±14.30	35.37±4.41*	26.31±16.71	NS
Dissolved Oxygen (mg/l)	7.35±1.54	7.41±1.62	7.47±1.14	6.42±0.64	5.0
Total dissolved solids (mg/l)	13.34±5.79	13.46±5.09	22.32±1.70*	13.94±7.23	2000
Surface Water Temperature(ºC)	30.91±0.75	31.53±1.28	30.79±0.73	30.52±1.02	<40
Turbidity (NTU)	11.74±13.76	17.35±15.87*	18.38±9.54	36.06±26.07*	10
Acidity (mg/l)	7.76±0.96	8.69±1.54	14.22±4.8	21±11.11*	NS
Alkalinity (mg/l)	23.45±4.12	21.11±4.96	25.44±2.40*	17.44±4.47	500
Chloride (mg/l)	9.52e3±5.52 e3	7.0e3±7.1e3	1.28e4±1.14 e3*	7.12e3±2.9e3	600
Sulphite (mg/l)	0.00	0.00	0.00	0.00	400
Sulphate (mg/l)	105±66	80.89±26.72	300±57	260±66	400
Nitrite (mg/l)	0.00	0.00	6.79±1.36	12±4.84*	0.2
Nitrate (mg/L)	23.85±15.90	24.16±15.07	9.13±0.44	14.57±5.66*	30
Ammonia (mg/l)	0.01±0.02	0.00	0.01±0.00	0.04±0.03	0.5
Total Organic Matter (mg/l)	4.13±7.92	0.19±0.10	0.20±0.09	0.23±0.18	NS
Total Organic Carbon (mg/l)	0.09±0.04	0.12±0.15	0.16±0.07	0.21±0.02	5
Phosphate (mg/l)	1.76±0.47	2.91±1.93	6.55±0.71	8.7±2.55	0.03
Biological Oxygen Demand (mg/l)	14.1±1.45	14.6±1.00	13.44±1.13	22.33±14.02*	100
Chemical Oxygen Demand(mg/l)	29.4±4.30	30.89±1.76	27.55±3.24	44.77±25.96*	250

** implies significant differences; Zone 1: Apapa, Atlas cove and Iddo; Zone 2: Ogun River, Okobaba and Imore*

Table 2: Mean Physiochemical properties of Lagos Lagoon Surface water in the dry season 2013/2014 measured in the shipping (zone 1) and non-shipping (zone 2) sections

SURFACE WATER HEAVY METAL CONCENTRATIONS IN AREAS ASSOCIATED WITH SHIPPING AND NON-SHIPPING ACTIVITIES IN THE LAGOS LAGOON

The variations in heavy metal concentrations in the surface water in the two zones indicated that there was no significant (P>0.05) variations in the value of Fe during the rainy and dry season across the zones in first and second sampling years (Table 3 and 4). The mean concentration of Cu was significantly (P<0.05) higher in zone 1(zones under influence of shipping activities) in rainy season (1.50±2.17 mg/l, first sampling year and 4.27±2.11 mg/l, second sampling year) compared to zone 2, (0.01±0.02 mg/l and 2.87±3.16mg/l) respectively (Table 3). In the first sampling year of the rainy season, Zn was ($P<0.05$) significantly higher in Zone 1 (0.54±0.20 mg/l) compared to zone 2 (0.10±0.06 mg/l). However, by the second year, Zn was found to be significantly ($P<0.05$) higher in zone 2 during the rainy session (Table 3). The mean concentration of Hg and Cd were significantly ($P<0.05$) higher in zone 1 second sampling year (0.14± 0.13 mg/l and 3.72 ±2.15 mg/l) during the rainy season compared to zone 2 (0.04±0.23mg/l and 0.74±1.29mg/l). There was no significant variation ($P>0.05$) in the mean concentration of Cr and Co across the zones and samplings years in the rainy season (Table 3).

The mean concentrations of Zn, Pb, Ni, Hg, Cd and Cr did not vary significantly ($P>0.05$) in surface water during the dry season in both zones (Table 4).

Properties	2013 zone 1	2013 zone 2	2014 zone 1	2014 zone 2	WHO limits
Iron	2.01±1.96	3.56±1.37	0.81±0.87	2.30±2.02	1.0
Copper	1.50±2.19*	0.01±0.02	4.27±2.11*	2.87±3.16	1.5
Zinc	0.54±0.20*	0.10±0.06	0.05±0.02	10.58±2.30*	15.00
Lead	0.003±0.004	0.001±0.002	0.00±0.00	.0500	0.01
Nickel	4.50±1.43	4.71±1.15	5.32±1.47	4.19±1.21	5.00
Mercury	0.45±0.33	0.46±0..31	0.14±0.13*	0.04±0.23	0.01
Cadmium	0.31±0.29	0.20±0.31	3.72±2.15*	0.74±1.29	2.00
Chronium	3.66±3.20	3.08±2.56	3.65±1.60	3.30±2.34	2.00
Cobalt	0.6±1.13	0.49±0.65	0.43±0.40	0.64±0.95	NS

** implies significant differences; Zone 1: Apapa, Atlas cove and Iddo; Zone 2: Ogun River, Okobaba and Imore; NS- Not stated*

Table 3: Heavy metal concentrations (mg/l) in the surface water in areas associated shipping (zone 1) and non-shipping (zone 2) activities in the Lagos lagoon in the rainy season 2013/2014

Properties	2013 zone 1	2013 zone 2	2014 zone 1	2014 zone 2	WHO limits
Iron	2.45±1.21	3.32±1.57	1.05±1.55	2.17±3.33	1.0
Copper	3.7±1.89*	1.67±2.13	1.05±1.55	2.17±3.33	1.5
Zinc	3.15±4.61	2.43±3.96	9.40±4.48	11.13±2.30	15.00
Lead	0.008±0.01	0.01±0.02	.0000	.0000	0.01
Nickel	4.81±1.12	3.81±2.14	3.21±1.08	3.20±2.00	5.00
Mercury	0.07±0.10	0.03±0.02	0.06±0.09	0.05±0.04	0.01
Cadmium	0.32±0.30	0.10±0.18	4.17±0.97	4.86±1.66	2.00
Chronium	3.67±3.20	3.52±2.07	3.82±2.01	3.42±1.87	2.00
Cobalt	0.25±0.29	0.31±0.29	0.74±0.74	0.75±0.84	NS

** implies significant differences; Zone 1: Apapa, Atlas cove and Iddo; Zone 2: Ogun River, Okobaba and Imore; NS- Not stated*

Table 4: Heavy metal concentrations (mg/l) in the surface water in the areas associated shipping (zone 1) and non-shipping (zone 2) activities in the Lagos lagoon in the dry season 2013/2014

MACROBENTHIC SPECIES DIVERSITY IN THE AREAS ASSOCIATED WITH SHIPPING AND NON- SHIPPING ACTIVITIES IN THE LAGOS LAGOON

The results of the macrobenthic fauna assessment are indicative of generally higher species abundance in zone 2 (areas not under influence of shipping activities (Table 5). A total of 4 phyla, 5 classes and 20 species were encountered in the study. The zone 2 had higher number of species (20) compared to zone 1 (18 species). There was also a general significantly higher ($P<0.05$) species abundance (N) in the rainy season compared to the dry season. Overall, Phylum mollusca were the most abundant and diverse taxa with 80% abundance and the least were the phylum chordata with 3% abundance. The bivalve, *Gryphaea gazar* was the most abundant species in zone 1with 25.39% abundance followed by *Thais coronate* with 15.55%, while the gastropod, *Neritina senegalensis* was the most abundant species observed in zone 2 with 17.03% abundance, followed by *Tympanotunus fuscatus* with 16.21%. There was a notable absence of the arthropod *Balanus pallidus*, a fowling organism in the zone 1. Among all the species observed in all the sampled stations in both seasons and zones, *Neritina senegalensis* had the highest percentage abundance (13.38%).

Specifically, Gastropods were significantly higher ($P<0.05$) in both seasons season in zone 2 compared to zone 1. Among the Bivalves, there was however no significant difference ($P>0.05$) in the species abundance in both seasons when both zones are compared. The observed crustaceans did not also show significant inter seasonal nor inter zone differences. There were no chordates in the sediment of zone 1 while in zone 2, the chordate, the mudskipper, *Periophthalmus* sp. was evident for both seasons. Among the observed polychaetes, there were no significant inter zonal differences ($P>0.05$) in the rainy season but the difference was significant in the dry season ($P<0.05$).

The community structure analysis using Shannon-Wiener and Margalef indices showed rather diverse and balanced strata. However, the equitability index showed that the non-shipping zone (zone 2) had a slightly more even species number per taxa (Table 5).

Taxa/Species	Zone 1 Rainy 2013	Zone 1 Rainy 2014	Zone 1 Dry 2013	Zone 1 Dry 2014	Zone 2 Rainy 2013	Zone 2 Rainy 2014	Zone 2 Dry 2013	Zone 2 Dry 2014
Phylum Mollusca								
Class Gastropoda								
Tympanotunus fuscatus	0	11	0	0	76	75	71	74
Tympanotunus fuscatus varradular	0	4	2	0	81	68	20	25
Pachymelania aurita	0	0	0	1	16	32	5	10
Neritina senegalensis	13	7	7	0	120	135	16	40
Neritina glabrata	10	30	1	0	95	110	14	25
Thais coronate	30	52	15	12	40	5	48	16
Class Bivalvia								
Mytilus edulis	32	32	0	26	45	65	4	38
Pera perna	5	0	3	18	4	24	0	0
Gryphaea gazar	90	75		13	2	17	60	1
Tellina nymphalis	10	0	4	0	5	0	12	4
Macuma Cumana	10	0	2	8	0	1	0	0
Phylum Arthropoda								
Class Crustacea								
Balanus pallidus	0	0	0	0	2	12	6	2
Sesarma huzardi	17	17	4	5	10	10	8	10
Penaeus notialis	0	2	0	0	0	0	2	6
Clibanarius africanus	38	11	22	2	10	41	15	4
Callinectes amnicola	2		34	1	5	5	11	7
Cardiosoma armatum	1		0	0	2	0	2	4
Phylum Chordata								
Class Actinpterygii								
Periophthalmus sp.	0	0	0	0	18	44	9	3
Phylum Annelida								
Class Polychaeta								
Nereis sp.	5	9	0	2	40	10	10	7
Heteromastus filiform	2	2	0	2	0	0	9	3
Taxa_Species Diversity (S)	**14**	**12**	**10**	**11**	**17**	**16**	**18**	**18**
Individuals	**265**	**252**	**94**	**90**	**571**	**654**	**322**	**279**

Shannon – Wiener (H)	2.087	2.018	1.785	1.958	2.272	2.343	2.425	2.34
Margalef Index (d)	2.33	1.989	1.981	2.222	2.521	2.314	2.944	3.019
Equitability_Index (J)	0.7908	0.8122	0.7751	0.8166	0.802	0.8452	0.8391	0.8096

Table 5: Macrobenthic Community Structure Analysis in the areas associated with shipping (zone 1) and non- shipping (zone 2) activities in the Lagos lagoon during the rainy and dry seasons sampling in 2013/2014

IV. DISCUSSION

The findings from this study indicated that although there were no overall significant differences in physicochemical characteristics for most parameters in the shipping and non-shipping areas of the Lagos lagoon in both rainy and dry season for the two years of sampling. Given the nature of the distribution of the sampling areas this is expected because activity, rather than geography was the key determinant in categorization. Also in view of the flowing, tidal and non-unidirectional nature of the Lagos lagoon, surface mixing is expected to attenuate the differences in physicochemical characteristics (Amaeze *et al.*, 2014) especially those not limited to salinity, given the high salinity gradient of this water body. The Lagos lagoon receives fresh water inputs from various creeks and large rivers, thus the more hinterland sections are relatively less saline than the seaward sections creating an euryhaline system. This is especially the case in the rainy season when large volumes of river water discharge into the lagoon. There was significant differences in salinity and turbidity between the shipping and non-shipping activities impacted areas of the lagoon, with the former having higher mean seasonal salinity while the later had higher mean seasonal turbidity. Significant inter sampling zone salinity was also reported in this lagoon by previous investigators (Ayoola and Kuton, 2009). The significantly higher turbidity reported in the non-shipping areas can be attributed to the fact that they are shallower, being further from the sea and also are continuously receiving waters discharged from inland water bodies. Except for Iron which was higher in the surface water of the non- shipping areas, mean concentrations of other metals were either higher in the shipping areas or without significant difference. Only lead and zinc were significantly higher in the shipping area and this trend was also only observed in the rainy season of the first year sampling exercise, thus indicating that it does not show any conclusive trend.

The observed macrobenthic fauna, clearly showed an inter zone bias with significantly higher species abundance in the rainy and dry seasons of both sampling years occurring in the non-shipping zone.

The percentage abundance as recorded by *Gryphaea gazar* in zone 1; *Neritina senegalensis* and *Tympanotunus fuscatus* in zone 2, indicated high dominance following the value of 15% and above recommended by Rosenberg and Resh (1993). Low dominance of benthos species indicated relative stability of the ecosystem. The very high dominance observed in the zones indicates imbalance communities strongly dominated by one or more numerous species during the study period. According to Rosenberg and Resh (1993), 15% or more of the total numbers of organisms indicate dominance, 5% indicates sub-dominance, 1% denotes common while less indicates rare species.

Clearly, the impact of dredging to allow for larger vessel as shown in the almost absence of *Tympanotunus fuscatus in zone 1* and possibly anti-fouling paints is evident in the absence of *Balanus pallidus*. The areas associated with shipping activities (Apapa port, Atlas Cove jetty and Iddo terminal) have been previously reported to harbour lower diversity of macrobenthic fauna (Doherty, 2014). Dredging of the Lagos channel is a routine activity conducted by the Lagos Channel Management Limited (LCM) in conjunction with Nigerian Ports Authority (NPA) in other to manage the continuous deposition of sand at the bottom of the water in the Lagos harbour. This is done to maintain or even improve the capacity of the harbour areas to accommodate larger cargo or tanker vessels. Given that dredging is a mandatory practice in most harbour like ours, destruction of the sediment structure is inevitable, leading to loss of important biota which performs key ecosystem function of filtering the water column. LCM had achieved at least -12.5m depth for the majority of Lagos Port by 2010, allowing major shipping companies to steam direct to Lagos, rather than first stopping at a rival port to lighten ship (reduce draft) (http://lagoschannelnigeria.com/dredge). When compared against the depth of less than 2m for most other parts of the lagoon, the possible impact on the macrobenthic fauna in the port area is notable. Also the absence of vertebrates across seasons from near shore sediment samples in the shipping areas points to a distorted ecological balance which may be attributed to shipping activities.

V. CONCLUSION

For the first time the Lagos lagoon has been assessed on the basis of the impacts of shipping activities using non-shipping areas (which do not receive large vessels) as reference. The impact of shipping activities in the Nigerian coastal waters has been elucidated in this study and the findings points to the need for a commissioned industry study by the Nigerian Maritime Administration and safety Agency (NIMASA), National Inland water ways Authority (NIOWA), Nigerian Ports Authority (NPA) and other relevant regulatory/administrative agencies.

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