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Pollution and effects of hydrological patterns on water and sediments quality characteristics from porto-novo lagoon bionetwork

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Abstract

Impact assessment of hydrological patterns on Porto-Novo lagoon water, sediments quality characteristics, and pollution status were carried out for 12 months. Water quality parameters and metal pollutants were also evaluated.The water body was stratified into 12 strata based on the morphology of the lagoon and various human activities on the lagoon. Data were collected based on season, sampling stations, metal pollutants, and water quality parameters. The results were analyzed in the laboratory and interpreted using exploratory data analysis statistics. There is no significant difference in the means of dissolved oxygen and pH in different months between July and June at 5% level of probability. However, there is a significant difference in the means of temperature, turbidity, electrical conductivity, salinity, total dissolved solids, COD, BOD, total hardness, and depth in different months at 5% level of probability. The order of amount of metallic contaminants in sediments from Porto-Novo Lagoon between July and December (Rainy season) are in these order; Mn> Fe> Zn> Pd> Cr> Cu> Ni> Cd> Va> Hg> MH_3Hg.The metallic pollutants are significantly difference (p=0.0) during rainy season. The trends of existence of metallic pollutants in sediments from Porto-Novo Lagoon from January to June (dry season) are in these order; Fe> Mn> Zn> Cu> Cr> Pd> Ni> Cd> Va> Hg> MH_3Hg. The difference of the metal pollutants in the dry season at p=0.05 is significance. It is obvious that the hydrological periods affected all the tested physicochemical characteristics and also determine the metal pollutants status of Porto-Novo Lagoon water and sediments. It is therefore recommended that the state of emergency should be declared on Porto-Novo Lagoon for adequate environmental revamping and protection by environmental expert and regulatory agencies.

Keywords: Pollution, Hydrological Pattern, Sediments, Water, Bionetwroks.

Introduction

The industrialrevolution and anthropogenic activities are the major sources of contaminants in the aquatic environment and affecting the objectivity of the aquatic biota by impairing both the quality of the water and the hydrological budget thereby leading to immense destruction to aquatic ecosystems, thus causing environmental degradation and extermination of some ecologically important organisms, distortion of food chains and food webs. Pollution of an aquatic ecosystem affects its physicochemical potentials and this potential is progressively diminishing the host community that is destroying the fragile ecosystem. Various uses of water bodies are extremely compromised due to pollution and the consequences on the environment cannot be over-emphasized[1].

Substances introduced into the environment either from anthropogenic activities or by natural phenomenon that constitute health risk to both human and animals is called pollution, other legitimate uses of the environment. Lagoon pollution has been progressively significant over the recent years and this has been found to add significantly to ecological problems in many countries of the world, therefore, an assessablewater quality which is the ambient environment for aquatic organisms are crucial before any significant level of pollution can be determined and controlled in such country. Lagoon pollution that finds their way into lagoon through an exact source is referring to pollutants that enter a watercourse from a single, recognizable source, such as drainage or canal. However, lagoon pollution which enters through isolated source are refers to diffuse impurity that does not originate from a single distinct source[2].

In Lagoon ecosystem, the importance of hydrology in physicochemical characteristics and nutrient dynamics is sturdily established. Moreover, Lagoon types and characteristics are determined by the Morphology and meristic features of the lagoon[3]. Extreme rainfall events would supplement short-term freshwater contribution. Paerl *et al*[4] on the contrary; lesser precipitation would reduce freshwater inputs in the lagoon. The unpredictable conventional increase or decrease, and strength of occasional rainfall is consequently predicted to give an increase or decrease variability, both spatially and temporally of pollutants in the lagoon. The climatic condition affects the quantity and quality of a particular water body[5].

The main focus of water qualityassessment from Porto-Novo Lagoon is to monitor the trends in the level of pollution using physicochemical characteristics such as Biological oxygen demand, pH, temperature, dissolved oxygen, pH, Total dissolved salts, Chemical oxygen demand, Electrical Conductivity, ammonia, nitrite, nitrate, sulphate, and turbidity/ transparency over two hydrological cycles. Porto-Novo climatic condition is tropical with 2 rainy seasons (maximum and minimum) and 2 dry seasons (maximum and minimum). The lagoon hydrology depicts volume of water in a range of 44.09 mm- 244, 84 mm. Porto-NovoLagoon is located at the capital of the Republic of Benin. Porto-NovoLagoon ecosyem which is an arm of Gulf of Guinea has topography of 0 meter above sea level and it falls between N6°28'0.01"(Lat.) and E2°36'0" (Long.) as cited by Babalola and Fiogbe[6].

Porto-Novo becomes a repository as a result of its ecological location in which all discharged water from the drainage, sewage, wastewater from surrounding municipalities are emptied. Also, the effect of increased urbanization, human activities and indiscriminate garbage disposition along the lagoon coast are the main cause of the lagoon pollution by metallic pollutants and other lethal substances[7].

Methodology

Site location: Porto-Novo Lagoon is geographically located in Porto-Novo municipality which is serves as seat of Government of Benin Republic and having Latitude 6^{o} 29' 36''N longitude 2^{o} 2' 18''E. It is located on a coastal lagoon at the extreme southeastern part of the country (Figure-1)[7].

Site description: The research work was conducted on Porto-NovoLagoon ecosyem which is an arm of Gulf of Guinea has topography of 0 meter above sea level and it falls between N6°28'0.01"(Lat.) and E2°36'0"(Long.) Figure-2. Porto-Novo Lagoon from Benin Republic is one of the major aquatic ecosystems in West Africa sub-Sahara with high sustainable fisheries resources with close proximity to and separated from the sea by the sand bank systems. The Porto-Novo Lagoon is located about 30 km North-Eastern of Cotonou, which is the economic nerve center of Benin Republic[7]. The lagoon shape shows a three-sided shape with total area of 30 km^2 (subterranean) and 20 km^2 (superficial) respectively with 6 km in length (West-East) and breadth diverges amid 2km and 4 km. Porto-Novo lagoon is an ecological unit surrounded by the two major cities in Benin Republic, Cotonou and Porto-Novo municipalities and it is joined to Lake Nokoué through Totchè channel[7]. Porto-Novo lagoon is connected to Badagry lagoon (Nigeria) through Porto-Novo creeks.

Sampling procedures: The sampling sites was divided into 12 stations and precisely positioned by using Garmin GPS model 72H.In each sampling site, lagoon water samples by navigating through the study area. Water samples were taken between July and December for the first season and between January and June for the second season to have samples from one hydrological cycle[6].

Geo-Referenced Points: The study sites were mapped out and sampling points were selected according to lagoon physical structures (Figure-2). The main data were collected from 12 study sites from Lagoon ecosystem which was cautiously designated. Water samples were taken from each study sites as identified by portable Global Position Satellite. All necessary precautions involve in environmental study were duly observed[6].

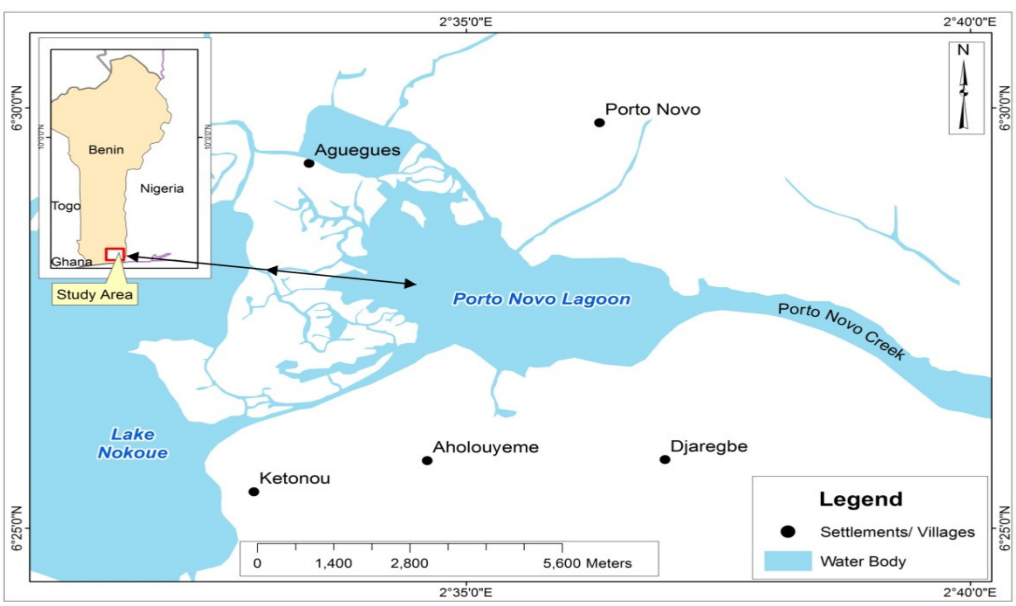

Figure-1: Location of the Study.

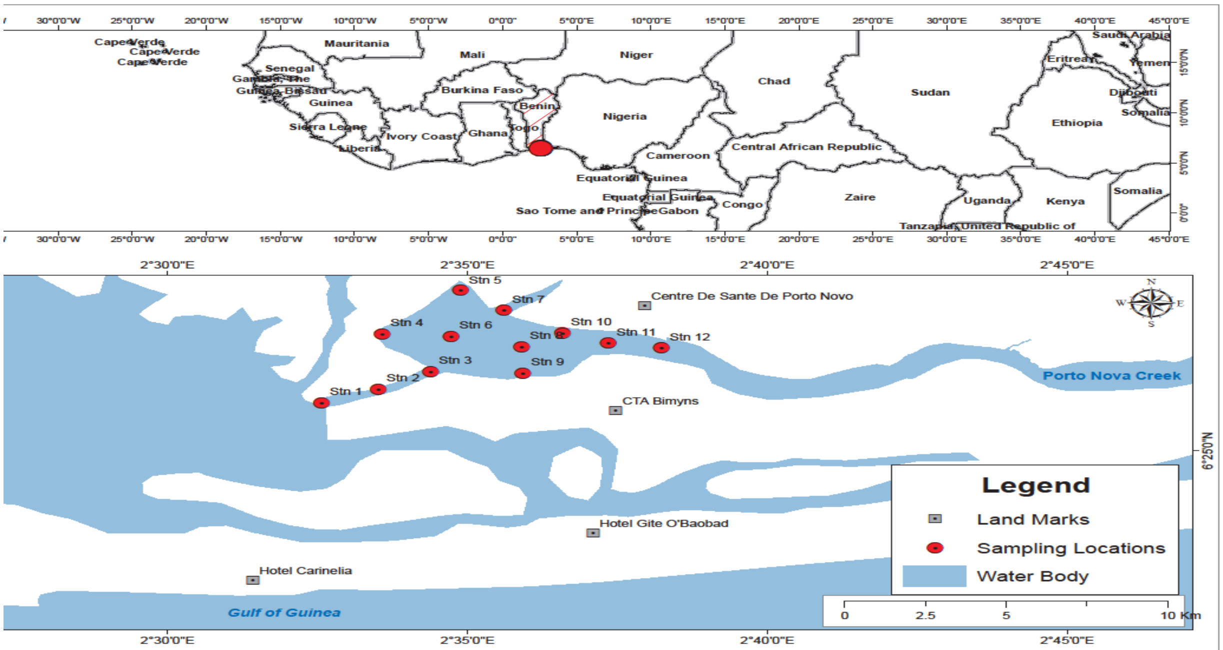

Figure-2: Geo-Referenced Points on Porto-Novo Lagoon.

Structure and Specimen Assessment Survey: The study site was visited one day in a month using outboard dugout wooden canoe for navigation on water. Water samples were collected between the 6.00hr and 12noon from twelve different sampling stations from freshwater brackish of Porto-Novo Lagoon by using stratified random sampling method as described by Babalola and Agbebi[2]. Water quality parameters of the lagoon were taken both *in-situ* and *ex-situ* using appropriate water test kit equipmenton monthly basis during the study period. Water samples are collected using 1-liter sterile plastic container each for all the sampling stations for the analyses of all the selected test parameters as cited by Ademoroti[8].

A collection of surface sediments with the aid of Soil Grab by using randomized completely design method of sampling method with the main focus on point and non-point sources of pollution. In every tow of sediments, a quartile of sediment was removed and kept in polythene bags and store in a refrigerator (<4°c) in preparation for the laboratory analytical results of all the metal pollutants of interest as mentioned by Ademoroti[8]. The laboratory analyses *(ex-situ)* for all the samples collected from Porto-Novo Lagoon ecosystem during the study period were carried out by using Atomic Absorption Spectrophotometer (Flame- AAS) (model; Thermo Electron Corporation, S Series AA Spectrometer with Flame, UK). in the laboratory of the Department of Oceanography and Water Chemistry, National Institutes for Oceanography and Marine Research, Lagos Nigeria.

Results and discussion

To evaluate the disparity in pollution level of lagoon water between the two hydrological periods, exploratory data analysis was used. A probability level of 0.05 or less was considered significant.

Research outcome: All physicochemical parameters from Porto- Novo lagoon water are reported as shown in Table-1.

The lowest means of dissolved oxygen (4.85mg/l) is recorded in October while the highest means (7.74mg/l) is recorded in March; the means during rainy and dry seasons ranged between 6.12±1.198mg/l - 7.02±0.792mg/l. There is no significant difference in the means of dissolved oxygen in different months at 5% level of probability. However, the temperature was taken *in-situ* and the least means was taken in August (25.8°C) and the highest means of 31.03°C in the month of May. It ranged between 28.61±2.198°C - 29.69±1.783°C during the study periods. There is a significant difference in the means temperature in different months at 5% level of probability.

The turbidity was measured using Secchi disk graduated in meters, and the least is reported in August (0.18m) whereas the highest is reported in March and April with means of 0.77m each. The annual means standard deviation range is set between 0.39±0.168 m - 0.54±0.246 m. There is a significant difference in the mean values of turbidity in different months at 5% level of probability.

The seasonal electrical conductivity from Porto-Novo Lagoon water ranged between 18.27±10.559 µS/cm - 24.08±11.026 µS/cm and January had the highest means of 37.68 µS/cm, although July had the least (8.11 µS/cm). There is a significant difference in the means of electrical conductivity in different months at 5% level of probability.

The salinity of Porto-Novo Lagoon water was taken in-situ using had held digital meter. The least mean value recorded is 0.10% in July and the highest mean value is 8.3% in April. However, the annual range is set between 0.33±0.274% and 4.4±3.511%. There is a significant difference in the mean value of salinity in different months at 5% level of probability.

The annual total dissolved solids ranged between 8.69±3.734 mg/l and 15.32±7.837mg/l. The lowest and the highest concentrations of 4.09mg/l and 26.18mg/l in July and February were recorded respectively. There is a significant difference in the means of total dissolved solids in different months at 5% level of probability.

The seasonal pH of freshwater brackish of Porto-Novo Lagoon ranged between 6.8±0.000 and 6.9±0.126. During the rainy season, the pH remained constant at 6.8 however; the lagoon pH had the elevated values during dry season and lowest values in rainy season, 7.1 and 6.7 in May and June respectively. The difference in the pH values during the sampling periods is not significant at 5% level of probability.

The annual means of chemical oxygen demand from complex Porto-Novo Lagoon ecosystem was reported between two seasonal periods from 12 study points as revealed in Table-1. The two hydrological periods ranged between 12.77±0.964 mg/l and 16.35±1.321 mg/l was observed. The mean assessment of chemical oxygen demand from 12 sampling stations and for different months are significantly different at p =0.05.

Table-1 indicates the seasonal variations in biological oxygen demand from Porto-Novo Lagoon ecosystem. The annual means of BOD ranged between 7.24±1.317mg/l and 9.03±0.629 mg/l. There is a significant difference in the mean range of Biological oxygen demand from the study sites and during different months at p =0.05.

Average values of total hardness concentrations from Porto-Novo Lagoon water as shown in Table-1. January had 7624.47 mg/l total hardness concentration from all the sampling stations while December had 39.92mg/l total hardness concentrations from all the 12 sampling stations. The means of total hardness are significantly different at p =0.05 from the 12 sampling stations and for the different months.

Annual means depth of 4.47±0.06m in Porto-Novo Lagoon from 12 sampling stations during hydrological periods was observed as shown in Table-1. The means depth are significantly different at p =0.05 from all the sampling stations. The sampling periods do not affect the depth of the lagoon but the different depth observed is determined by the topography of the lagoon floor.

Table-2 illustrates the means of metallic pollutants in the sediment from Porto-Novo Lagoon during the study periods between July and December 2014 and between January and June 2015.

The seasonal variations of metal pollutants from Porto-Novo Lagoon sediments shows that some of the metallic pollutants identified are in quantifiable elevation and spatially distributed from Sampling Station 1 to 12, between rainy and dry seasons. 3- Factor variance analysis is used in the research such as metallic pollutants, periods, and sites.

The trends of occurrence of metallic pollutants in the sediment from the Lagoon ecosystem from July to December are in the following arrangement; Mn> Fe> Zn> Pd> Cr> Cu> Ni> Cd> Va> Hg> MH_3Hg. The results from July to December shows that Methyl mercury had the lowest average means concentrations of 0.08±0.04mg/kg, and Manganese had the highest average means concentrations of 43672.38±68,930.76 mg/kg. All the metallic pollutants in the lagoon ecosystem during the study periods are significantly different at p =0.05

The trends of incidence of metallic pollutants in the sediments from the Lagoon ecosystem during between January and June as presented in Table-2 are as follows; Fe> Mn> Zn> Cu> Cr> Pd> Ni> Cd> Va> Hg> MH_3Hg. During January to June sampling periods, Methyl mercury was below had the lowest concentration of 0.005±0.001mg/kg while Iron (Fe) had the highest concentration of 46296.67±1761.68mg/kg in the sediments. All the metallic pollutants in the lagoon ecosystem between January and June are significantly different at p =0.05.

Discussion: Pollution of an aquatic ecosystem affects its physicochemical potentials and hydrological cycle which also increasingly rescinding the community that is destroying this fragile ecosystem. Various uses of water bodies are extremely compromised due to pollution and the consequences of this pollution on the environment cannot be overemphasized.

The Republic of Benin uses to have hydrological cycle periods of high and low rainy seasons and high and low dry seasons[9] which have an influence on ambient temperature and consistently affect the surficial water temperature of Porto-Novo Lagoon. This phenomenon is responsible for disparities of values of temperature obtained during the study periods. However, the high mean standard deviation of temperature observed during dry season over the rainy season could be as a result of an extended period of insolation with the attendant high ambient temperature.

Consequently, non-sequential values in temperature may perhaps distort the biogeochemical progression of lagoon sediments thereby leading to increase in the solubility and toxicity of certain metal pollutants such as cadmium, zinc,and also, influence tolerance limits of some aquatic organisms to metal pollutants bioaccumulation, this is in accordance with the report of Adandedjan *et al*[10]. Water temperature is an essential factor to consider when evaluating water quality characteristics of water bodies. The best water temperature range for lagoon ecosystem is 20-33°C [11].

Dissolved oxygen is of major importance as an indicator of water condition in lagoon ecosystem and is perhaps the most critical water quality parameter in the aquatic ecosystem. Dissolved oxygen in water plays a vital role in oxidation and reduction potential of the water body[12,13]. During the rainy season, Dissolved oxygen concentration is higher than that of season without rain, this finding agreed with a report of Baron[14]. The diversity in dissolved oxygen concentration in the Porto-Novo Lagoon ecosystem could also be as a result of bacterial breakdown of organic matters in the lagoon that use up dissolved oxygen in some sites for the purpose of oxidative reduction processes[2]. The distributions and elevation of various metallic pollutions in the Lagoon ecosystem may possibly be as a result of various aerobic and anaerobic zones in the lagoon ecosystem which cause changes in redox potential levels of various metal pollutants as reported by Haiyan *et al*[15]. The dissolved oxygen range for aquatic organisms in the tropical region is between 5mg/L -6mg/L [16]

Table-1: Total and Means (± SD) of the Physicochemical Characteristics of Lagoon water.

Rainy Season (2014)	DO (mg/)	Temp (^{0}C)	Tub (m)	Cond. (µS/c)	TDS (mg/L)	Sali (%)	pH	Depth (m)	*BOD (mg/L)	***COD (mg/L)	****TH (mg/L)
July	6.01	27.35	0.26	8.11	4.09	0.10	6.8	90.79	8.42	14.96	95.00
Aug	6.01	25.81	0.18	9.68	8.64	0.16	6.8	90.81	8.10	16.27	102.83
Sept	7.74	26.82	0.35	13.05	8.22	0.14	6.8	90.80	8.04	16.42	105.33
Oct	7.53	30.36	0.62	16.22	6.32	0.72	6.8	90.75	7.07	17.24	105.33
Nov	7.35	30.55	0.55	33.50	15.14	0.64	6.8	90.82	7.00	18.32	59.50
Dec	7.48	30.78	0.38	29.09	9.75	0.24	6.8	89.92	4.83	14.90	39.92
Mean ±SD	7.02± 0.792	28.61± 2.198	0.39± 0.168	18.27± 10.559	8.69± 3.734	0.33± 0.274	6.8± 0.000	90.65± 0.358	7.24± 1.317	16.35± 1.321	84.65± 28.022
Dry Season (2015)	DO (mg/L)	Temp (^{0}C)	Tub (m)	Cond. (µS/c)	TDS (mg/L)	Sali (%)	pH	Depth (m)	**BOD (mg/L)	***COD (mg/L)	****TH (mg/L)
Jan	7.57	30.95	0.38	37.68	13.94	0.4	6.9	90.97	9.76	11.59	7624.4
Feb	7.12	30.95	0.38	34.38	26.18	0.4	6.9	90.87	9.40	12.05	6447.0
Mar	6.88	28.64	0.77	29.12	23.84	6.5	6.9	90.78	9.17	12.53	5122.90
April	4.85	29.98	0.77	14.75	7.39	8.3	6.9	90.75	7.91	12.89	4455.26
May	5.21	31.03	0.73	16.66	10.97	7.4	7.1	90.97	9.10	13.25	3580.37
Jun	5.09	26.57	0.21	11.86	9.59	3.4	6.7	90.85	8.85	14.33	284.14
Mean ±SD	6.12± 1.198	29.69± 1.783	0.54± 0.246	24.08± 11.026	15.32± 7.837	4.4± 3.511	6.9± 0.126	90.87± 0.092	9.03± 0.629	12.77± 0.964	5007.38± 2550.209
Permissible Levels											
WHO Limit	6	40	5	250	1000	**	6.8	**	30	250	100
USEPA Limit	**	**	**	**	500	**	8.5	**	**	**	500
EU Regulation	**	**	**	250	1000	**	9.5	**	**	**	**
LASEPA	4	26	35	70	2000	35	6.0	**	50	80	10

= Not Available, *= Biological oxygen demand (mg/L), *=Chemical oxygen demand (mg/L), ****= Total Hardness (mg/L).

Table-2: Total and Means (± SD) of Sediments Quality from Porto-Novo lagoon (n=12).

	Range	Hg	Cd	Cu	Zn	Cr	Fe	Mn	Pd	Ni	Va	MH_3Hg
July-Dec (2014)	Min	0.04	5.9	9.1	80.7	34.7	688.6	519.7	8.20	9.8	0.00	0.01
	Max	0.015	16.4	35.2	296.7	99.7	27926.5	37.7	37.70	25	0.39	0.04
	Total	0.91	130.6	253.6	1746.6	788.8	177166.6	524068.45	269.16	201.7	1.18	0.23
	Mean (±SD)	0.08± 0.04	10.88± 0.29	21.13± 6.63	145.55± 61.65	65.73± 22.49	14763.88± 9021.83	43672.38± 68930.76	22.40± 10.30	16.73± 3.79	0.12± 0.14	0.02± 0.01
Jan-June (2015)	Min	0.01	1.00	4.98	112.5	5.86	610.8	167.8	1.39	1.66	0.00	0.002
	Max	0.03	2.77	78.9	476.5	16.8	133727	786.2	6.37	11.67	0.07	0.006
	Total	0.17	22.07	397.48	2797	133.27	555560.8	5243.13	45.46	43	0.22	0.042
	Mean (±SD)	0.02± 0.01	1.84± 0.56	33.12± 19.91	233.08± 101.05	11.11± 3.80	46296.67± 41761.68	436.92± 241.02	3.78± 1.75	3.60± 2.62	0.02± 0.02	0.005± 0.001
Permissible level/ Agency	FEPA	0.001	< 1.0	< 1.0	< 1.0	< 1.0	20	200	27.20	2.73	< 1.0	N/A
	EU	0.001	0.005	0.05	5.0	0.05	0.2	0.05	18.80	3.18	N/A	N/A
	USEPA	0.002	0.01	1.0	1.0	0.1	1.0	0.05	37	2.59	0.04	0.002

*N/A=Not Available

The distribution of salinity within the lagoon is influenced by the magnitude that the input of freshwater mixes with the incoming seawater[17]. The salinity of Porto-Novo lagoon ranged between 0.10% and 8.34%. The elevated concentration was detected during season without rain while the concentration decreases in season with rain. The relationship between salinity concentration and metal pollutants in water is that an increase in salinity also increases the absorbable form of metal pollutants by the organisms in the ecosystem[18].

The electrical conductivity of Porto-Novo Lagoonhad the least annualmeans value of 8.11 µS/cm and highest meanvalue 37.68 µS/cm. The highest mean value falls within the range of freshwater conductivity (50-500 µS/cm) as stated by Boyd and Lichtkoppler[12]. The heterogeneity of electrical conductivity in the complex Porto-Novo Lagoon ecosystem could perhaps dueto effects of dynamic nature of nutrients and organic matters in the lagoon. EPA[19]. Also, the characteristics nature of lagoon sediments could also alter the concentration of electrical conductivity of water as elucidated by Barron[14] but there is no correlation between electrical conductivity and the recurrent variations of metallic pollutants in water[20].

The Lagoonp H under investigation ranged between 6.86 and 7.21, this falls within the acceptable range for aquatic life as reported by Wurts and Durborow[21]. The observable high pH in some months may not be unconnected with the nature of activities this community engaged in, they practice substituent animal husbandry which generates organic matters that release nutrients through oxidation processes such as ammonia. Radke[22] and also, laundry activities could also be responsible for the elevated pH as published by Anderson[23] and Vander-Heide[24]. According to Lenntech[25], anthropogenic causes of pH fluctuations are usually related to pollution. The pH of water determines the solubility and biological of chemical constituents such as nutrients and metal pollutants and also, the solubility of these metallic pollutants depends on their degree of their harmfulness. Metal pollutants are likely to have high toxicity in acidic medium due to high solubility effect and trans-bioaccumulation in the environment also increases with high pH[26].

There is an irregular pattern of turbidity from complex Porto-Novo Lagoon ecosystem, this is due to the fact that the Republic of Benin which is equatorial has four complementary hydrological seasonalities of maximunm dry and rainy seasons, and minimum dry and rainy seasons respectively[7]. The irregularities in the pattern may be due to progressive changes in ecological variables that generate concentration and hydrological gradients whichdepend on the hydrodynamics of the ecosystem due to runoff, erosion, and re-suspension from seasonal water flow[27] and Allen and Mallarino[28]. Sand mining by the riparian community in some selected locations on Porto-Novo Lagoon during the period of low rainy season and tides could also be responsible for seasonality increase in Porto-Novo Lagoon silt turbidity. Sand mining can affect water quality and aquatic organisms and also, dissolved metal pollutants can attach to suspended particles from run-off or sediments during sand mining and enter the water[29].

The physicochemical parameters of the water play a vital role in metalpollutants levels of toxicity in water, therefore, significant relationships exist between total dissolvedsalts and metal pollutants concentrations in the lagoon water[30]. Elevated levels of total dissolved salts observed during the seasonal periods of the high and low dry seasons from Porto-Novo water may perhaps due to reduced precipitation and elevated rates of evaporation of surface water[2].

Low concentrations and similarity in the total hardness during the months of July, June, August, September, October, November and December may perhaps be owing to considerable soluble salts dilution of calcium and magnesium in lagoon water from precipitation[2]. High total hardness observed in the months of January, February, March, April, May and June respectively could be as a result of lagoon sediments geochemical composition, hydrodynamic and influx from Nokoué Lake that has been adulterated with ocean salts having sulphate and chloride ions that associated with calcium and magnesium from the lagoon. This agreed with the report of Pandey and Shukla[31]. The significant effect of water total hardness on metal pollutant toxicity is apparent[32].

Biological oxygen demand from lagoon water offered a very fair measure of its hygienic condition and the amount of putrescible material in the water[33]. The Biological oxygen demand values of an annual mean range of 9.76mg/L - 4.83 mg/ was observed and it is above the permissible level for rivers and considered the Porto-Novo Lagoon ecosystem polluted. France *et al*[34]. This could be linked to organic matters decomposition through oxidation processes by microorganisms emanated from dunghills and fecal materials generated around Porto-Novo municipality and deposited into the water that uses up dissolved oxygen to stabilize the organic materials of wastewater. This agreed with scientific publication of Mancy and Weber[35] and Marske and Polkowski[36]. Micronutrients such as nitrates and phosphates in lagoon can add to high BOD levels[37]. However, a high concentration of BOD from lagoon could also be from metal pollutants oxidation processes. Xiang *et al*[38] reported that presence of metal pollutants ion in water increases the BOD by the use of dissolved oxygen to form metal oxides.

Chemical Oxygen Demand in water offers a guide to evaluate the effect discharged wastewater will have on the aquatic environment. There is a significant difference in the mean value of Chemical Oxygen Demand for 12 sampling stations and for different months (July 2014-June 2015) at 5% level of significance. This implies that COD concentrations are homogeneously distributed throughout the sampling stations and between the two hydrological periods. This perhaps may further explain the heterogeneous nature of the lagoon sediments that has much influence on water quality. However, the variations in concentration of COD in the lagoon could be linked to metal pollutants oxidation as reiterated by Xiang *etal*[38].
There is a positive correlation between depth and all the physicochemical parameters investigated from Porto-Novo Lagoonecosystem[39]. Sampling station 1 had shallower depth with high dissolved oxygen and high transparency from light penetration but in station 11 there is reduced dissolved oxygen and turbidity are high. However, there is a direct relationship between depth, dissolved oxygen, temperature and other water quality parameter variables. According to Babalola and Agbebi[2], increases or decreases in any water quality variables in any water bodies will either increase or decrease another variable. Lagoon morphology plays important roles in physicochemical and biological characteristics of the water bodies[4]

Conclusion

Water quality as an indicator of aquatic environment is a factor capable of determining the level of pollution in such environment. Not all measured water quality parameters from Porto-Novo Lagoon met the regulatory body acceptable limits. It is observed from this study that water quality parameters have been used to categorize this water body has been a freshwater brackish lagoon. The parameters measured were carefully selected and well distributed to cover the entire dimension of Porto-Novo Lagoon as well as four hydrological periods occurring in the Republic of Benin as it affects metal pollutants concentrations in the sediment. The hydrological periods affected all the tested physicochemical characteristics from Porto-Novo Lagoon water, their values are either inversely or directly proportional to each other depending on the season of the year and the extent of pollution either from natural occurrence or human activities that find their ways into the lagoon. Also, the disparity in the water parameters also plays a significant part in the varied distributions of metal pollutants in Porto-Novo Lagoon sediments. Recommendation is thus made that a proper legislation should be declared on the Lagoonecosystem for adequate environmental revamping and protection by environmental expert and regulatory agencies.

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