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Post-Remediation Assessment of Levels of Contaminants within Oya Lake, Ikarama, Bayelsa State

Amukali[1*], O., Obadoni[2], B. O., Audu[3], S. I. & Imaitor-Uku[4], E. E.

[1]Geography & Environmental Management Department, Niger Delta University, Bayelsa State, Nigeria

[2]Department of Botany, Ambrose Alli University, Ekpoma, Edo State, Nigeria

[3]Department of Chemistry, Benue State University, Makurdi, Benue State, Nigeria.

[4]Department of Geography, Isaac Jasper Boro College of Education, Sagbama, Bayelsa State, Nigeria
***E-mail:amukaliogo@yahoo.com**

ABSTRACT
Oil spillage induces environmental health concerns within vulnerable areas. Oya Lake has been impacted upon by Oil spillage. Although, remediation works were carried out within the impacted area, deliberate effort was made to conduct a post-impact assessment of the levels of contaminants within the study area in order to ascertain the present pollution status of the area. Thus, physico-chemical and biological parameters were used to assess the contamination levels within the area and were carried out following standard procedures and methodologies. Values for physico-chemical, anions, cations and coliform counts as set by reputable national and international regulatory bodies, were within maximum permissible values for soils, sediments and surface water bodies of the Lake. However, most heavy metals and hydrocarbon contents studied were generally higher than the maximum permissible limits in soils, sediments and surface water bodies of the Lake. This portends danger for living organisms, that depend on resources generated within the study area since values recorded in this study implies serious health and environmental concerns. It is therefore recommended that appropriate Microbe-Assisted Phytoremediation Technology (MAPT) be designed with native species to help remediate the Lake because natural attenuation alone cannot efficiently and sustainably restore and rejuvenate the Lake.
Keywords: Post-Remediation; Oil spillage; Polycyclic Aromatic Hydrocarbons; Heavy Metals; Oya Lake

INTRODUCTION

According to Amnesty International (2013), on 7 December, 2008 there was a major oil spill near Oya Lake in Ikarama community, Bayelsa state, Nigeria. Owing to agitations from community members, Amnesty International and Shareholders Alliance for Corporate Accountability (SACA), Ibid (2013) reported that the Multinational Oil Company whose from whose pipelines the oil spilt, carried out clean up works within the vicinity from 19 March to 4 May, 2010 and this was followed by another in August, 2013 owing to insinuations that the impacted area was not properly cleaned up, initially. According to the indigenous people of Ikarama, Oya Lake was formerly a massive fishing ground upon which the people relied on for ages as a means of livelihood. Also, it served as a source of drinking water especially for fishermen and farmers who usually worked within the study area. But, after the spill, all that became history (Ibid, 2013).

Beller *et al*. (1996) emphasized that, just like any other technical appliances, pipelines are subject to ‘‘tear and wear’’, thus can fail with time. However, oil spills in the Niger Delta are caused by corrosion, poor maintenance of oil infrastructure, equipment failure, sabotage and theft of oil

(Amnesty International, 2013). The impact of oil spillage is enormous because when oil spills, every organism within its reach gets affected. One of the greatest challenges to humanity today is the endangering of biota as a result of environmental pollution from crude oil (Ezeonu *et al*., 2012). It was further stated that to estimate the biological danger of oil after a spill, knowledge of the harmful effects of the components is necessary. This necessitated the evaluation of various parameters of pollution for assessment of the impacts of contaminants on biodiversity and the environment (Ibid, 2012).

Otitoloju *et al*., (2009) was of the opinion that pollution by heavy metals in terrestrial ecosystems has been recognized as a serious environmental concern, due to their non-biodegradability and tendency to bioaccumulate in plants and animal tissues. Apart from Heavy metals causing decrease in biodiversity of species due to changes in composition of communities that eliminate the most sensitive species (Beyrem *et al*., 2007) and promoting the tolerance of opportunistic species (Syrek *et al*., 2006), they generally could contaminate food chains and cause serious health and environmental problems on a long-term basis.

Polycyclic Aromatic Hydrocarbons belong to the group of persistent organic pollutants (Vacha *et al*, 2010) and over 90% of the PAHs are strongly fixed and hence stored in the soils (Wild & Jones, 1995). Anthropogenic and natural activities are responsible for the input of PAHs into the environment but the main input source is anthropogenic (Baek *et al*, 1991) while natural sources contribute less (Wickle, 2000; Wickle, 2007). According to Banger *et a*l (2010), the petrogenic sources of PAHs include unburned petroleum and its products (gasoline, kerosene and, and lubricating oil) where as pyrogenic sources include high temperature combustion products such as incomplete combustion of organic materials. According to Vacha *et al* (2010), benzo(a)pyrene is the most toxic compound of the PAHs. Presence of PAHs in agricultural soils does not usually lead to acute intoxication of humans but affects after long-term exposure (Janosek *et al*, 2007). Sources of drinking water and traditional occupations such as fishing and water transportation are greatly affected by crude oil contamination (Ezeonu et al., 2012).

Natural attenuation has proven to be successful for cleaning up benzene, toluene, ethylene, and xylene (BTEX) compounds present in ground water (Barton 2000). However, it is applied mainly on sites with “low” environmental or public value, when time is not a limiting factor, because restoration can take a long time (decades), or at sites where no other restoration techniques are applicable, thus cannot be applied at sites close to domestic areas or at sites with high environmental value (Kuiper, 2003). This work was borne out of the need to assess the current pollution status via assessing the physical, chemical and biological contamination status of the study area and predicting possible impacts.

Study Area

The Niger Delta is located within the southern part of Nigeria. It is home to numerous creeks, rivers and possesses the world’s largest wetland with significant biological diversity (Twumasi & Merem, 2006). Oya Lake is located within Ikarama community in Yenagoa Local Government Area of Bayelsa State, Niger Delta, Nigeria. The GPS locations of the sampled Points were; Point I (005° 08’ 517’’N and 006° 27’ 367’’E) and Point II (005° 08’ 481’’N and 006° 27’ 481’’E) for soil while for sediment, Point I was (005° 08’ 509’’N and 006° 27’ 382’’E) and Point II (005° 08’ 523’’N and 006° 27’ 419’’E), respectively. Both Points were affected by the oil spillage that ravaged the study area. Point I was an area that never received any form of prior remediation effort while point II witnessed remediation. The population of Ikarama community has been put at over 7,000 people (CENSUS, 2006).

Theoretical/Conceptual Framework

Man’s environment exists in a very delicate balance that could be altered by anthropogenic activities. Alteration of man’s environment usually leads to serious consequences on organisms inhabiting or depending directly or indirectly on such environments. Man’s environment consists of massively interwoven relationships that could offset negative feedback mechanisms upon alteration (Enger & Smith, 2010). Pollutants are major triggers of these negative feedback mechanisms (Wolfson *et al*, 2002). Pollution results when an organism’s supportive environment is rendered unsafe or unfit for the organism’s dwelling (Kolo, 2006). A pollutant is any substance which when discharged into the environment, has a tendency to cause pollution (Kolo, 2006). Therefore, soil, sediment or surface water pollution results when pollutants are discharged into such environments to the extent that they accumulate to toxic levels. Contaminants could infiltrate food chains (Ezeonu *et al*., 2012) and resultantly raise serious health and environmental concerns.

The concept of Environmental Sustainability has been adopted for this study. Amukali (2012) emphasized the fact that item 7 of the Millennium Development Goals (MDGs) seeks to ensure environmental sustainability. This goal seeks to reduce environmental degradation arising from natural and man-made causes as well as inefficient use of resources and to improve environmental management through private sector participation and environmentally-friendly practices (UNDP, 2006). Sustainable development is a process of change wherein resources exploitation, the direction of investment, the orientation of technological development and institutional change are all in harmony and enhance both current and future potentials to meet human needs and aspirations (Ibid, 2006).

The 1980 World Conservation Strategy (WCS) emphasized three sustainable objectives; that essential ecological processes and life support systems must be maintained; that genetic diversity must be preserved and that any use of species or ecosystem must be sustainable. This concept asserts that meeting the needs of the present generation, should not compromise that of future generations because it recognizes that there is no difference between preserving the environment and promoting development, in that you cannot have one without the other (Niger Delta Development Commission, 2006).

Onwuka (2005) emphasized that environmental sustainability is of paramount importance to the Niger Delta people, both rural and urban poor population, since it's fundamental to their total well-being and development. He further stressed that the poor rely mainly on natural resources for their subsistence lifestyle and that any threat to the environment affects their livelihood source, health and makes them more vulnerable to other socio-economic factors. UNDP (2006) further stated that this is largely because over 60% of the people in the region depend on the natural environment-living and nonliving for their livelihood. Without proper environmental management, the developmental process which the oil industry is supposed to achieve would only be a mirage and many would be subjected to more insufficient livelihood options, poor health and vulnerability to persistent poverty. Thus, the exploitation, production, transportation and utilization of crude oil should be done in a sustainable manner that should not compromise the integrity of the area.

METHODOLOGY

Soil and sediment samples were collected from distinct designated Points within the study area. Soil samples were collected from two different sample points, the first about 5m away from edge of the surface water bodies which was from a region that witnessed initial remediation activity while the second was about 100m away from the first point. Soil and sediment samples were collected on 1st September, 2016 at about 2.40pm to 3.16pm. In addition, sediment samples were collected underneath waters of the Oya Lake and which was about 5m from the edge of the lake while the second Point was collected about 100m away from the first Point but still inside the Lake. Both soil and sediment samples were collected with the aid of an auger, dipped down into each medium and turned 360° before being withdrawn and samples taken. Collected samples were then instantly wrapped in foil papers and appropriately labeled before being taken to the laboratory for analysis.

Surface water samples were collected from two distinct locations Points too. Two surface water sample sets were collected around 11.00am – 12.00pm on same day. These were done by immersing 2 liters containers completely in the water and as soon as it got filled, it was corked beneath the water surface before being pulled out. The surface water samples collected were taken to the laboratory for analysis. At every point, two sets of samples were collected: one for AAS analysis and the other for anions like phosphate, sulphate and nitrate. No further treatment was needed for the anions, thus the samples were analyzed right away to minimize chemical changes in the sample and prevent losses to the environment (Radojevic & Bashkin, 1976).

All standard methods and procedures were adopted and followed in the analyses of different parameters. Varian 220 fast sequential Atomic Absorption Spectrometer (AAS) was used for the determination of all metals considered in this work while TPHs and PAHs were analyzed using Gas Chromatography device (USEPA, 2007).

Pre-treatment of the water samples' elemental analysis was necessary because of the likelihood of samples containing suspended particles along with metals. Pre-treatment of samples involved addition of an acid to preserve the sample, destroying organic matter and bringing all metals into solutions as recommended by Radojevic & Bashkin (1976). A few drops of concentrated HNO_3 were added to the water samples after collection to preserve the samples, destroy organic matter and minimize absorption on the walls of the containers. Preparation of standard stock solutions and working standards were done following the methods by USEPA (2007) for calcium, magnesium, sodium, potassium, iron, copper, zinc, cadmium, lead, chromium and aluminium. McConkey broth single and double strengths were also prepared and coliform counts were then investigated following the method adopted by Kolo (2007) wherein five tubes each of 50ml, 10ml and 1ml of single strength McConkey Broth Medium were inoculated with volumes of the water samples and incubated for 24 hours at 24°C. All formal physico-chemical standards and methodologies were strictly followed. Varian 220 fast sequential Atomic Absorption Spectrometer (AAS) was used for the determination of all metals studied in this work

RESULTS AND DISCUSSIONS

Physicochemical Analysis

Land is one of the most important resource upon which man depends (Singh & Juwarkar, 2014). Generally, lives of most organisms thrive at neutral pH. Ezeonu *et al*. (2012) stated that most bacteria survive better in the pH range of 6.5 to 8.5, and yeasts and molds thrive better at pH range of 4.5 to 5.3. Thus, pH levels within soils and sediments do show that micro-organisms could be environmentally stressed to death. It is said that pH is one of several environmental conditions that can serve to inactivate enzymes when levels are not optimal (Sublette, 2001).

Table 1: Physicochemical Parameters of Soils and Sediment Samples.

Physico-Chemical Parameters						
S/No.	Parameters	P1 SS	P2 SS	P1 SD	P2 SD	Max. Perm. Limit
1	pH	5.72	6.03	5.31	5.68	NA
2	Temperature °C	24.5	24.3	24.8	24.6	NA
3	Electrical Conductivity (µS/cm)	153.10	142.00	164.40	117.00	NA
4	Alkalinity (mg/kg)	8.00	4.00	16.00	12.00	NA
5	Total Organic Carbon (%)	0.21	0.17	0.44	0.52	NA

Physico-chemical parameters for soil and sediment samples were all within maximum permissible limits. In addition, Ezeonu *et al* (2012) stated that the optimal pH range for biodegradation is considered to be 6.0 to 8.5. Evidence from this study showed that for this area to be effectively and successfully bioremediated, the pH has to be limed to get the pH to goal. Very high or too low temperatures could affect the lives of living organisms. Values for temperature of soil and sediment samples show that they could sustain lives of most living organisms. In addition, electrical conductivity, alkalinity and total organic carbon all do not show evidence of serious health and environmental concerns.

Anion Contents

Anions in this present study were found to be within acceptable maximum permissible limits, hence do not pose any great health and environmental concerns (Table 2).

Table 2: Anions in Soil and Sediment Samples.

Anions						
S/No.	Parameters	P1 SS	P2 SS	P1 SD	P2 SD	Max. Perm. Limit
6	Chloride (mg/kg)	15.11	11.33	20.76	18.89	NA
7	Available Phosphate (mg/kg)	6.74	5.61	1.87	1.25	NA
8	Nitrate (mg/kg)	3.22	4.38	1.53	1.31	NA
9	Sulphate (mg/kg)	10.65	8.75	107.38	97.64	NA

Cation Contents

The cations are not of much health and environmental concerns in this present study as they were found to be within acceptable limits by relevant regulatory bodies (Table 3).

Table 3: Cations in Soil and Sediment Samples

Cations						
S/No.	Parameters	P1 SS	P2 SS	P1 SD	P2 SD	Max. Perm. Limit
10	Calcium (meq/100g)	0.15	0.23	0.45	0.37	NA
11	Magnesium (meq/100g)	0.24	0.17	0.76	0.82	NA
12	Sodium (meq/100g)	0.96	0.67	0.32	0.26	NA
13	Potassium (meq/100g)	0.19	0.14	0.77	0.65	NA
14	Exchangeable Acidity (meq/100g)	1.13	0.98	1.58	1.29	NA
15	ECEC (meq/100g)	2.67	2.19	3.88	3.39	NA

Heavy Metal Contents

Generally, sediment samples were found to be significantly higher than soil samples at both sampled points, with the exception of lead and cobalt (Table 4). This is an indication that sediments within the Lake act as a dominant sink for contaminants from where excess reserves are released to surface waters whenever disturbed. Also, another possibility could be the existence of movement of leachates from the soil to surface water bodies, sediments and from the sediments back to surface waters, back again to the sediment, and the cycle continues in that trend. Apart from cobalt and aluminium, all the other parameters studied in this present study (iron, zinc, lead, copper, cadmium and chromium) all had values that were higher than the maximum permissible values. Thus, there are very high chances that these persistent heavy metals would form aggregations with the 'silty-clayey' soils and sediments from where they would be leached steadily into surface and ground waters.

Table 4: Analyses Results of Heavy Metals for Soil and Sediment Samples

Heavy Metals				Source: Akpoveta *et al*., 2010.		
S/No.	Parameters	P1 SS	P2 SS	P1 SD	P2 SD	Max. Perm. Limit mg/kg
16	Iron (µg/g, dried wt.)	283.67	232.38	317.55	353.72	38,000
17	Zinc (µg/g, dried wt.)	49.58	56.66	69.24	71.37	90
18	Lead (µg/g, dried wt.)	13.66	9.39	8.71	8.59	10
19	Copper (µg/g, dried wt.)	36.89	35.19	43.20	46.10	30
20	Cadmium (µg/g, dried wt.)	7.14	13.02	10.99	22.19	0.5
21	Chromium (µg/g, dried wt.)	3.13	2.43	4.87	5.22	100
22	Cobalt (µg/g, dried wt.)	<0.001	<0.001	<0.001	<0.001	8
23	Aluminium (µg/g, dried wt.)	0.01	0.01	0.02	0.02	NA

ECEC= Effective Cation Exchangeable Capacity, <0.001 implies below detection limit of equipment and NA= not available.

In addition, high tendencies exist that the roots of aquatic and terrestrial plants would absorb contaminants, bioaccumulate them within their systems and living organisms that depend on the food chain could suffer health problems. Damages to kidneys, brains, lungs and other bodily systems could result from heavy metals contamination in mammals. Thus, suffice it to be stated that two possible sources for heavy metals exists within the study area. First, when high pressured crude oil is pumped through rusty pipelines (probably, leaded) over long distances, they could pick up heavy metals and when they spill into the environment, they inevitably enrich same with heavy metal contaminants. Secondly, the presence of heavy metals could mean the existence of large natural resource deposits within the area.

Hydrocarbon Contents

Both TPHs and PAHs components pose serious health and environmental concerns. Total petroleum hydrocarbons are acutely toxic (Heitkamp & Cerniglaa, 1998) just as the presence of PAHs in the environment is of high environmental and health significance owing to their high toxicities and persistence (Banger *et al*., 2010). Holoubek (2005) specifies the intake of PAHs by plants via the intake by roots from the soil solution and leaves of plants.

Table 4: Hydrocarbon contents of Soils and Sediment Samples

Hydrocarbons						
S/No.	Parameters	P1 SS	P2 SS	P1 SD	P2 SD	Max. Perm. Limit µg/kg
24	Total Petro. Hydrocarbon (mg/kg)	18.33	17.96	29.41	22.10	
25	Polycyclic Aromatic Hydrocarbons					
	Non-carcinogenic (mg/kg)	$9.7x10^5$	$8.4x10^5$	$3.85x10^6$	$1.06x10^6$	>1,000 µg/kg
	Carcinogenic (mg/kg)	$2.72x10^6$	$2.18x10^6$	$5.90x10^6$	$4.77x10^6$	>1,000 µg/kg
	Total PAHs (mg/kg)	$3.69x10^6$	$3.01x10^6$	$9.75x10^6$	$5.84x10^6$	>1,000 µg/kg

Values of both TPHs and PAHs at both sampled Points I and II were generally found to be higher in the sediment samples as compared to soil samples. However, soils and sediment samples were found to be astronomically higher than the adopted maximum permissible limits. For instance, based on the levels of PAHs and human risk assessment, Maliszewska-Kordybach (1996) classified the European soils having total PAHs >1,000 µg/kg as heavily contaminated; the other classes were contaminated (600-1000 µg/kg), weakly contaminated (200-600µg/kg) and not contaminated (<200 µg/kg). On the bases of this classification and comparison, it could be concluded that the soils and sediments of the study area are dangerously contaminated and efforts should be made at remediating the study area as soon as possible. This is to prevent further food chain contamination of the environment by both TPHs and PAHs and organisms (man, inclusive) that feeds on any food stuffs growing within affected soils stand chances of being chronically affected by the pollutants.

Furthermore, evidence from this study indicated that exotic plant species growing within the area must have a tendency for special affinity for mopping up the TPHs and PAHs in the soils owing to the discovery that the levels of both classes of contaminants were significantly lower in soils at $p<0.005$ level of significance than those of the sediments from both sampling points. This is promising for screening of phytoremediators that could be used to remediate the study area. Also, this implied that the soils and surface waters of the study area have a high propensity of gradually releasing their TPHs and PAHS content to the sediments were they settle at the bottom of the Lake. Thus, sediments act as a viable sink for both contaminants and any remediation effort must take into cognizance, the need to remediate not only soil and surface waters, but also sediments.

Water Analysis Results

Results for Analyses of Physico-chemical Parameters

Results for water analysis are presented in Tables 5- 10. The pH fell within the maximum permissible limit of 6.0 – 8.5 (NIS, 2007) benchmark. This water body could sustain the bacterial growth and existence (Ezeonu *et al*., 2012). The water pH values at both sampled points showed that the water body ought to be limed before a successful and effective bioremediation process could be carried out. The values of pH recorded in this study could be attributed to large volumes of water received by the pond during wet season when the sampling took place and this should help in effectively dispersing and neutralizing contaminants within the water body.

Table 5: Physico-Chemical Parameters of Surface Water Samples

	Physico-Chemical Parameters	Sample Points		
S/No.	Parameters	P1 SW	P2 SW	Max. Perm. Limit
1	pH	6.58	6.40	6.0 – 8.5
2	Temperature (°C)	29.1	28.9	25 – 30 °C
3	Total Dissolved Solids (mg/l)	47.61	41.10	1,000 mg/l
4	Electrical Conductivity (µS/cm)	94.80	81.60	1,000 µS/cm
5	Dissolved oxygen (mg/l)	4.50	5.30	>4 mg/l
6	Biological Oxygen Demands (mg/l)	1.00	1.50	0.1 – 1.9 mg/l
7	Chemical Oxygen Demands (mg/l)	2.50	3.75	200 mg/l
8	Total Suspended Solids (mg/l)	100.00	210.00	20 mg/l
9	Turbidity (N.T.U.)	97.41	208.40	5 N.T.U.
10	Total Alkalinity (as mg/l $CaCO_3$)	10.00	6.00	30 – 500 mg/l
11	Total Hardness (as mg/l $CaCO_3$)	28.00	24.00	100 mg/l

Temperature values between sampling Points I and II were not different at $p<0.005$ level of significance. The maximum permissible limit of temperature of between 25-30 °C for drinking water was not exceeded by both sampled sites in this study. Bhutia (2005) stated that areas prone to discharge of industrial wastes usually have temperature ranges above those of their surrounding environments. This is an indication that there was no new oil spill within the study area. Also, tremendous amounts of rain water received by the pond must have helped in decreasing and maintaining an almost constant temperature between both sampled points. Higher surface water temperatures limit migration, spawning, egg incubation, growth and metabolism as well as rates of respiration.

Sample Point I had a higher TDS value than Point II but both fell within WHO (1996) recommendation of 1000mg/l for the protection of fisheries and aquatic lives and NIS (2007) recommendation of 500mg/l as maximum permissible limit for domestic water supply. The high TDS with respect to low Dissolved Oxygen (DO) agrees with the findings of Ademoroti (1996). High levels of TDS in drinking water may be objectionable to consumers due to its taste and this could cause excessive scaling in water pipes, boilers and household appliances (Kolo, 2007). Though significant differences occurred between both sampled points for electrical conductivity, however, both points fell within acceptable limit of 1,000µS/cm. Higher rate of conductivity at Point I could be due to excessive accumulation of salts, impurities in rain water, spilled oil, through run-off from agricultural lands and possible emissions of flared gases getting into such waters.

Higher values of DO above 4mg/l fell within acceptable limit for drinking water (NIS, 2007). Also, the waters fell within the stream standard for fishing having attained maximum permissible limit for stream standard for fishing of greater than 2 (Pescord, 1977), hence the ability of such surface waters to support fishing activities. Higher DO signify higher biological activity while wet seasons influences higher biological activities more than dry season at both study sites (Amukali, 2012), hence significant differences between study sites and seasons at $p<0.05$ level of significance.

BOD of 1.00 and 1.50 mg/l were recorded at Points I and II (Table 1) respectively. Based on Radojevic and Bashkin (1999) classification, both sampled points could be said to be moderately clean. All values recorded in this study were within the benchmark maximum permissible range for BOD of between 0.1 – 1.9mg/l (USEPA, 1999). Both values were below the stream standard for fishing of between 3.0 – 6.0mg/l for BOD (Pescord, 1977). Thus, the surface waters in this present study cannot sustainably support aquatic lives. The maximum permissible limit of 200mg/l for drinking water (USEPA, 1999) was not attained by both studied sites. Thus on the grounds of COD in this present study, the water is within acceptable limit for domestic use.

The values of TSS at Points I and II show that the maximum permissible limit for TSS for drinking water of 500mg/l (NIS, 2007) was not exceeded even though significant differences occurred between Points I and II, respectively. Very high difference in TSS within the same Lake is of urgent health and environmental concern. Excessive influx of suspended solids within the lake could be attributed to oil spillage and decaying organic materials.

Turbidities were very high at both Points I and II (97.41 NTU and 208.40 NTU) as shown in Table 5 above. The recommended maximum permissible limit of 5NTU turbidity level for drinking water (NIS, 2007) was astronomically exceeded. High turbidities could be as a result or massive containment of organic or inorganic materials, oil spillage or gas flaring. Waziri (2006) attributed high values of turbidities in the dry season to decreased vegetation and evapo-transpiration during cooler months. In this study, surface turbidities could impair aquatic visibility and this could have some impacts on their health and the environment.

Total alkalinity was higher at Point I than Point II (Table 1) but both fell within the range adopted as maximum permissible level by USEPA (1991). The higher value at point 1 could be due to the presence of chemicalized substances released through oil spillage (Amukali, 2012). Higher alkalinities in surface waters could also be due to the influences of rocks, soils, certain plant activities and dissolved salts. Total Hardness ranges from 28.00 to 24.00mg/l in concentration indicate that the water is soft when compared with the WHO standard for drinking water of 100mg. This shows that the water is suitable for domestic use and hence will form lather easily with soap.

Cation Content of Surface Water Samples

Results as shown in Table 6 above indicate that cations like calcium, magnesium, sodium as well as potassium all fell within their respective maximum permissible limits for drinking water, except magnesium which fell below the normal requirement at both locations as stipulated by the Nigerian Environmental Regulatory Agency (NIS, 2007).

Table 6: Levels of Cations in Surface Water Samples

Cations				
S/No.	Parameters	P1 SW	P2 SW	Max. Perm. Limit
12	Calcium (mg/l)	1.20	0.80	50 mg/l
13	Magnesium (mg/l)	0.49	0.45	37 – 150 mg/l
14	Sodium (mg/l)	2.63	1.92	200 mg/l
15	Potassium (mg/l)	1.35	1.19	1 – 2 mg/l

Anion Content of Surface Water Samples

The anions determined in this study were phosphate, sulphate, nitrate and chloride. From the analyses results, none of the anions showed any evidence of surface water contamination since they all fell below the maximum acceptable limit for drinking water as Nigerian regulatory body (NIS, 2007). Hence, anions in this water do not show signs of being injurious to man when used for domestic purposes.

Table 7: Levels of Anions of Surface Waters

Anions				
S/No.	Parameters	P1 SW	P2 SW	Max. Perm. Limit
16	Phosphate (mg/l)	3.87	2.24	10 – 50 mg/l
17	Sulphate (mg/l)	10.13	9.35	100 mg/l
18	Nitrate (mg/l)	1.29	0.97	50 mg/l
19	Chloride (mg/l)	15.30	11.27	250 mg/l

Heavy Metal Content of Surface Water Samples

At both sampled Points, apart from zinc, cobalt and aluminium which were below detectable limits, iron, lead, copper, cadmium as well as chromium had values that were far higher than the maximum permissible value for drinking water (NIS, 2007). At such high levels, people who use the water for drinking stand very high chances of suffering from iron-related overload and poisoning, cancers as well as terratogenic effects in unborn children.

Table 8: Levels of Heavy Metals of Surface Waters

Heavy Metals				
S/No.	Parameters	P1 SW	P2 SW	Max. Perm. Limit
20	Iron (mg/l)	2.10	1.73	0.3 mg/l
21	Zinc (mg/l)	0.13	0.05	3 mg/l
22	Lead (mg/l)	0.51	0.27	0.01 mg/l
23	Copper (mg/l)	1.27	1.21	0.5 mg/l
24	Cadmium (mg/l)	2.18	2.14	0.003 mg/l
25	Chromium (mg/l)	0.19	0.15	0.05 mg/l
26	Cobalt (mg/l)	<0.001	<0.001	0.05mg/l
27	Aluminium (mg/l)	<0.001	<0.001	0.2 mg/l

This is owing to the persistent nature of these toxic pollutants in the water. It is possible that these persistent pollutants must have polluted the food chain and anybody or organism that feeds either from fruits (guava, banana, or other food crops within the area) or fish that reside within the Lake, the contaminants would bioaccumulate into their bodies, and these could resultantly cause mutagenic, carcinogenic as well as terratogenic effects vulnerable species.

Hydrocarbon Content of Surface Water Samples

The values of both TPHs and PAHs in surface waters of the study area were higher at Point I than Point II. ATSDR (2013) stated that The U. S. Environmental Protection Agency limits maximum contamination levels for benzo(a)anthracene (0.0001mg/l), dibenz(a,h)anthracene (0.0003mg/l), indenol (1,2,3-c,d)pyrene (0.0004mg/l) as 0.0002mg/l for benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene and chrysene, respectively in water. Ibid (2013) further stated that in 1980, USEPA while developing ambient water quality criteria to protect human health from the carcinogenic effects of PAHs exposure recommended zero (non-detectable level for carcinogenic PAHs in ambient water) value. In addition, according to WHO, The European Commission and The

International Agency for Research on Cancer, the concentration of benzo(a)pyrene in drinking water should be lower than 15ng/l for such waters to be safe for drinking. Thus, it could be stated that Oya Lake's surface waters are extremely toxic and injurious to any living organism that should depend on it. At such toxic, levels, it could be difficult for most animal species to survive, especially fish species that may not be able to tolerate this level of toxicity.

Table 9: Levels of Hydrocarbons of the Surface Waters

Hydrocarbons				
S/No.	Parameters	P1 SW	P2 SW	Max. Perm. Limit by ATSDR (2013)
28	Total Petroleum Hydrocarbon (ng/l)	$3.67x10^6$	$3.42 x10^6$	
29	Polycyclic Aromatic Hydrocarbons (ng/l)	-	-	
	Non-carcinogenic PAHs (ng/l)	$9.95x10^5$	$6.85x10^5$	0.2 ppb
	Carcinogenic PAHs (ng/l)	$1.068x10^6$	$1.05 x10^6$	0.2 ppb
	Total PAHs	$2.063x10^6$	$1.76 x10^6$	0.2 ppb
Microbiological				
30	Total Coliform Count (MPN/100ml)	0	0	0

<0.001 implies below detection limit of equipment.

The International Agency for Research on Cancer has enumerated effects of TPHs in man and other animals to include damages to the central nervous system, peripheral neuropathy (numbness of feet and legs), reduction in immunity, and general effects on blood, lungs, skin, eyes, decreased fertility and effects on developing foetus (ATSDR, 1999). In the aquatic environment, the effects of PAHs on invertebrates include inhibited reproduction, delayed emergence and increased mortality while the effects in fish include fish erosion, liver abnormalities cataracts and immune system impairments (Neilson, 1994; Salizzato et al., 2000; USEPA, 2009).

Evidence from Table 9 above shows that the water is free of coliforms of whatever nature. The zero coliform could be owing to poisoning as induced by high toxicities of the TPHs and PAHs as well as persistent heavy metals (iron, lead, copper, cadmium and chromium) present in the study area's water body.

CONCLUSION

In this present study, the following conclusions could be drawn, with respect to the adopted maximum permissible limits. These were as follow;

Soil samples of the study area adjoining Oya Lake has been found to still be badly contaminated with some persistent heavy metals, TPHs and PAHs from where they leached into adjoining surface water bodies (especially Oya Lake) and settle at the bottom of the lake.

Sediment samples within Oya Lake were found to be badly contaminated with some persistent heavy metals, TPHs as well as PAHs and has proven to be a major sink for the contaminants. Thus, the sediments received theses contaminants from both adjoining soils and water bodies, accumulated same and gradually released same to the surface water, whenever it was disturbed.

Surface water samples of Oya Lake was seriously contaminated with some persistent heavy metals, TPHs as well as PAHs and this portends great danger to aquatic organisms that reside within, those that have migrated or those trying to migrate to the lake.

The physico-chemical parameters, anions as well as cations of the study area's soils, sediments and surface water body were all within the recommended maximum permissible limits as set out by various national and international environmental regulatory bodies and this could be attributable to the massive flood that swept the study area in 2012 and which must have helped to disperse the quantities of most of such contaminants that were present. Positive biogeochemical processes must have also contributed to reducing values recorded for these parameters.

Apart from zinc, aluminium and cobalt which were below permissible limits, iron, lead, copper, cadmium as well as chromium were all found to be far above the recommended maximum permissible limits. This is an indication of heavy metal pollution within the area and these could be very detrimental to the health and well being of all living organisms that depend on the environment in one way or another since food chain contamination by them could be mutagenic, carcinogenic and highly terratogenic.

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