Research Journal of Applied Sciences, Engineering and Technology 2(3): 274-282, 2010
ISSN: 2040-7467

Submitted Date: March 22, 2010 Accepted Date: April 16, 2010 Published Date: May 10, 2010

Assessment of Wastewater Discharge Impact from a Sewage Treatment Plant on Lagoon Water, Lagos, Nigeria

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Abstract: The aim of this study was to assess the wastewater discharge impact from the University of Lagos campus treatment plant on the lagoon system. In order to achieve this objective water samples were collected from nine sites and analyzed for different wastewater quality variables. The field survey was carried out between July and November in order to capture both the wet and dry seasons. Average removal efficiencies of measured parameters from treated effluents are 26% for Total Dissolved Solids (TDS), 73% for Biological Oxygen Demand (BOD), 65.8% for Chemical Oxygen Demand (COD) and 72% for Total Nitrogen (Total N) for the wet season campaign. During the dry season average removal efficiencies of measured parameters are 54% for TDS, 54% for BOD, 39% for COD and 42% for Total N. These values are lower than values obtained for the wet season except for TDS. Most parameters in effluents exceeded the National Environmental Protection Regulations, Effluent Limitation standards for discharge into river bodies. Average concentrations of TDS, BOD and COD in lagoon water show higher concentrations than in the treated effluent and are above the regulatory requirements. The research recommends further study on the possible influence of water dynamics and sampling methods on water quality of the lagoon. The overall results from this research conclude that the lagoon is being polluted by effluents discharge from the university treatment plant thereby exposing the health of local residents who use it for recreation and for food production purposes.

Key words: Lagoon, parameters, pollution, sewage, treatment, water quality

INTRODUCTION

Sewage disposal in natural waters is a common practice among many nations. Large inputs of organic matter and nutrients from raw sewage to a weak hydrodynamic environment poses environmental and health problems from deterioration of water quality (Ribeiro and Araujo, 2002; Cimino *et al*., 2002; Rajagopalan, 2005; Al-Dahmi, 2009). Inadequate or faulty sewerage and/or sewage treatment system are major causes of pollution in natural waters. The exponential growth in urbanization through migration of people from rural and semi-urban areas to cities in search of livelihood, has contributed to the deploring sewerage situations in most major cities of the world notably in developing countries. In its report, Central Pollution Control Board (CPCB), 1995 indicated that only 40-50% of the populations of the major Indian metro-cities of Delhi, Bombay, Calcutta, Madras and Bangalore are served by sewer systems. Even where sewers exist, they are poorly designed, constructed or maintained. Report has it that over 5,200 water bodies in the United States do not meet ambient water-quality standards for their designated uses as a result of pathogens, while nearly 4,800 are impaired as a result of nutrients, causally linked to failed onsite treatment and disposal systems (USEPA, 2000).

Raw sewage contains urine and faeces from toilet flushing as well as other types of human waste; it may also contain such things as toilet paper and wipes. These may as well include tampons and other feminine sanitary products. The pathogens in raw sewage can contaminate ecological systems in addition to sickening humans and animals. In addition, raw sewage contains a variety of other constituents, including oxygen-demanding organics, which can deplete dissolved oxygen in receiving waters; pathogenic microorganisms, which can spread disease (*E. coli* and hepatitis A; cholera); and nutrients, which can stimulate the growth of aquatic plants (Theodorou, 1997; Akoachere *et al*., 2008). Sewage may also contain potentially toxic, mutagenic, or carcinogenic compounds (Al-Muzaini *et al*., 1999). Besides being exposed to bacteria and viruses, a person exposed to raw sewage may develop a range of illnesses, including gastroenteritis, which is marked by diarrhoea, vomiting, and abdominal pain. The sometimes-fatal Weil's disease is another common problem, which causes symptoms that resemble the flu and can lead to liver and kidney damage.

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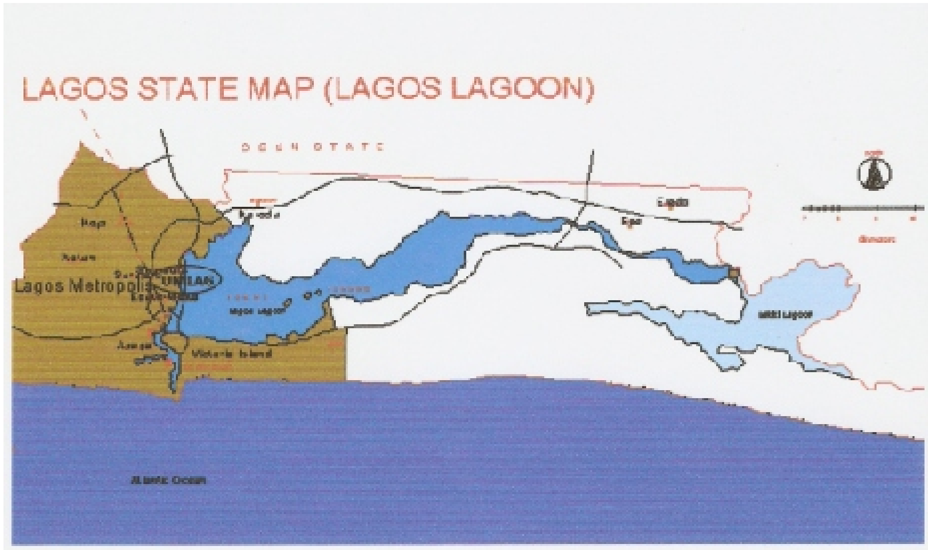

Fig. 1: The areal extent of Lagos Lagoon showing University of Lagos (UNILAG), after Okusipe (2004)

Occupational asthma, caused by inhaling certain organisms, is another risk of exposure. Excessive deposition of chemical nutrients in water bodies such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Solids (TS), pH, and conductivity impairs the quality of the water bodies and as well endanger aquatic life (Mallin and Cahoon, 2007). Eutrophication, which may result from organic load on water bodies, is one of the numerous problems created by sewage pollution (Diaz *et al.*, 2002; Garg, 2006). Even though, water bodies in their natural form contain chemical compounds such as the bicarbonates, nitrates, chlorides, sulphates, various problems however arise with the increase in the amount of these compounds within the water bodies. The buildup of salts from sewage can interfere with water re-use as salts like sodium chloride, potassium sulphate pass through conventional water and waste water treatment plants without change. High salt concentrations in waste effluents can increase the salinity of the receiving water, which may result in adverse ecological effects on aquatic life (Chapman, 1996). Water which contains salts is not useful for irrigation either as utilization of such water leads to the salinization of the soil, which in turn leads to soil erosion. The toxins released into the rivers through sewage water are consumed by fishes and other organisms, thus increasing the possibility of these toxins entering the food chain (Gomez-Couso and Mendez-Hermida, 2006). The growth of coral reefs is adversely affected by toxins present in the polluted water.

The Lagos lagoon which is the focus of the current research like many coastal lagoons, serves as a seaport, centre for recreational sailing and a sink for disposal of domestic and industrial wastes. A paucity of information exists on the extent of pollution of the lagoon (Iwugo *et al.*, 2003). The consequences of inappropriate sewage disposal in the city are numerous which include degradation and devaluation of the environment, high cost of curative and preventive healthcare, contamination of waterways, and destruction of aquatic life. The current study was aimed at assessing the impact of discharges from the university sewage treatment plant on the lagoon.

MATERIALS AND METHODS

The study area: The lagoon, which is the focus of this study is located behind the University of Lagos, Lagos, Nigeria. The lagoon system is an extensive water body in the heart of the metropolis, and cuts across the southern part of the metropolis, linking the Atlantic Ocean (in the west and south) and Lekki Lagoon (in the east). It is about 6354.788km^2 in area and 285 km in perimeter (Okusipe, 2004). The University of Lagos lagoon front, which acts as a sink for effluents from the university sewage treatment plant is the main thrust of this study. The University of Lagos lagoon front is part of the Lagos Lagoon system (Fig. 1). Along its path, the lagoon provides places of abode and recreation, means of livelihood and transport. Generally within the metropolis, untreated excreta, together with commercial and industrial effluents are discharged into the Lagos lagoon system daily. In addition to wastewater from industries, there are domestic sewage discharges; garbage and wood shavings from sawmill depots along the shores of the lagoon (Iwugo *et al.*, 2003, FOE, 2006). The proliferation of urban and industrial establishments along the shores of the lagoon has resulted in serious pollution problems.

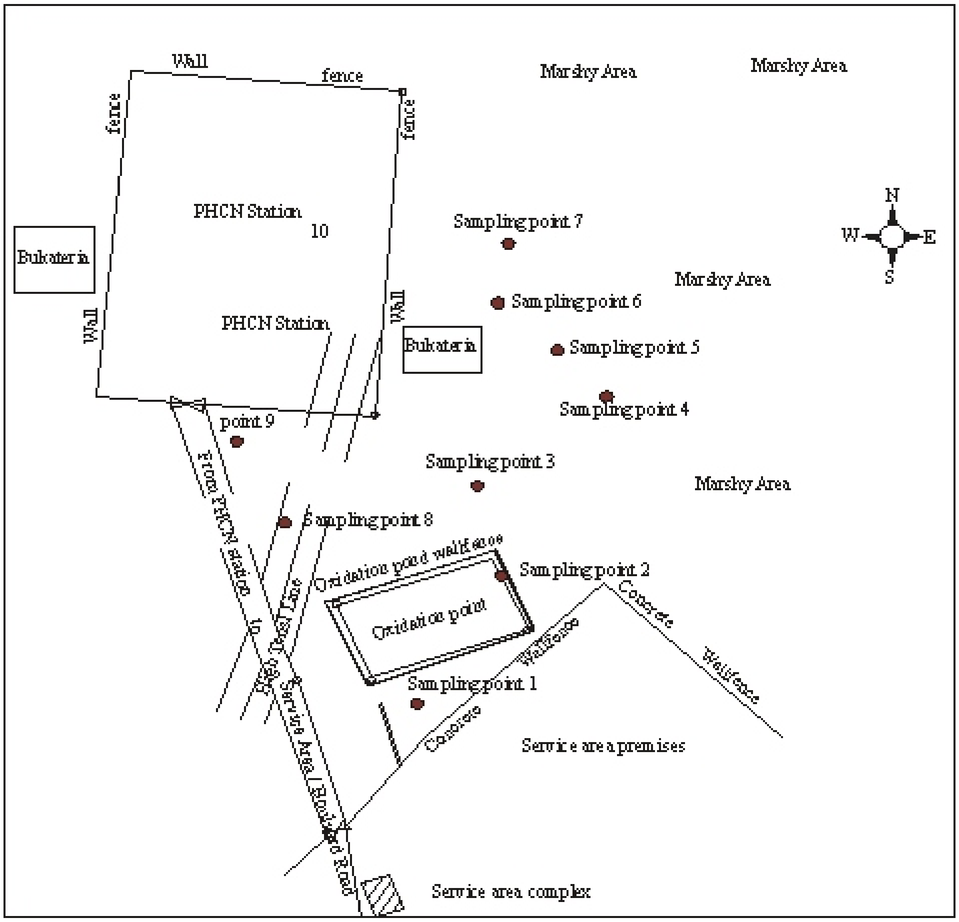

Fig. 2: Schematic drawing of sampling sites

Field sampling and laboratory analysis: Field samplings of influent, effluent and water samples from the lagoon were carried out between May and November 2007. Nine sampling points designated P_1 to P_9 from sampling locations within the treatment plant premises and along the lagoon (Fig. 2). Site P_1 was located at the inlet of the treatment plant where influent samples were collected. Site P_2 was located at the effluent discharge point from the treatment plant before it reaches the lagoon.

The qualities of influents and effluents were measured at these two points to determine the efficiency of the treatment plant in renovating the sewage. Site P_3 was a point located approximately 5 m after the effluent discharge point into the lagoon. Sites P_4 through P_7 were located at distances 10, 15, 20 and 25 m, respectively after the effluent discharge point into the lagoon. Sampling points P_8 and P_9 were located at distances of 10 and 20 m respectively from the effluent discharge point off the direction of flow in order to assess the lateral spread of sewage in lagoon system (Fig. 2).

A total number of 77 water samples were collected from the lagoon for the determination of the following important pollution indicator parameters pH, Conductivity, DO, TDS, BOD, COD, Total Nitrogen at 9 sampling sites between May and November 2007. The chosen sampling period enabled us to evaluate seasonal variations in treatment plant's efficiency and on the lagoon system. Samples were collected in polyethylene bottles, pre-cleaned by washing with non-ionic detergents, rinsed with deionized water prior to usage.

Before the final water samplings were taken, the bottle were rinsed three times with lagoon water and then filled. Water samples for BOD and COD tests were collected in polyethylene bottles covered with aluminum foil. The sample bottles were labeled according to sampling sites. All samples were preserved at 4°C and transported to the laboratory at the university. The Physico-chemical analyses of the selected wastewater parameter were conducted following standard analytical methods (APHA/AWWA/WEF, 2005). Results of

Table 1: Physico-chemical characteristics of influent and effluent during the wet season campaign

Sample	Distance (m)	Date	pH	Cond. (μS.m^{-1})	TDS (mg.l^{-1})	DO (mg.l^{-1})	BOD (mg.l^{-1})	COD (mg.l^{-1})	Total N (mg.l^{-1})
P_1	Influent	05/7/07	7.50	751.00	440	1.80	790.00	1150.00	35.00
		19/7/07	6.80	751.00	420	2.00	690.00	905.00	25.00
		02/8/07	7.10	830.00	470	2.30	554.00	985.00	25.10
		16/8/07	8.70	971.00	400	2.10	610.00	1085.00	29.00
		30/8/07	7.50	685.00	350	2.00	622.00	1140.00	35.00
		13/9/07	7.20	584.00	290	2.50	340.00	760.00	18.50
		27/9/07	7.50	685.00	350	2.10	622.00	1120.00	35.00
P_1	Mean±SD		7.47±0.60	751±123	389±62	2.11±0.23	604±138	1021±146	28.9±6.4
P_2	Effluent	05/7/07	7.1	600	280	3.4	160	600	1.75
	Discharge	19/7/07	7.1	759	362	2.6	150	295	10.3
	Point	02/8/07	7.2	742	345	3.5	140	260	7.25
		16/8/07	9.0	286	300	2.9	150	286	8.30
		30/8/07	7.8	502	250	2.5	202	390	10.2
		13/9/07	7.5	430	207	3.0	135	225	8.30
		27/9/07	7.8	502	250	2.5	202	390	10.20
P_2 Mean±SD			7.64±0.67	546±169.1	284.8±55.2	2.9±0.41	162.7±28	349±126.8	8.04±3.0

Table 2: Physico-chemical characteristics of receiving lagoon water during the wet season campaign

Sample	Distance (m)	Date	pH	Cond. (μS.m^{-1})	TDS (mg.l^{-1})	DO (mg.l^{-1})	BOD (mg.l^{-1})	COD (mg.l^{-1})	Total N (mg.l^{-1})
P_3	5	05/7/07	7.4	700	500	3.6	25	55	4.00
		19/7/07	6.8	1120	602	3.0	210	440	6.35
		02/8/07	6.9	1380	650	2.8	170	310	7.85
		16/8/07	8.3	800	300	3.1	110	245	6.20
		30/8/07	7.3	450	230	2.8	164	320	4.30
		13/9/07	7.6	415	210	3.1	48	102	7.80
		27/9/07	7.3	450	230	2.8	164	320	7.50
P_3	Mean ± SD		7.37±0.50	759.3±372.0	388.8±189.8	3.03±0.29	127.3±68.8	256±139.9	6.3±1.6
P_4	10	05/7/07	8.0	700	400	3.9	30	60	3.10
		19/7/07	7.2	1180	570	2.8	120	200	6.35
		02/8/07	7.4	1080	635	2.3	80	180	3.85
		16/8/07	8.8	780	400	3.5	32	65	2.00
		30/8/07	7.6	798	406	3.3	45	92	4.30
		13/9/07	7.3	692	343	3.9	48	102	4.10
		27/9/07	7.6	798	406	3.3	45	92	4.30
P_4	Mean ± SD		7.7±0.55	861.1±190.9	451.4±107.2	3.28±0.58	57.1±32.2	113±55.0	4.0±1.32
P_5	5 m	05/7/07	7.8	700	320	4.2	10	22	0.90
		19/7/07	7.3	736	345	3.4	80	140	4.18
		02/8/07	7.6	651	320	3.2	62	110	3.10
		16/8/07	8.7	600	300	3.6	190	405	9.80
		30/8/07	8.1	490	239	3.7	210	450	10.4
		13/9/07	7.2	387	195	4.0	120	230	5.90
		27/9/07	8.1	490	239	3.7	210	450	10.4
P_5	Mean ± SD		7.83±0.52	574.9±127.6	279.7±55.39	3.69±0.34	126.0±79.5	258.1±176.8	6.38±3.87
P_6	10m	05/7/07	7.7	460	240	4.2	15	28	1.24
		19/7/07	6.9	760	365	2.5	130	250	8.50
		02/8/07	7.3	1140	540	2.4	105	190	4.87
		16/8/07	9.1	500	233	4.1	110	230	6.00
		30/8/07	8.2	465	230	4.2	120	235	6.80
		13/9/07	7.3	500	254	4.2	70	150	3.90
		27/9/07	8.2	465	230	4.2	120	235	6.80
P_6	Mean ± SD		7.81±0.74	612.8±255.6	298.86±116.8	3.68±0.84	95.71±40.46	188.28±78.6	5.44±2.37
P_7	15m	05/7/07	7.3	750	348	4.5	10	18	0.8
		19/7/07	7.3	1270	559	2.6	110	240	7.9
		02/8/07	7.2	1120	525	2.6	90	202	5.2
		16/8/07	8.9	745	400	4.3	140	260	6.8
		30/8/07	7.3	610	300	4.7	110	218	6.5
		13/9/07	7.1	261	126	4.2	45	75	3.3
		27/9/07	8.2	465	230	4.2	120	235	6.8
P_7	Mean ± SD		7.61±0.67	745.9±352.9	355.42±155.7	3.87±0.87	89.28±45.86	178.28±93.27	5.32±2.48

laboratory analysis were subjected to data evaluation by statistical methods (Kottegoda and Rosso, 1997; Gupta, 2009).

RESULTS AND DISCUSSION

Wet season: Table 1 presents the results of physico-chemical analysis of influents and effluents for the wet season while Table 2 and 3 present the physico-chemical characteristics of lagoon water for the wet season campaign. The pH values varied from 6.8 to 8.7 in the influent stream and between 7.1 and 9.0 in the effluent from the university's treatment plant for the three months of survey. The pH of effluent is found within the stipulated pH range of 6.0 to 9.0 in the National effluent limitations guidelines for discharge into receiving water body by the Federal Environmental Protection Agency (FEPA, 1991). The passage of effluents through the lagoon had little effect which is essentially neutral to weakly basic with the pH values varying between 7.37 and 7.81 between P_3 and P_7 downstream of P_2 (Table 2). The only exception to this observation is the pH results

Table 3: Physico-chemical characteristics of receiving lagoon water at P_8 and P_9 during the wet season

Sample	Distance (m)	Date	pH	Cond. (µS.m^{-1})	TDS (mg.l^{-1})	DO (mg.l^{-1})	BOD (mg.l^{-1})	COD (mg.l^{-1})	Total N (mg.l^{-1})
P_8	5 m	05/7/07	7.1	281	142	4.6	5	5	0.22
		19/7/07	6.8	274	135	3.8	30	57	1.60
		02/8/07	7.4	292	140	4.0	22	45	0.98
		16/8/07	8.6	284	140	4.0	24	120	3.20
		30/8/07	7.4	300	160	4.9	75	140	3.30
		13/9/07	7.2	240	115	4.5	50	110	3.00
		27/9/07	7.4	300	160	4.9	75	140	3.30
P_8	Mean ± SD		7.41±0.57	281.6±20.73	141.71±15.45	4.38±0.45	40.14±27.25	88.14±52.62	2.23±1.28
P_9	10m	05/7/07	4.6	240	120	4.65	2.00	5.00	0.15
		19/7/07	6.9	202	94.6	5.0	5.00	5.00	0.14
		02/8/07	6.8	322	156	4.8	2.00	2.00	0.03
		16/8/07	9.2	245	123.3	4.2	5.00	10.0	0.30
		30/8/07	7.2	258	140	4.8	5.00	10.0	0.20
		13/9/07	6.7	165	86	5.3	5.00	5.0	0.30
		27/9/07	7.2	258	140	4.8	5.00	10.0	0.20
P_9	Mean ± SD		6.94±1.34	241.43±49.07	122.84±25.33	4.79±0.33	4.14±1.46	6.7±3.25	0.19±0.09

for the 16th of August where the values obtained are basic for influent, effluent and lagoon water. The mean pH values of 6.94 and 7.41 obtained for the lagoon water after passage of effluents through P_8 and P_9 at distances 5 and 10 m away from point of discharge in lateral direction show no significant deviation from results obtained from P_3 to P_7 (Table 3). From observation, no major industries or any other pollution activities is located in the vicinity of the project that could cause extreme changes in the pH of the effluents or of the receiving lagoon. Among major factors that could be of consideration are treatment plant's performance, season, tides and students' residency. Tidal status and wind conditions are known factors which could influence marine or lagoon water quality (Bordalo, 2003). The pH values obtained for the lagoon waterfalls within the national quality range pH in water for domestic water use of 6.5 to 8.5 (NSDWQ, 2007). On the basis of the pH values alone, the lagoon would not be adversely affected for use as domestic or recreational purposes.

Electrical conductivity values varied between 584 and 971 µS.m^{-1} in influent (P_1) and ranged from 286 to 759µS.m^{-1} in effluent (P_2). Even though the Nigerian effluents limitation guidelines did not stipulate any value for electrical conductivity, the values obtained for the effluents are not within international acceptable limits (Chapman, 1996). Electrical conductivity values in the lagoon varied widely from one sampling point to another and by sampling dates (Table 2).

There is also no noticeable abatement pattern in the conductivity values obtained between P_3 and P_7 downstream of P_2, the point of effluents discharge into the lagoon. In fact, the mean conductivity values, which ranged from 574.9 and 861.1 µS.m^{-1} in the lagoon are greater than the mean values of 546 and 751 µS.m^{-1} obtained for the effluent and the influent respectively. This shows a very low performance of the treatment plant. It is also noticed that the effluent discharge increased the electrical conductivity in the lagoon therefore indicating increased impact on the receiving water body.

Influent concentrations of TDS varied between 290 and 470 mg.l^{-1}, while that of DO varied between 1.8 and 2.5 mg.l^{-1} respectively. The corresponding concentrations of the same parameters at P_2, effluent discharge point shows some level of purification (Table 1). The mean concentrations of both parameters corroborate this assertion. The TDS mean value of 389 mg.l^{-1}, was reduced to 284.8 mg.l^{-1} in effluent. This represents an overall purification efficiency of about 27%. Increased aeration obtained for the effluent, with mean concentrations of 2.9 mg.l^{-1} over that of influents of 2.11 mg.l^{-1} further confirms some level of purification of the sewage water by the treatment plant.

However, there are marginal increases in the TDS values in the lagoon water from P_3 to P_7 (Table 2), the values ranging from 126 to 650 mg.l^{-1}. TDS mean concentrations value range between 279.7 and 451.4 mg.l^{-1}. These values are found within the specified limit of 2000 mg.l^{-1} by the Regulatory body (FEPA, 1991). At P_8 and P_9, an appreciable level of reduction is noted in the concentrations of the two parameters in the lagoon (Table 3). TDS mean concentrations are 141, 71 and 122.84 mg.l^{-1} at P_8 and P_9 respectively, both representing 63.5 and 68% attenuation levels. Dissolved oxygen concentrations are equally high with mean concentration values of 4.38 and 4.14 mg.l^{-1} respectively. Interestingly, there is no clear attenuation pattern in the concentrations of both the TDS and DO from P_2, point of effluent discharge, to P_7 at 15 m away downstream.

Influent concentrations of BOD varied between 340.0 and 790.0 mg.l^{-1} while in the effluent the range is between 135 and 202 mg.l^{-1}, which indicate an appreciable level of purification of the influent by the sewage treatment plant. For instance, obtained mean concentration values for BOD, 604 and 162.7 mg.l^{-1} at influent and effluent respectively indicates 73% purification level in respect of BOD. Even with this level of performance, BOD concentrations are still extremely high in effluent, varying between 135 and 202 mg.l^{-1}. The values far exceed the limit discharge of 30 mg.l^{-1} allowed

Table 4: Physico-chemical characteristics of influent and effluent during the dry season campaign

Sample	Distance (m)	Date	pH	Cond. ($\mu S.m^{-1}$)	TDS ($mg.l^{-1}$)	DO ($mg.l^{-1}$)	BOD ($mg.l^{-1}$)	COD ($mg.l^{-1}$)	Total N ($mg.l^{-1}$)
P_1	Influent	11/10/07	7.4	466	236	3.0	170	330	12.5
		25/10/07	7.1	430	220	3.2	150	280	11
		8/11/07	7.2	454	226	2.5	165	310	11
		22/11/07	7.3	480	232	2.2	170	230	11
P_1	Mean ± SD		7.25±0.13	457.5±21.19	228.50±7.0	2.27±0.22	163.75±9.46	287.50±43.49	11.37±0.75
P_2	Effluent	11/10/07	7.3	460	230	3.2	100	250	8.2
	Discharge	25/10/07	6.8	425	200	4.0	50	125	7.5
	Point	8/11/07	7.3	440	215	3.8	70	176.4	5.6
		22/11/07	7.3	450	220	3.7	80	150	5.0
P_2 Mean ± S.D.			7.17±0.25	443.75±14.93	216.25±12.5	3.60±0.38	75.0±20.81	175.35±54.01	6.57±1.52

Table 5: Physico-chemical characteristics of receiving lagoon water for dry season campaign

Sample	Distance (m)	Date	pH	Cond. ($\mu S.m^{-1}$)	TDS ($mg.l^{-1}$)	DO ($mg.l^{-1}$)	BOD ($mg.l^{-1}$)	COD ($mg.l^{-1}$)	Total N ($mg.l^{-1}$)
P_3	5 m	11/10/07	7.2	294	146	3.6	100	205	5.4
		25/10/07	6.7	300	150	3.9	80	140	4.5
		8/11/07	7.1	311	157	3.3	95	185	4.7
		22/11/07	7.2	310	163	3.0	100	200	4.9
P_3	Mean ± SD		7.05±0.24	303.75±8.18	154.0±7.53	3.45±0.39	93.75±9.46	182.5±29.58	4.87±0.39
P_4	10m	11/10/07	7.4	576	288	4.2	20	50.2	3.2
		25/10/07	7.3	590	290	4.1	15	38.3	3.0
		8/11/07	7.2	598	294	3.8	16	40.8	2.9
		22/11/07	7.1	605	299	3.6	18	45.7	3.1
P_4	Mean ± SD		7.25±0.13	592.25±12.44	292.75±4.85	3.92±0.27	17.25±2.22	43.75±5.28	3.05±0.13
P_5	15m	11/10/07	7.5	290	154	3.5	95	165	4.6
		25/10/07	7.4	275	145	3.7	75	123	4.5
		8/11/07	7.3	300	153	3.0	85	160	4.7
		22/11/07	7.2	325	161	2.9	95	181	4.8
P_5	Mean ± SD		7.35±0.13	297.50±21.01	153.25±6.55	3.27±0.39	87.50±9.57	157.25±24.53	4.65±0.13
P_6	20m	11/10/07	7.4	295	208	4.2	40	60	3.5
		25/10/07	7.4	360	190	4.3	35	60	3.2
		8/11/07	7.2	417	210	3.8	40	80	3.5
		22/11/07	7.2	440	216	3.3	45	85	3.7
P_6	Mean ± SD		7.30±0.11	378.0±64.75	206.0±11.19	3.90±0.45	40.00±4.08	71.25±13.15	3.47±0.21
P_7	25m	11/10/07	6.8	192	89.6	4.4	30	70	3.5
		25/10/07	7.2	155	85.4	4.2	25	45	3
		8/11/07	7.1	200	98.3	3.7	30	60	3.2
		22/11/07	7.2	208	105	3.5	35	70	3.6
P_7	Mean ± SD		7.07±0.19	188.75±23.43	94.57±8.78	3.95±0.42	30.00±4.08	61.25±11.81	3.32±.27
P_8	10m (Lateral)	11/10/07	7.1	187	91.5	4.8	25	45	2.5
		25/10/07	6.8	160	85.5	4.9	15	40	2.5
		8/11/07	7.3	190	94	4.6	20	35	2.6
		22/11/07	7.2	215	108	4.7	20	40	2.9
P_8	Mean ± SD		7.10±0.22	188.0±22.49	95.75±9.28	4.75±	20.0±0.13	40.0±4.08	2.62±0.19
P_9	20m (Lateral)	11/10/07	6.9	118	63.2	5.3	2.0	5.8	0.1
		25/10/07	7.3	110	60.2	5.2	2.0	5.6	0.1
		8/11/07	7.2	142	65.7	5.0	5.0	12.6	0.2
		22/11/07	7.3	180	87.6	5.1	2.0	6.10	0.3
P_9	Mean ± SD		7.1750±0.19	137.50±31.43	69.17±12.49	5.15±0.13	2.75±1.50	7.52±3.39	0.21±0.11

into the surface water as stipulated in the nation's Effluent limitation guidelines for all categories of polluters (FEPA, 1991). The effluent values are six times higher than the acceptable limit. This indicates the inefficiency of the treatment plant in removing biochemical oxygen-demanding substances in the influent.

Analysed samples for BOD in lagoon water were at concentrations ranging from 25.0 to 210.0 $mg.l^{-1}$. High levels of attenuation in BOD concentrations could be observed on specific dates and at specific sampling points between P_3 and P_7. Noticeable are the BOD concentrations in lagoon water in all the sampling points on July 5 (Table 2). The obtained reduction level in BOD for this very day is as high as 94%. A number of factors could be responsible: increased dilution rate as a result of rainfall, heaviest rainfalls are common in June and July of the year. There are no other visible explanations for this observation. For the COD, influent concentrations varied between 760 and 1150 $mg.l^{-1}$ while in the effluent, its values varied between 225 and 600 $mg.l^{-1}$ (Table 1). There are no specified values for COD in the effluent limitation guidelines

Analysed samples for COD in lagoon are at concentrations ranging from 22.0 to 440.0 $mg.l^{-1}$, between P_3 and P_7. As earlier on observed, there are no particular patterns of attenuation in the COD levels in the lagoon. The observed non-systematic attenuation pattern indicates different pollution points along the flow direction downstream of the effluent discharge point P_2. The same variability in concentrations in BOD and COD are observed in P_8 and P_9 but at very high reduction levels specifically at P_9 (Table 3). Obtained mean concentrations for BOD and COD at P_8, are 40.14 and 88 $mg.l^{-1}$ respectively while at P_9 mean BOD and COD concentrations stand at 4.14 and 6.7 $mg.l^{-1}$. The results show lesser impact of the effluent at the lateral direction away from the flow direction, even though greater dispersion is expected in the direction of flow in a more active water body (Bordalo, 2003; Garg, 2006). High BOD and COD loads as noted downstream of discharge point P_2, especially from P_3 to P_7 pose a threat to the aquatic environment and would have negative effects on lagoon quality as well as cause harm to the aquatic life (Chapman, 1996; Metcalf and Eddy, 2003; Garg, 2006).

Dry season: Table 4 and 5 present the results of the physico-chemical analysis of the raw effluents (influent), effluent and lagoon water. The pH values in the influent are essentially neutral to weakly basic and varied between 7.1 and 7.4 and between 6.8 and 7.3 in the effluent from the treatment plant. The pH values of effluents are found within the pH range of 6 to 9 stipulated by the effluent limitation guidelines for discharge into surface water. The pH of lagoon is both weakly acidic and weakly alkaline with pH values ranging between 6.7 and 7.5. The pH range from 6.5 to 8.5 units is acceptable in drinking water (NSDWQ, 2007). As observed during the wet season the pH values obtained for the lagoon during the dry season are found within this range. Equally based on these guidelines, the pH of the river water would not adversely affect its use for domestic or recreational purposes. For the protection of the aquatic environment, the pH should be within the range of 6.5 to 9 units; also, discharges should not alter the ambient pH by more than 0.5 pH units in the mixing zones (McNeely *et al.*, 1979, Chapman, 1996).

Electrical conductivity values varied between 430.0 and 480.0 $\mu S.m^{-1}$ in influent (P_1) and ranged from 440 to 460.0 $\mu S.m^{-1}$ in effluent (P_2). Electrical conductivity values in the lagoon varied between 110 $\mu S.m^{-1}$ at P_9 and 605.0 $\mu S.m^{-1}$ at P_4. These values are higher than internationally acceptable levels (Chapman, 1996; Morrison *et al.*, 2001).

Influent concentrations of TDS varied between 220 and 236 $mg.l^{-1}$, while that of DO varied between 2.2 and 3.2 $mg.l^{-1}$ respectively. The corresponding concentrations of the same parameters at P_2, effluent discharge points show some level of purification (Table 4). The mean concentrations of both parameters corroborate this assertion. The TDS mean value of 228.5 $mg.l^{-1}$, was reduced to 216.25 $mg.l^{-1}$ in effluent, which represents an overall purification efficiency of only 5%. Increased aeration obtained for the effluent, with mean concentrations of 3.68 $mg.l^{-1}$ over that of influent of 2.73 $mg.l^{-1}$ further confirms some level of purification of the sewage water by the treatment plant.

TDS values in lagoon water varied from 85.4 to 299.9 $mg.l^{-1}$ between P_3 and P_7 (Table 5). TDS mean concentrations value range between 69.17 and 292.75 $mg.l^{-1}$. At P_8 and P_9, an appreciable level of reduction is noted in the concentrations of the two parameters in the lagoon (Table 5).

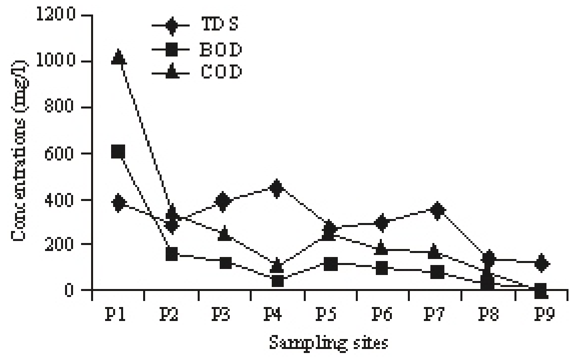

Fig. 3: Trend in mean concentrations of TDS, BOD and COD in influent, effluent and Lagoon (Wet Season)

TDS mean concentrations are 95.75 and 69.17 $mg.l^{-1}$ at P8 and P9 respectively, both representing 55.65 and 68% attenuation levels. Dissolved oxygen concentrations are equally high with mean concentration values of 4.75 and 5.15 $mg.l^{-1}$ respectively. Interestingly, there is no clear attenuation pattern in the concentrations of both the TDS and DO from P_2, point of effluent discharge, to P_7 at 15 m away downstream and P_9, 10 m away from P_2 laterally off direction of flow.

The BOD and COD levels in the influent varied between 165, 170, 230 and 330 $mg.l^{-1}$ respectively. Even though BOD is not a pollutant itself, it is a measure of organic pollution. High BOD load there poses a threat to the aquatic environment by reducing the dissolved oxygen concentration to levels that affect aquatic organisms (Chapman, 1996; Garg, 2006). For the COD, it is a measure of the amount of oxygen required to chemically oxidize the organic matter in water (Chapman, 1996; Metcalf and Eddy, 2003; Garg, 2006). Though, both BOD and COD indicate the potential dissolved oxygen demand in water, there is no strong correlation between these two measures. From literatures, there are no specific guidelines proposed for BOD, but waters with BOD levels less than 4 $mg.l^{-1}$ are deemed clean (McNeely *et al.*, 1979). The BOD levels in the receiving water body (from P_3 to P_7) range from 15 to 100 $mg.l^{-1}$ while the mean concentration values range between 30.0 and 93.75 $mg.l^{-1}$. These values are mostly above the stipulated value of 30$mg.l^{-1}$ allowed to be discharged into the river body (FEPA, 1991). There is an appreciable removal of BOD and COD from the influent after treatment, mean concentrations range from 163.75 to 75 $mg.l^{-1}$ for BOD, and 287.5 to 175.35 $mg.l^{-1}$ for the COD. However, obtained mean concentration values for BOD at P_8 and P_9 stand at 20 and 2.75 $mg.l^{-1}$ respectively, while COD mean concentrations at the two sites (P_8 and P_9) are 40 and 7.52 $mg.l^{-1}$ respectively. From this consistency, it could be said that lateral dispersion of treated waste from the point of discharge, P_2 is not significant, therefore has little impact on the lagoon water in that direction.

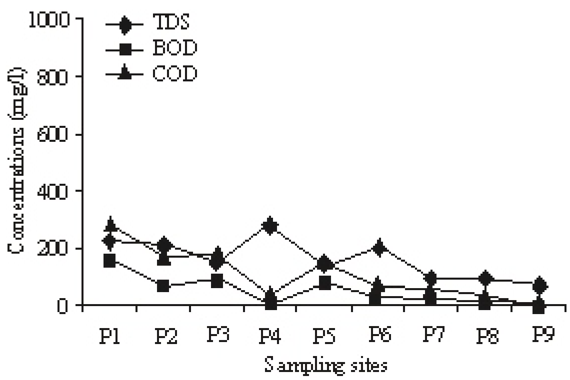

Fig. 4: Trend in mean concentrations of TDS, BOD and COD in influent, effluent and Lagoon (Dry Season)

Comparison: The trends in the mean concentrations of BOD, COD and TDS for both wet and dry seasons are presented in Fig. 3 and 4 respectively. From all indications, an appreciable level of renovation has been achieved by the university treatment plant. Its level of performance however did not meet with the regulatory requirements in both seasons even though it appears a better performance was achieved during the dry season, but not so (Fig. 3-4). The adduced reason for the above observation has to do in part with differences in organic load of the treatment system during both seasons; organic load was higher during the wet season (Table 1-5). The wide variations observed between the wet and dry seasons appear difficult to explain as one expects dilution effect of influent and effluent to be high during the wet season because of rainfall intensity with a corresponding increase in the volume of the lagoon. One therefore expects increased lagoon water to lead to increased rate of dispersion of contaminants with greater dilution. Contrary to expectations, concentrations in TDS, BOD and COD were higher in the lagoon during the wet season than during the dry season. One expects higher concentration of organic loads during the dry season than in the wet. Instead, there are visible abatements in TDS, BOD and COD concentrations during the dry season (Fig. 4). The only valid explanation here is the question of residency of students.

The school was in session during the rainy season campaign, the students' population increased the volume of influents, which robbed off the effects of dilution in the lagoon. In both seasons however, it is observed that lateral dispersion of contaminants is very limited as shown by the results obtained at sampling sites P_8 and P_9 (Table 2, 3 and 5). The trend could be seen in Fig. 3 and 4.

CONCLUSION

The results from the current campaign reveal poor performance of the university treatment plant in both seasons but more specifically during the wet season due to overloading. The removal efficiencies for the following measured parameters during the dry season stand at 54% for TDS, 54% for BOD, 39% for COD and 42% for N. The removal efficiencies during the wet season for TDS, BOD, COD and N stand at 26, 73, 65.8 and 72% respectively. From the results of pollution assessment of lagoon water, it is revealed that the receiving river body has been impacted negatively. Results of analysis of the following specific water quality parameters of water samples from the river body, TDS, BOD and COD show higher levels than in treated effluent and are above the Nigerian Regulatory Standards (FEPA, 1991). Hence, discharges from the university treatment plant appear to have impacted the lagoon water. It is however observed that the present level of contamination of the lagoon is not only from the university treatment plant as there are other possible sources of pollution which could not be decipher in this current study. The high nutrient values in the lagoon would also affect its uses for other purposes such as recreational and fishing activities. The existing central sewage treatment plant needs to be upgraded to improve its treatment performance.

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