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.

Keywords: 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.
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-Cousou 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 6354.788km² 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.
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 P1 to P9 from sampling locations within the treatment plant premises and along the lagoon (Fig. 2). Site P1 was located at the inlet of the treatment plant where influent samples were collected. Site P2 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 P1 was a point located approximately 5 m after the effluent discharge point into the lagoon. Sites P3 through P9 were located at distances 10, 15, 20 and 25 m, respectively after the effluent discharge point into the lagoon. Sampling points P3 and P9 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
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 P1 and P3 downstream of P1 (Table 2).

The only exception to this observation is the pH results laboratory analysis were subjected to data evaluation by statistical methods (Kottegoda and Rosso, 1997; Gupta, 2009).
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 P1 and P2 at distances 5 and 10 m away from point of discharge in lateral direction show no significant deviation from results obtained from P1 to P6 (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 (P1) and ranged from 286 to 759 μS·m⁻¹ in effluent (P2). 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 P1 and P6 downstream of P1, 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 P6, effluent discharge point shows some level of purification (Table 1). The 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 P1 to P6 (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 P7 and P8, 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 P7 and P8 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 P7, point of effluent discharge, to P8 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...
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 P₃ and P₇. 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 P₃ and P₇. 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 P₂. The same variability in concentrations in BOD and COD are observed in P₃ and P₇ but at very high reduction levels specifically at P₇ (Table 3). Obtained mean concentrations for BOD and COD at P₇ are 40.14 and 88 mg l⁻¹ respectively while at P₇ 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 points P₈ and P₉, especially from P₁ to P₉, 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 μS·m⁻¹ in influent (P₁) and ranged from 440 to 460.0 μS·m⁻¹ in effluent (P₇). Electrical conductivity values in the lagoon varied between 110 μS·m⁻¹ at P₁ and 605.0 μS·m⁻¹ at P₉. 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 P₇, 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 P₁ and P₇ (Table 5). TDS mean concentrations value range between 69.17 and 292.75 mg·l⁻¹. At P₈ and P₉, an appreciable level of reduction is noted in the concentrations of the two parameters in the lagoon (Table 5).

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 P₁, point of effluent discharge, to P₉ at 15 m away downstream and P₉₁, 10 m away from P₉ 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 P₁ to P₇) 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 P₈ and P₉ stand at 20 and 2.75 mg·l⁻¹ respectively, while COD mean concentrations at the two sites (P₈ and P₉) 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, P₉ is not significant, therefore has little impact on the lagoon water in that direction.

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

**REFERENCES**


