

The hydrochemistry and biota of a thermal coolant water stressed tropical lagoon

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Abstract: The effect of coolant or waste heat discharge on the water characteristics, phytoplankton, zooplankton and benthic macro invertebrate at the Egbin area of the Lagos lagoon were investigated from February to July, 2000 at three (3) stations. The water quality reflected the influences of coolant water introduction, net tidal seawater inflow in the dry season and freshwater incursions effects in the raining season. Whereas the phytoplankton recorded 83 species, the zooplankton recorded 23 species and the benthos five species. Comparatively higher cyanobacteria diversity for the phytoplankton, water temperatures, transparency coupled with reduced dissolved oxygen levels were recorded at station 1 throughout the study and possibly reflect the effects of coolant water introduction. Notable phytoplankton species recorded were *Aulacoseira granulata*, *A. granulata* var. *angustissima*, *Gonatozygon* and *Spirogyra africana* that marked the wet season. Similarly, *Acartia clausii*, *Paracalanus parvus* and *Cylops* sp were frequently occurring for the zooplankton and the benthos was notably represented by *Pachymenia aurita*, *Tympanotonus fuscatus* and *Aloidis trigona*. Furthermore, whereas the phytoplankton was dominated by diatoms, copepods and gastropods dominated the zooplankton and benthos of the study area respectively. The effects of elevated temperature reduced as stations were increasing distant from the waste heat deposition site. [Life Science Journal. 2009;6(3):86-94] (ISSN: 1097 – 8135).

Keywords: Coolant water, phytoplankton, zooplankton, benthos, macro invertebrate fauna, lagoon, thermal station

Introduction

The Lagos lagoon system is the largest of the four lagoon systems of the Gulf of Guinea (Chukwu, 2002). This aquatic ecosystem is habitat to a variety of biota which include the plankton, nekton and benthos in a complex trophic interrelationship (Emmanuel and Onyema, 2007). The Lagos lagoon environment apart from being sheltered from reduced hydrodynamics of the sea, serves for fishing, a seaport, recreation destination, nursery, feeding and spawning ground for a diverse number of fish and fisheries (Akpata *et al.*, 1993; Chukwu, 2002; Onyema *et al.*, 2003). There are a number of published work on the species spectrum distribution and aspects of the ecology of phytoplankton (Nwankwo 1988, 1996; Nwankwo *et al.*, 2003), zooplankton (Olaniyan, 1969; Akpata *et al.*, 1993; Onyema *et al.*, 2003; 2007; Emmanuel and Onyema, 2007) and macro-invertebrate fauna (Onyenekan, 1988; Brown and Oyenekan, 1998; Brown, 1998; Ogunwenmo, 2002) of the Lagos lagoon.

In Nigeria, over 85% of all industries are located in the Lagos Metropolitan area (Odiete, 1999). These industries discharge their effluents through channels and drainage systems into nearby storm water drains and coastal waters (Nwankwo, 2004). Of particular interest are sewage outfalls, textile mills, woodwastes, breweries and chemical facilities located in several layouts of the metropolis. Also important in this regard are thermal plants used for electricity generation and which release waste heat into the aquatic environment (Ajao, 1996). A number of electricity generating power plants exist in Nigeria. These include plants in Ijora (Lagos State), Afam-Imo river (Rivers State), Oji river (Enugu State), Ughelli (Delta State) and Egbin (Lagos State) which is the

largest in the country with a generation capacity of 1320 Watts (Ukuoma, 1989). The Egbin thermal station accounts for a quarter of Nigeria's installed power capacity presently. However, the station is only able to generate between 350 and 800 Megawatts of electricity especially in the last few years which is below its installed capacity. This has been largely due to the consistent vandalisation of its gas supply pipelines and hence translates to under production and acute shortage of electricity. This scenario has been the bane of the national power industry in Nigeria. Thermal plants are known to release coolant (hot) waters as a major waste fallout of the internal combustion process (Ajao, 1996; Odiete, 1999; Chukwu, 2002, 2006).

Materials and Methods.

Description of study site.

The coast of South-western Nigeria is a meandering network of lagoons and many creeks, of which the Lagos lagoon with an area of 208 sq km is about central and important in terms of size (FAO, 1969; Nwankwo, 2004). The study site of this work (Egbin) with co-ordinates at about Longitude 3°40' and Latitude 6° 34'E is located to the east of the Lagos lagoon (Fig. 1). The lagoon is open all year round via the Lagos harbour and experiences both tidal and salinity regimes. It provides the only opening to the sea for the lagoons of South-western Nigeria (Onyema, 2008). Sea water associated with semi-diurnal tidal regime and fresh water from adjoining wetlands are the two main factors that determine the physico-chemical parameters and biology of the lagoonal area (Nwankwo, 1996; Chukwu and Nwankwo, 2004; Onyema and Nwankwo, 2009). In the Lagos lagoon, there is a direct relation between the

seasonal bimodal rainfall pattern, the environmental gradient and the biotal gradient. Owing to the dynamics of river inflow and seawater incursion, the Lagos lagoon experiences brackish condition that is more discernable in the dry season (Onyema *et al.*, 2008). In the wet season, the increased river inflow creates freshwater and low brackish conditions in various parts of the lagoon. Most of the lagoon area are colonized by riparian mangrove swamp community. Some notable macro-floral species in the area include *Rhizophora racemosa*, *R. harrisoni*, *Paspalum vaginatum*, *Avicennia germinans*, *Phoenix reclinata*, *Raphia hookeri*, *Elaeis guineensis*, *Acrotiscum aureum* and *Cocos nucifera*.

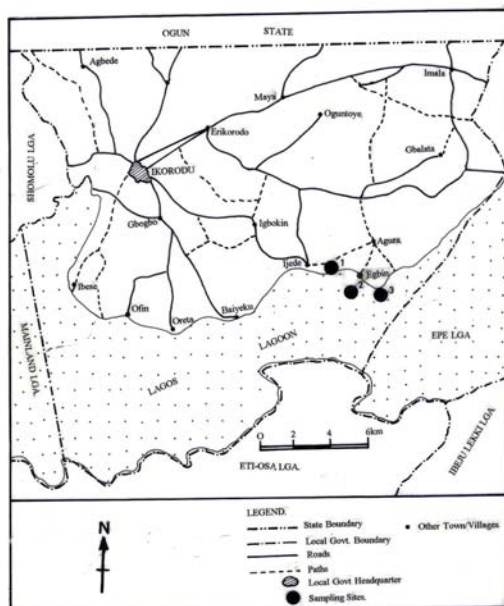


Fig 1: Part of the Lagos lagoon showing important town in the area including Egbin

Collection of samples

Monthly samples were collected over a period of six months between September, 2004 and February, 2005 for water chemistry analysis, phytoplankton, zooplankton and benthos. Samples were collected from three stations designated as stations 1, 2 and 3. Station 1 being the site closest to the facility and receives the discharged of

coolant water from the thermal station, station 2 is located about 200m away from station 1. Furthermore, Station 3 is located downstream (200m) from station 2.

Collection of water samples

Surface water samples were collected for the survey for physico-chemical characteristics analysis using 1.5L plastic containers with screw caps. Collection of samples from the sites were between 10 and 15hr. Water samples were collected just a few centimeters below the water surface. The plastic containers were labeled appropriately and transported to the laboratory and stored in refrigerator ($\leq 5^{\circ}\text{C}$) prior to further laboratory analysis.

Collection of plankton samples.

Plankton sample were collected with a $55\mu\text{m}$ mesh size standard plankton net towed from a motorized boat for 5 minutes at low speed (<4 knots) at the three sampling stations (1, 2 and 3). The net was then hauled in after this time and the plankton sample transferred into a 250 ml well labeled plastic containers with screw cap. Samples were labeled aptly and preserved with 4% unbuffered formalin and stored in the laboratory prior to microscopic analysis of the plankton. This is after samples have concentrated to 10 ml.

Collection of benthic samples

Sampling was carried out at three stations using a Van Veen grab (0.1m^2) from an anchored boat. Three grab hauls for benthic samples were also taken from each station, the collected material was washed through a 0.5mm mesh sieve in the field. Preservation of the residue in the sieve was with 10% formalin solution. These were then stored in labeled plastic containers and transported to the laboratory. The sediment samples collected at each station were placed in three different labeled polyethylene bags for physical and chemical analysis in the laboratory. The samples were stored in the fridge prior to analysis.

Physico-chemical analysis

Table 1 below tabulates the methods and reference used in the determination of some of the physico-chemical parameters.

Table 1: Summary of environmental factors and method/device used for their estimation for water samples

| Parameter/ Unit | Method / Device | Reference |
|--|------------------------------------|----------------|
| 1 Water temperature ($^{\circ}\text{C}$) | Mercury – in – glass thermometer | Brown (1998) |
| 2 Transparency (cm) | Secchi disc | Nwankwo (1984) |
| 3 Rainfall (mm) | Acquired from NIMET, Oshodi, Lagos | |
| 4 Total Dissolved Solids (mg l^{-1}) | Cole Palmer TDS meter | |
| 5 Total Suspended Solids (mg l^{-1}) | Gravimetric | APHA (1998) |
| 6 pH | Electrometric / Cole Parmer Testr3 | |
| 7 Conductivity ($\mu\text{S/cm}$) | Philip PW9505 Conductivity meter | |
| 8 Salinity (‰) | HANNA Instrument | APHA (1998) |
| 9 Dissolved oxygen (mg l^{-1}) | Titration | APHA (1998) |
| 10 Nitrate – nitrogen (mg l^{-1}) | Colorimetric | APHA (1998) |
| 11 Phosphate – phosphorus (mg l^{-1}) | Colorimetric | APHA (1998) |
| 12 Sulphate (mg l^{-1}) | Turbidimetric | APHA (1998) |

| | | | |
|----|-----------------------------|--|---|
| 13 | Copper (mgL ⁻¹) | Atomic Absorption Spectrophotometer Perkin Elmer 5000 AAS | Perkin Elmer Application methods (2002) |
| 14 | Iron (mgL ⁻¹) | Atomic Absorption Spectrophotometer Perkin Elmer 5000 AAS | Perkin Elmer Application methods (2002) |
| 15 | Lead (mgL ⁻¹) | Atomic Absorption Spectrophotometer Perkin Elmer 5000 AAS | Perkin Elmer Application methods (2002) |

Sediment analysis

Total organic matter (Ash method).

A portion of the sediment stored in plastic containers in the freezers was oven dried at 500°C after allowing the frozen samples to thaw. The drying process continued until a constant weight of the sample was obtained. 5g of the dried sample was placed in a pre-weight crucible and kept in a muffle furnace for 8 hours at 6000°C. It was then cooled. The crucible and its content were re-weighted and the total organic matter (T.O.M.) was calculated as a percentage of the original weight.

$$T.O.M. = \frac{\text{Loss of weight on ignition (Xg)}}{\text{Initial weight}}$$

Where X (g) = A1 (g) - A2 (g)

A1 = Initial weight of sample

A2 = Final weight of sample

Sediment texture

The sediment collected for all the stations during the study were separated into different textures. Water was added into the measuring cylinder and was thoroughly shaken for 2 minutes after which the cylinders were left to settle down for 24 hours. After 24 hours the sediment had separated into different fractions mainly sand, clay and silt, and the percentage of each texture was determined using the formula:

$$\% \text{ Sediment texture} = \frac{\text{Height of sample}}{\text{Total height of sediment}} \times 100$$

Plankton analysis.

In the laboratory five drops of the concentrated sample (10ml) were investigated at different magnifications (50X, 100X and 400X) using a Wild II binocular microscope with calibrated eye piece and the average recorded. The drop count method described by Lackey (1938) was employed. Since each drop is 0.1ml the results on abundances were multiplied accordingly to give the values as numbers of organisms per ml which is the standard unit. Appropriate materials were used to aid identifications. The final data were presented as number of organisms per ml (cells, filaments, colonies). Appropriate texts were used to aid identification (Phytoplankton- Hendey 1958, 1964; Wimpenny, 1966; Patrick and Reimer, 1966, 1975; Whitford and Schmacher, 1973; Vanlandingham, 1982; Nwankwo, 1990, 1995, 2004).

Zooplankton- Newell and Newell, 1966; Olaniyan, 1975, Barnes *et al.*, 1993 and Waife and Frid, 2001).

Benthic sample analysis.

Preserved benthic samples were washed with tap water to remove the preservative and any remaining

sediment in order to make sorting easier. The animals were sorted on a white tray into taxonomic groups (Phyla, class, families, species) using suitable texts (Olaniyan, 1975; Oyenekan, 1975; Edmunds, 1978; Schreider, 1990; Barnes *et al.*, 1993) as identification guide.

Species Richness Index (d)

The Species richness index (d) according to Margalef (1951) is a measure of diversity and was used to evaluate the community structure. The equation below was applied and results were recorded to two decimal places.

$$d = \frac{S - 1}{\ln N}$$

Where:

d = Species richness index

S = Number of species in a population

N = Total number of individuals in S species.

Menhinick's Index (D) (Ogbeibu, 2005).

$$D = \frac{S}{\sqrt{N}}$$

S = Number of species in a population

N = Total number of individuals in S species.

Shannon and Wiener diversity index (Hs)

Shannon and Wiener (1963) diversity index (H)

$$H_s = \sum P_i \ln P_i$$

Where

H_s = Diversity Index

I = Counts denoting the *i*th species ranging from 1 – n

P_i = Proportion that the *i*th species represents in terms of numbers of individuals with respect to the total number of individuals in the sampling space as whole.

Species Equitability (j).

$$j = \frac{H_s}{\log_2 S}$$

Where

J = Equitability index

H_s = Shannon and Wiener index

S = Number of species in a population

Simpsons dominance index (C) (Ogbeibu, 2005).

$$C = \sum (n/N)^2$$

Where n = the number of species in the *i*th species.

N = the total number on individuals.

Correlation Coefficient Values (r)

The Pearson correlation coefficient (r) (Ogbeibu, 2005) for the relationship between water quality characteristics, and

biotic component at the different stations were obtained using the formula:

$$r = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{[n(\sum X^2) - (\sum X)^2][n(\sum Y^2) - (\sum Y)^2]}}$$

Where

r = Coefficient of correlation

X and Y = Variables under consideration

RESULT

Physico-chemical parameters

Water temperature recorded at sampling stations were between 27 and 40°C. The highest water temperature value (40°C) was recorded in May at Station 1, while the lowest value (27°C) was recorded in February, June and July at Station 3. Temperature values recorded the highest estimates at Station 1 throughout the study. Transparency values were higher in dry months than wet months. Values were between 66 and 196cm. The highest value (196cm) was recorded in February at Station 1, while the lowest (66cm) was recorded in June at Station 2. Measurable difference was recorded between total suspended solid values in dry and wet months. An estimate of 450 mgL⁻¹ (highest value) occurring in July at Station 1 while the lowest was in April at Station 2 and 3 respectively. The total dissolved solids content was higher in the dry months than the wet months. Values were between 394 mgL⁻¹ (July at Station 3) and 12546 mgL⁻¹ (March at Station 2). The pH values were between 6.23 (May at Station 3) and 6.96 (May at Station 2). Conductivity values were higher in the dry months than wet months and ranged between 7.9 x 10⁻⁴ and 2.5 x 10⁻² Scm⁻¹ during the study period. Dissolved Oxygen values during the study period were between 3.2 (May at Station 1) and 5.7 mgL⁻¹ (June at Station 3). Values were comparatively lower in Station 1 than other stations Table 2. Salinity was between 1.1 (July at Stations 1 and 3) and 12.1‰ (March at Station 2). The nitrate-nitrogen values were higher in the wet months. Values were between 0.12 (July, Station 3) and 3.98 mgL⁻¹(March at

Station 2). Low phosphate-phosphorus values were recorded throughout the study period. The highest value (0.640mgL⁻¹) was recorded in March at Station 2, with the lowest (0.019 mgL⁻¹) in July at Station 3. Sulphate estimate was higher in the dry months than in the wet months and ranged between 35.5 (July at Station 3) and 1135 mgL⁻¹ (March at Station 2). Heavy metal levels were high throughout the study, however higher levels were recorded in the dry than wet season. The highest Lead content (0.978 mgL⁻¹) was obtained in February at Station 2, while the lowest value (0.011 mgL⁻¹) occurred in May at Station 2. The highest value recorded for Copper (3.618 mgL⁻¹) occurred in March at Station 1, whereas the lowest value (0.006 mgL⁻¹) was in May at Station 2. The range of value recorded for Iron was between 0.06 mgL⁻¹ in June at Station 2 and 3.618mgL were recorded in March at Station 1, respectively. The values for oil and grease obtained in samples collected during the dry months were higher than the values obtained during the wet months. A range of between 9.0 (occurring in March at Station 1) and 1.0 mgL⁻¹ (in July at Station 3) was recorded.

Sediment

Table 3 shows the total organic matter of sediment (%) at the study area. Total organic matter for the study was between 0.1 and 0.3% which translates to 2 – 6% dry weight. With regard to percentage sediment texture composition, where as sand content varied from 49 to 97%, clay ranged between 0 and 28% and silt between 0 and 21%. Total hydrocarbon content ranged between 0.14 and 0.32 mgL⁻¹ for station 1, 0.03 and 0.21 mgL⁻¹ for station 2 and 0.1 and 0.43 mgL⁻¹ for station 3 throughout the study (Table 3). The percentage sediment profile for each station during the study period is shown in Table 3. Station 1 was predominantly sandy (78 – 97%); clay, 1 – 13%, and silt; 3 – 21%. Station 2 was mixture of and clay, sand (56-79%), clay (21-33%) and silt (0-19%). Station 3 however had more of clay (49-90%) sand (4-36%) and silt (1-15%).

Table 2: TOTAL ORGANIC MATTER OF SEDIMENT (%) AT EGBIN THERMAL STATION

| Parameter | February | | | March | | | April | | | May | | | June | | | July | | |
|-------------------------|----------|-----|-----|-------|-----|-----|-------|-----|-----|-----|-----|-----|------|-----|-----|------|-----|-----|
| STATIONS | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| Wt. Before ignition (g) | s | s | s | s | s | s | s | s | s | s | s | s | s | s | s | s | s | s |
| Wt. After ignition (g) | 4.9 | 4.9 | 4.9 | 4.8 | 4.8 | 4.9 | 4.9 | 4.9 | 4.7 | 4.9 | 4.9 | 4.7 | 4.9 | 4.7 | 4.7 | 4.7 | 4.8 | 4.8 |
| Difference | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.3 | 0.1 | 0.1 | 0.3 | 0.1 | 0.1 | 0.3 | 0.3 | 0.2 | 0.2 |
| % | 2 | 2 | 2 | 4 | 4 | 2 | 2 | 2 | 6 | 2 | 2 | 6 | 2 | 2 | 6 | 6 | 4 | 4 |

Table 3: PERCENTAGE SEDIMENT TEXTURE OF SEDIMENT AT EGBIN THERMAL STATION

| | February | | | March | | | April | | | May | | | June | | | July | | |
|------|----------|----|----|-------|----|----|-------|----|----|-----|----|----|------|----|----|------|----|----|
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| Sand | 83 | 79 | 94 | 94 | 74 | 75 | 96 | 68 | 68 | 78 | 78 | 65 | 95 | 83 | 49 | 97 | 66 | 83 |
| Clay | 12 | 21 | 0 | 0 | 23 | 24 | 0 | 25 | 29 | 1 | 15 | 28 | 5 | 13 | 36 | 0 | 15 | 13 |
| Silt | 4 | 0 | 6 | 6 | 3 | 1 | 4 | 7 | 3 | 21 | 7 | 7 | 0 | 4 | 15 | 3 | 19 | 4 |

Biological characteristics.

Phytoplankton

A total of 83 phytoplankton species from 43 genera were recorded for this survey. Whereas the diatoms recorded 50 species from 22 genera, the cyanobacteria recorded, 24 species from 13 genera, the green algae, 7

species from 6 genera and the euglenoids were represented by 2 species from a sole genus. For the diatoms (bacillariophyceae) the pennate forms (32 Species) were more important than the centric forms (18 Species) in terms of species number. *Aulacoseira grannulata* and *A. granulata* var. *augustissima* were

notable species in the wet season and recorded high numbers. Other notable species were *Melosira moniliformis*, *Coscinodiscus centralis*, *Coscinodiscus eccentricus*, *Biddulphia aurita*, *Terpsinoe musica*, *Thalassionema fraunfeldii*, *Gyrosigma balticum*, *Pinnularia major*, *Pleurosigma angulatum*, *Synedra crystallina*, *Pinnularia major* and *Pleurosigma angulatum*.

For the cyanobacteria (cyanophyceae) the hormogones (15 Species) were better represented than the chroococoid forms (9 Species). Station 1 was better represented in terms of number of species and abundance than other stations for the cyanobacteria. Species represented were *Pseudanabaena galeata*, *Microcystis flos-aquae*, *Lynbya martensiana*, *Aphanocapsa* sp., *Calothrix coenervicola*, *Phormidium uncinatum*, *Schizothrix fasciculate*, *Oscillatoria formosa* and *Oscillatoria minima*.

For the green algae (Chlorophyceae) recorded 7 Species *Gonatoaygon* and *Spirogyra* spp were the two important green algae species recorded in terms of numbers. These species were recorded only in the wet season. Other were *Cladophora glomerata*, *Cladophora* sp., *Oedogonium* sp. and *Rhizoclonium* sp. The phytoplankton community structure parameters (bio-indices) are presented in Table 4. These bio-indices values showed both spatial and temporal variations.

ZOOPLANKTON

A total of 21 zooplankton species were recorded for the study (Table 5). Copepods, Cladocerans, Amphipods, Mysids, Chaetognaths and Cnidarians were represented. Of the lot, the Copepods (11 Species) particularly the calanoid copepods (9 Species) were the more diverse and frequently occurring species at all three (3) stations. *Paracalanus parvus* was the singular more important species recorded in terms of frequency and number. Other copepod species recorded include *Acartia clausii*, *Centropage typicus*, *Diaptomus* sp, *Isias claripes*, *Pseudocalanus elongates*, *Temora longicornis* (Calanoid copepod) *Cyclops* sp., and *Oithona nana* (Cyclopoid copepod). The cladocerans comprised of 4 species. They were *Diaphanosoma* sp., *Daphnia* sp., *Chydorus* sp, and *Bosmina* sp. The Amphipods were represented by *Gammarus* sp., *Hyperia galba*, the Mysids were represented by *Mysis oculata*, the Chaetognaths were represented by *Sagitta enflata* and the Cnidarians were represented by *Chysaora melanaster* and *Sarsia eximia*.

BENTHOS

All species belonged to the Phylum Mollusca. Whereas the Gastropods recorded 3 species (*Pachymelania aurita*, *Tympanotonus fuscatus* and *Neritina glabrata*), the bivalve recorded 2 species namely (*Iphigenia truncata* and *Aloidis trigona*). *Pachymelania aurita* and *Tympanotonus fuscatus* var. *radula* were the more important species with regards to occurrence and number, followed by *Aloidis trigona*.

DISCUSSION

Higher than previously documented temperature for the region was recorded for the Egbin area and this could be attributed to waste heat (hot water) discharged from the thermal facility. The temperature ranged between 27 and 40°C. Water temperature reduced as the stations were further away from the thermal plant. The variation in the other physical and chemical characteristics of the lagoon water especially at station 3 recorded known trends and ranges for the Lagos and Epe lagoon areas (Nwankwo, 1986, 1996, 1998; Onyema *et al.*, 2003). Some of the impact of temperature on water physico-chemistry and benthic organisms has been well documented (Pandey, 1983). Generally however, the higher transparencies for the three stations in the dry season may be due to dilution of particulates by sea water incursion (Onyema *et al.*, 2008). High transparencies have been reported by previous authors (Olaniyan, 1969; Yoloeye, 1976; Nwankwo, 1996; Chkwu and Nwankwo, 2004) especially in the dry season. According to Ajao (1996) for the Lagos lagoon the Egbin thermal plant serves as a point source of pollution in the lagoon because apart from impacting the lagoon with heated waste water, it also introduces metals, oil and grease to the lagoon environment. Quite high heavy metals levels were estimated especially in the dry season. The hydrogen ion index (pH) ranged between 6.23 and 6.96, hence acidic. pH changes can drastically affect the structure and function of the ecosystem both directly and indirectly. It could lead to increasing concentration of heavy metals in water through increased leaching from sediments (Oyenekan, 1988; Odiete, 1999).

The high salinity values recorded earlier could additionally be due to the effluent from the facility since thermal stations are known to discharge high saline waters in addition to heat as a result of evaporative concentration (Odieta, 1999). Salinity values were higher in the dry season at all stations. This period for the Lagos lagoon is known to experience reduced rain events and increased sea water incursion leading to higher salinity records (Brown and Kusemiju, 2002; Chkwu and Nwankwo, 2004; Nwankwo, 2004; Onyema, 2008; Onyema *et al.* 2008). The reduction in the nitrate – nitrogen, phosphate – phosphorus and sulphate values as well as the increase in total suspended solids (TSS) values observed in June and July may be due to dilution from floodwater and the introduction of allochthonous material. According to Dance (1981), the transportation of particulate matter in streams is a physical process while the transportation of particulate organic matter is positively related to precipitation and flow conditions. Evaporation and reduction of river inflow leading to concentration could have been responsible for the higher levels of nutrients in the dry season. With regard to biota and heavy metals Nwankwo (1993) was of the opinion that the levels of some heavy metals particularly zinc have increased well above the background level in the Lagos lagoon and may have produced inhibitory effects or the formation of complexes which may have placed some nutrients beyond the reach of

the Cyanobacteria population. High copper values well above the FEPA (1991) limitation guidelines of less than 1mgL^{-1} were recorded for the Egbin area.

According to Nwankwo (1988), *Aulacoseira granulata* and *A. granulata* var. *angustissima* were prominent in the eastern zone of the lagoon which is primarily fresh or associated with low salinity values. Similar floral spectrum was observed in this study but with another sub-dominant species, a desmid, *Gonatozygon* sp. This community has also been recorded by Onyema (2008) for the Iyagbe lagoon. These species could be regarded as possible indicators of fresh water / very reduced salinity conditions within the lagoon. Indicators of high brackish water conditions observed were *Biddulphia aurita*, *B. laevis*, *Gyrosigma balticum*, *Melosira moniliformis*, *M. nummuloides* while possible Cyanobacteria bloom species recorded were *Microcystis aereginosa* and *M. flos-aquae* (Nwankwo 1986; Nwankwo, 2004; Onyema *et al.*, 2003). These cyano-bacteria have also been previously reported in South-western Nigeria (Nwankwo *et al.*, 2003; Onyema, 2008). According to Onyema *et al.*, (2003) the high densities of *Aulacoseira granulata* and *A. granulata* var. *angustissima* recorded during the rains may have been recruited from the fresh eastern extremes of the lagoon where they are known to bloom. According to Nwankwo (1984) algal productivity in the Lagos lagoon is high and principally dominated by diatoms as was observed in this study. The prevalence in most samples of pennate forms might indicate their recruitment from the phytobenthos community (Nwankwo and Akinsoji, 1989; Onyema, 2007). According to Onyema and Nwankwo (2006) frequently occurring pennate forms in plankton samples could be a reflection of the mixing of the shallow Lagos lagoon and the phytobenthic community by tides and floodwaters at various seasons.

Generally the fluctuations in the water chemistry and microalgal flora at the different stations of the Lagos lagoon at Egbin were similar especially for stations 2 and 3. This may be due to their control by similar factors. Whereas salinity was the dominant factor during the dry months, rainfall associated with fresh water inflow dominated the wet months. More importantly, temperature was a key factor in both the dry and wet season especially at station 1. According to Nwankwo and Akinsoji (1989) there is the existence of an environmental gradient linked with rainfall pattern in the Lagos lagoon. There is yet to be a report of fish poisoning around the area. However ciguatera – marine fish poisoning has been reported as a possible consequence of thermal pollution in tropical seas, (De Sylva and Hine, 1972). It is caused by the spread of blue – green algae as a result of elevated temperature. The planktonic algae is eaten first by small browsing and grazing fishes and invertebrates, then by large predatory fishes such as Barracudas, Snappers, Grouper and jacks and finally by man. Nwankwo (1993), Nwankwo *et al.* (2003), Onyema (2008) have already reported potential harmful algae especially with regard to bloom condition in the region. Furthermore the cyanobacteria group which had a

marked representation at station 1 are known to produce a variety of potent toxin which are responsible for animal poisoning and human health problems worldwide. Additionally, the composition and abundance of cyanobacteria was strong and positively correlated with increasing temperature ($r = 0.68$) at station A. According to Odiete (1999) the cyanobacteria are tolerant and become dominant in temperatures above 32°C . Kadiri (2000) also reported a higher diversity of cyanobacteria in a warm spring than in a cold spring within the same area at Ikogosi, Nigeria.

According to Onyema *et al.*, (2003) in the Lagos lagoon, diatoms for the phytoplankton and copepods for the zooplankton dominate the plankton spectrum. A similar situation was been documented for this study. Similar finding have been noted by other authors (Olaniyan, 1975; Akpata *et al.*, 1993; Emmanuel and Onyema, 2007; Onyema *et al.* 2007, 2008). Zooplankton diversity and abundance was higher in the dry months possibly due to increases in salinity and hydrological stability (Onyema *et al.*, 2007) hence recruitment from the more brackish and western parts of the Lagos lagoon. There is evidence to show that the brackish conditions of the dry season caused the recruitment of marine species. For example, *Sagitta* sp a well known marine species of the Nigerian coastal waters was recorded at Egbin in February and March. The abundance of juvenile forms probably indicates that the water quality was relatively suitable for their habitation. The low zooplankton population recorded in May could be due to the sharp drop in salinity caused by rainfall. According to Nwankwo (1996) sharp drops or sharp rises in salinity is catastrophic to lagoon biota. The prevalence of copepods in the Lagos lagoon at Egbin confirms observations by Olaniyan (1975) that the copepods are taxonomically the most important zooplankton group in the Lagos lagoon. This present investigation also confirms earlier report (Nwankwo, 1990) that life in the lagoon is subject to vagaries of seasonal fluctuation from fresh water to brackish or marine conditions and only species showing a high degree of salinity tolerance are able to survive for sufficiently long periods.

The organic matter distribution in the Lagos lagoon has been attributed to anthropogenic inputs and to the sedimentation or depositional nature which is governed by the current flow and the fluxes due to the rising and falling of tide in the lagoon (Ajao *et al.*, 1996). The Total organic matter of the stations was generally low. Station 3 recorded the highest value of 6%. Bader *et al.*, (1970) as stated by Oyeneke (1981) suggested that the Total organic matter could be used as an index of the amount of food available to benthic animals. Station 3 with higher organic matter would be expected to support a greater composition and abundance of benthos than Stations 1 and 2. On the contrary, this was not the case. According to Brown and Oyeneke (1998) and Ajao and Fagade (1991) benthic invertebrates in the Lagos lagoon are sediment type specific. Water chemistry also of the overlying waters

according to them could also act as a key factor. The benthic macro fauna of the study area was numerically dominated by the gastropod - *Pachymelania aurita*. at all stations. Gray (1979) showed that chances in community structure were correlated with environmental disturbances notably pollution. Loss of biodiversity in the study area can therefore be linked to thermal pollution. For instance increases in temperature have been found to increase fish metabolic rate, spawning and also causes changes in the toxic action of various substances upon fish (Nikoslky, 1963). Large numbers of dead shells of these species were observed at all stations. Sediment structure and stability are important factors in benthic fauna distribution. Sand mining which is also common in the area may also constitute deleterious effects to benthic life. The benthic community in the area is arguably the *Pachymelania* community described by Oyekan (1988) as being the dominant macrofauna community of the Lagos lagoon. Other key members of this community recorded for the present study were *Tympanotonus fuscatus*, *Iphigenia truncata*, *Alodis trigona* and *Neritina glabrata*.

The values for community composition parameters of the biota encountered at Egbin varied in tandem with species diversity and abundance at the different stations. Generally, the low species diversity recorded for the three categories of organisms studied maybe a reflection of prevailing unfavorable conditions especially when compared to species diversity and density of similar studies in South-western Nigeria (Nwankwo, 1988, 1996; Oyekan, 1988; Brown and Oyekan, 1998; Onyema *et al.*, 2003, 2007). With regards to ameliorative measures, the amount of waste heat discharged to the lagoon can be reduced by improving the efficiency of the station, and by making productive use of heat or by using cooling towers, cooling ponds or spray ponds. There is therefore the need for treatment of the coolant water before discharge into the lagoon to forestall conditions of dire ecological damage to the ecosystem. In an experience carried out on the thermal waters for agricultural purposes (Gunderson and Bienfary, 1975), it was found that it is possible to convert a thermal waste discharge problem into an environmental benefit at a cost effective return.

Table 4: Physico-chemical parameters in the Lagos Lagoon at Egbin (February to July, 2000).

| | Feb | | | March | | | April | | | May | | | June | | | July | | |
|---|-------|--------|--------|--------|-------|--------|-------|--------|-------|-------|-------|-------|--------|--------|--------|---------|---------|---------|
| | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| Water temperature (°C) | 36 | 32 | 27 | 37 | 34 | 29 | 38 | 36 | 29 | 40 | 38 | 30 | 38 | 34 | 27 | 35 | 34 | 27 |
| Transparency (cm) | 196 | 189 | 184 | 190 | 190 | 184 | 167 | 145 | 148 | 186 | 184 | 168 | 85 | 66 | 78 | 91 | 89 | 83 |
| pH | 6.57 | 6.53 | 6.45 | 6.74 | 6.62 | 6.69 | 6.5 | 6.4 | 6.6 | 6.23 | 6.96 | 6.93 | 6.32 | 6.8 | 6.83 | 6.93 | 6.81 | 6.47 |
| Total Suspended Solids (mgL ⁻¹) | 2 | 16 | 20 | 6 | 28 | 26 | 32 | 0 | 0 | 0 | 276 | 90 | 82 | 106 | 106 | 450 | 390 | 334 |
| Total Dissolved Solids (mgL ⁻¹) | 6496 | 7074 | 8082 | 11130 | 12546 | 1964 | 10036 | 9228 | 8960 | 9416 | 9080 | 8060 | 564 | 1198 | 798 | 402 | 410 | 394 |
| Conductivity (Scm ⁻¹) | 0.013 | 0.0141 | 0.0162 | 0.022 | 0.025 | 0.0039 | 0.020 | 0.0039 | 0.018 | 0.019 | 0.018 | 0.016 | 0.011 | 0.0024 | 0.0016 | 0.00080 | 0.00082 | 0.00079 |
| Salinity (‰) | 6.5 | 6.7 | 7.7 | 10.1 | 12.1 | 7 | 9.3 | 7 | 7.4 | 7 | 6.7 | 7 | 1.4 | 1.4 | 1.4 | 1.1 | 1.2 | 1.1 |
| Dissolved Oxygen (mgL ⁻¹) | 3.6 | 4.3 | 4.7 | 3.7 | 5.1 | 5.4 | 4.7 | 4.9 | 5.5 | 3.2 | 4.7 | 5.3 | 4.8 | 5.3 | 5.7 | 5 | 5.1 | 5.4 |
| Phosphate (mgL ⁻¹) | 0.33 | 0.36 | 0.42 | 0.57 | 0.64 | 0.12 | 0.528 | 0.517 | 0.476 | 0.48 | 0.468 | 0.414 | 0.039 | 0.067 | 0.042 | 0.025 | 0.022 | 0.019 |
| Nitrate (mgL ⁻¹) | 2.1 | 2.94 | 3.25 | 3.92 | 3.98 | 0.86 | 3.61 | 3.58 | 3.28 | 2.99 | 2.88 | 2.57 | 0.19 | 0.38 | 0.28 | 0.15 | 0.14 | 0.12 |
| Sulphate (mgL ⁻¹) | 628 | 715 | 745 | 1008 | 1135 | 179 | 922 | 184 | 817 | 852 | 821 | 735 | 51 | 108 | 72 | 36 | 37 | 35.5 |
| Oil and grease (mgL ⁻¹) | 6 | 6 | 7 | 8 | 9 | 4 | 4 | 6 | 6 | 3 ND | ND | ND | 6 | 2 | 4 | 2 | 5 | 1 |
| Lead (mgL ⁻¹) | 0.874 | 0.978 | 0.699 | 0.455 | 0.438 | 0.843 | 0.164 | 0.183 | 0.466 | 0.178 | 0.011 | 0.008 | 0.1581 | 0.513 | 0.301 | 0.489 | 0.618 | 0.776 |
| Iron (mgL ⁻¹) | 7.443 | 7.866 | 8.644 | 12.618 | 10673 | 6.114 | 6.646 | 5.758 | 0.917 | 4.618 | 0.102 | 0.619 | 2.688 | 2.316 | 0.778 | 8.643 | 16.481 | 10.165 |
| Copper (mgL ⁻¹) | 1.564 | 1.956 | 1.688 | 3.618 | 2.768 | 2.768 | 0.926 | 0.914 | 0.886 | 0.631 | 0.06 | 0.67 | 0.883 | 0.716 | 0.967 | 0.913 | 0.996 | 0.878 |

Table 5: The benthic invertebrates around a coolant water discharge area at Egbin, Lagos state

| | FEB | | | MAR | | | APRIL | | | MAY | | | JUNE | | | JULY | | |
|------------------------------|-----|-----|----|-----|----|----|-------|----|---|-----|----|----|------|---|----|------|----|----|
| BENTHIC INVERTEBRATES | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| CLASS: GASTROPODA | | | | | | | | | | | | | | | | | | |
| ORDER: ARCHEOGASTROPODA | | | | | | | | | | | | | | | | | | |
| FAMILY I: POTAMIDAE | | | | | | | | | | | | | | | | | | |
| <i>Tympanotonus fuscatus</i> | 9 | 276 | 15 | 16 | 1 | 0 | 164 | 14 | 5 | 23 | 59 | 48 | 40 | 7 | 9 | 15 | 5 | 42 |
| FAMILY II: MELANIDAE | | | | | | | | | | | | | | | | | | |
| <i>Pachymelania aurita</i> | 8 | 338 | 12 | 25 | 24 | 15 | 22 | 47 | 7 | 32 | 28 | 14 | 220 | 8 | 12 | 21 | 21 | 24 |
| FAMILY III: NERITIDAE | | | | | | | | | | | | | | | | | | |
| <i>Neritina glabrata</i> | - | - | - | - | - | - | - | - | - | - | 2 | - | 4 | | 2 | - | - | 1 |
| CLASS: BIVALVIA | | | | | | | | | | | | | | | | | | |
| ORDER: HETERODONTIDAE | | | | | | | | | | | | | | | | | | |
| FAMILY I: DONACIDAE | | | | | | | | | | | | | | | | | | |
| <i>Iphigenia truncata</i> | - | - | - | - | - | - | - | - | 1 | - | - | 2 | - | - | 1 | - | - | 2 |

FAMILY II: ALOIDIDAE

| | | | | | | | | | | | | | | | | | | |
|------------------------------------|-----------|------------|-----------|-----------|-----------|-----------|------------|-----------|-----------|-----------|-----------|-----------|------------|-----------|-----------|-----------|-----------|-----------|
| <i>Aloidis trigona</i> | - | - | 30 | - | - | 1 | 2 | 12 | 14 | - | 8 | 10 | - | 9 | 9 | - | 9 | 9 |
| Total number of Species (S) | 2 | 2 | 3 | 2 | 2 | 3 | 3 | 3 | 4 | 2 | 4 | 4 | 3 | 3 | 5 | 2 | 3 | 5 |
| Species Abundance (N) | 17 | 614 | 57 | 41 | 25 | 16 | 188 | 73 | 27 | 55 | 97 | 74 | 264 | 24 | 33 | 36 | 35 | 78 |

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