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A review of some characteristics of freshwater and coastal ecosystems in Ghana

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Key words: pH, transparency, oxygen, nutrients, phytoplankton

Abstract

Data collected over a ten year period have been used to review some characteristics of freshwater and coastal ecosystems in Ghana. Studies were conducted on two recently formed man-made lakes, one river, five coastal lagoons and waters along the ocean front.

Freshwaters had near neutral pH while coastal waters were alkaline. In both ecosystems the pH of sediments were lower than those of corresponding waters. While the transparency of coastal waters varied within narrow limits, large variations were observed in freshwaters. The lowest concentration of nutrients occurred in the river and the highest in coastal waters.

In general, differences in these physical and chemical characteristics do not depend on whether the aquatic systems were fresh, brackish or saline. They seem to be more influenced by such factors as whether a water body: (1) was lotic or lentic, (2) was influenced by industrial or domestic activities, (3) was affected by impoundment, (4) received turbid water inflows, or (5) was eutrophic.

Introduction

Inland and coastal waters are linked in many ways. As rivers flow coastwards they bring materials, both particulate and dissolved, to coastal waters (estuaries, lagoons and near-shore waters) which are transitional zones existing at the borders of the sea, rivers and land. The quality of coastal ecosystems is therefore influenced by activities inland.

Coastal waters, especially estuaries, serve as traps for materials brought from inland as a result of flocculation, precipitation and sedimentation. They are fertile environments which serve as important nursery grounds for many species. Coastal waters may also influence off-shore productivity owing to nutrient fluxes.

While inland waters serve as a ready source of potable water, they also act, in common with coastal waters, as a habitat for fish and place for transportation and recreation. Thus both inland and coastal waters are generally subjected to similar anthropogenically induced stresses, notably pollution and over-exploitation.

This paper reviews some physical and chemical properties of freshwater and coastal ecosystems in Ghana by discussing data obtained from studies on two recently formed man-made lakes, the Kpong Headpond and Weija Reservoir, five coastal lagoons, the Laiwi, Sakumo II, Korle, Sakumo I and Fosu, the lower Volta River and waters along the ocean front in the Greater Accra region.

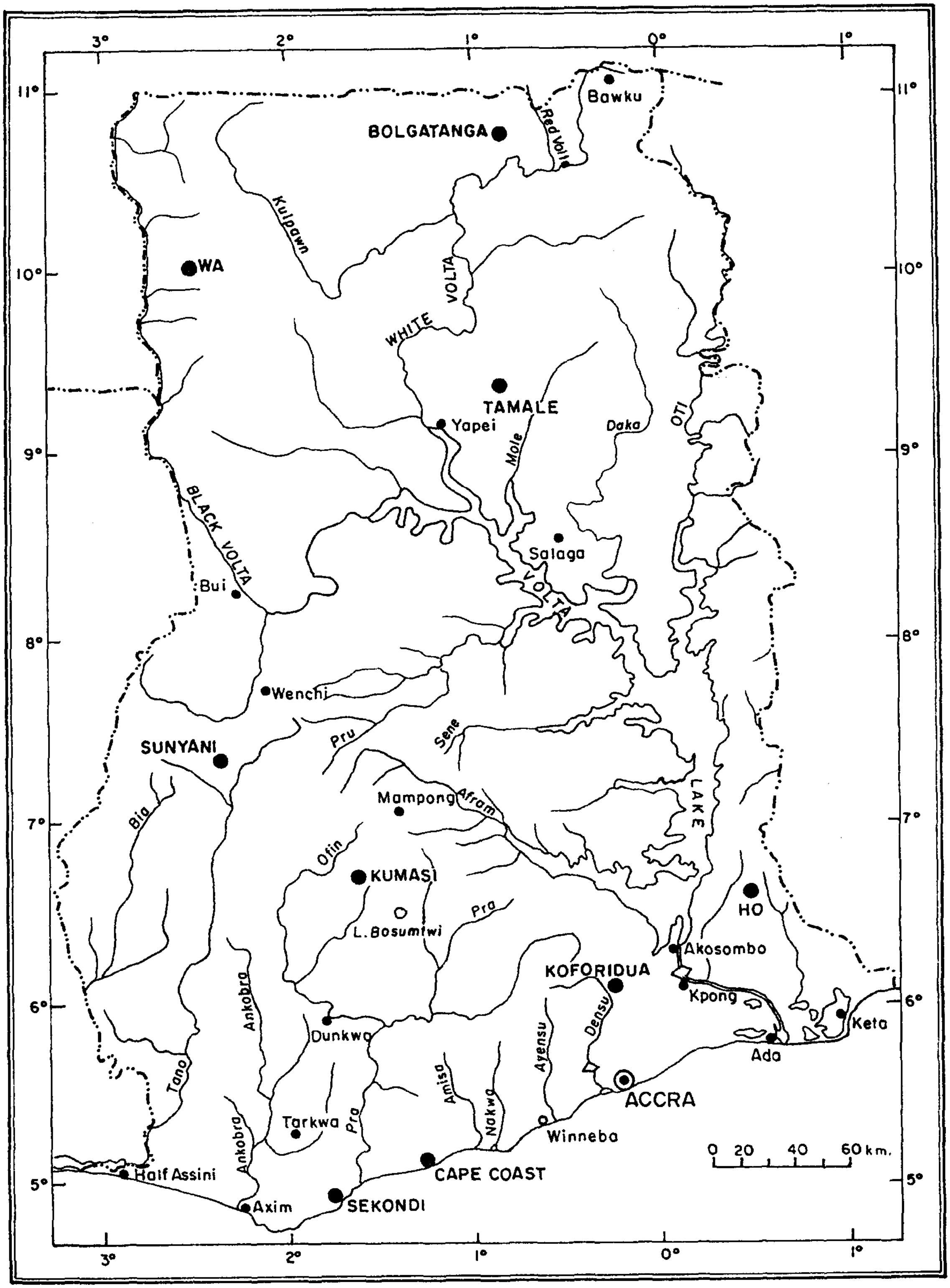

Fig. 1. Drainage pattern of Ghana.

Study area

The surface freshwater resources of Ghana are dominated by the Volta River System (Fig. 1). The Volta, which spans the entire length of Ghana to the east, originates in Burkina Faso and enters the Gulf of Guinea at 0° 42′ E, 5° 46′ N. At Akosombo, 100 km from the mouth, is situated the first Volta hydroelectric dam, constructed in 1964. Behind it, the Volta and its tributaries such as the Oti, Black Volta, White Volta, Afram, Pru and Daka have formed one of the largest manmade lakes in the world, covering an area of about 8316 km^2. A smaller shallower impoundment, the Kpong Headpond, covering an area of about 40 km^2, was completed in 1981 when another hydroelectric dam was completed at Kpong, 20 km downstream of Akosombo. The Lower Volta River thus flows downstream of Kpong for 80 km into the sea (Fig. 2). Also in southern Ghana are rivers which flow into the sea, often through coastal lagoons. The most prominent of these are the rivers Tano, Ankobra, Pra, Ayensu and Densu (Fig. 2). Along some of these rivers impoundments have been created to provide water for domestic, industrial and agricultural purposes. The most important of these is the Densu Reservoir formed in 1977 on the Densu River with an approximate surface area of 300 ha (Dassah & Abban, 1979) and depths ranging from 1–10 m.

The coastline of Ghana, which forms part of the Gulf of Guinea, extends between latitudes 4° 30′ N at Cape Three Points and 6° N in the extreme east and stretches for a distance of 550 km between 3° W and 1° E (Fig. 2). About 50 lagoons occur here more than half of which are very small, i.e. less than 5 km^2 in surface area

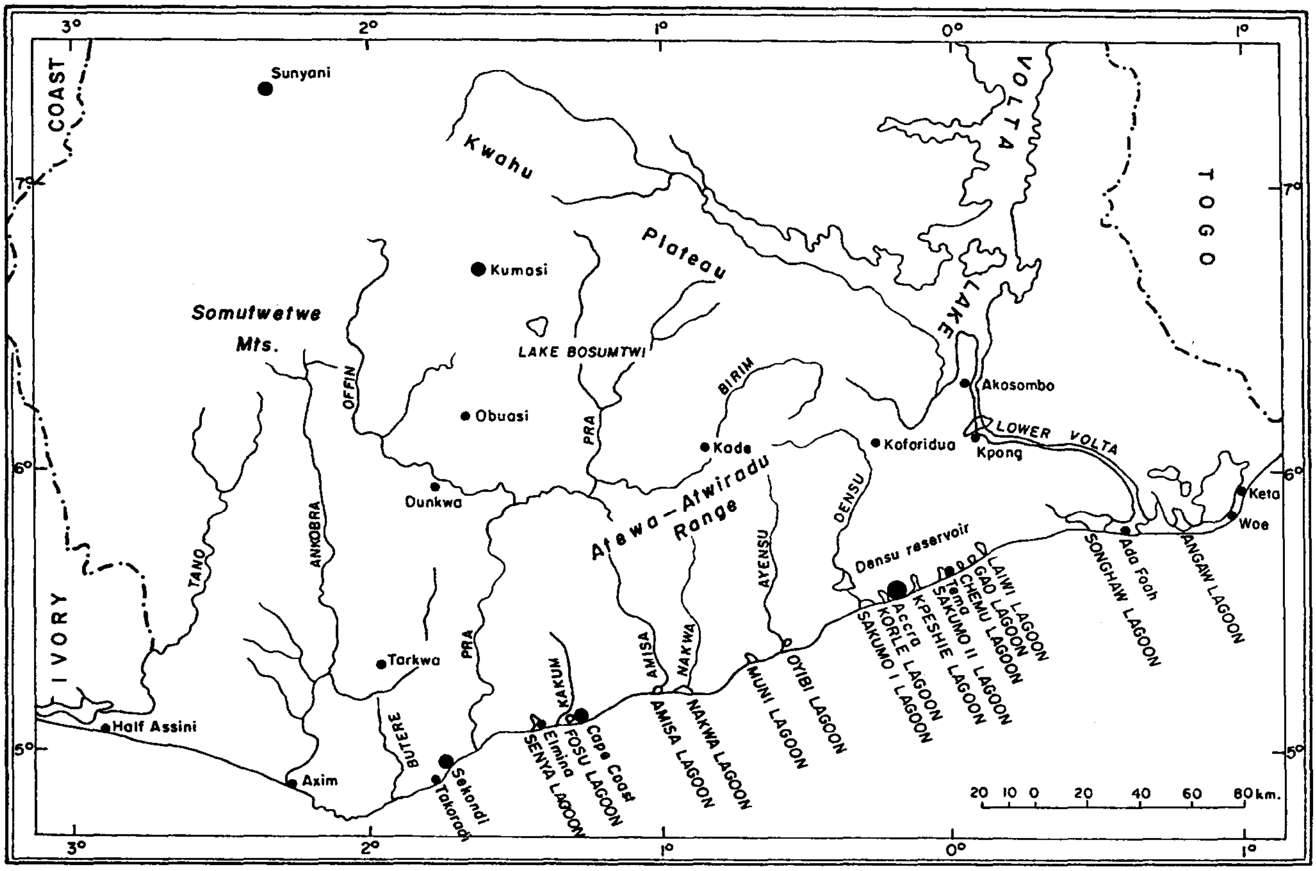

Fig. 2. Map of southern Ghana showing major rivers and lagoons.

(Boughey, 1957; Mensah, 1979). These lagoons are of two main types. The first remains closed to the sea during the dry season and include the Laiwi, Gao, Mukwe, Kpshie and Fosu Lagoons. The second type is always open to the sea and associated with rivers which flow all the year round. These include the Korle, Sakumo I, and Nakwa. Some lagoons such as the Chemu and Sakumo II which were originally closed are now connected to the sea by man-made culverts.

As Ghana lies in the belt of tropical and equitorial climates, temperatures are high, ranging between 25 and 35 °C with little variation throughout the year. There are two wet seasons in a year, the major one from May to June and a minor season from August to October. Rainfall amounts vary from an annual average of 215 cm in the southwest to 82 cm in the southeast.

Methods

Analysis of water and sediment were carried out on samples collected between 1976 and 1985 from the following fresh and coastal water bodies (Fig. 2):

1) The Lower Volta River and estuary;
2) Man-made lakes – Kpong Headpond and Densu Reservoir;
3) Coastal lagoons – the Laiwi, Sakumo II, Kpeshie, Korle, Sakumo I and Fosu;
4) Onshore waters in Accra West and East.

The sampling dates and total numbers of samples collected from each water body are outlined in Table 1. Surface water samples were collected with a plastic bucket from all locations. With the exception of the shallow lagoons and onshore waters, profile sampling was done using a 1.7 l Hydro-bios water sampler. Water samples were filtered and analysed for the following parameters:

Transparency – estimated by the use of a Secchi disc,
Orthophosphate – determined using ammonium molybdate and ascorbic acid (Mackereth *et al.*, 1978),
Nitrate-nitrogen – determined by hydrazine reduction followed by diazotizing to form an azo dye,
Ammonia-nitrogen – measured by the indophenol blue method (FAOUN 1975),
Dissolved oxygen – determined by a modification of Winkler method (FAOUN 1975),
Phytoplankton enumeration – estimated according to Palmer (1962),
pH – measured in the field with a portable Griffin pH meter.

Table 1. Dates of sampling and total numbers of samples collected.

Location	Total numbers of samples	Sampling dates
Lower Volta River	180	November 1976, March 1981, December 1981, August 1982
River Volta Estuary	60	As for the Lower Volta River and monthly from October 1979 to January 1980.
Kpong Headpond	36	June, August, October 1982 and January, February 1985.
Densu Deservoir	120	Monthly from December 1976 to March 1978 and half yearly from March 1979 to September 1982
Lagoons	24 each	August 1980, monthly from January to July 1981, Februari, March 1985.
Onshore waters	28 each	Monthly from January to July 1981, November 1984.

All analyses were carried out within one week during which water samples were stored in glass bottles at 4 °C. For each water body, sediment sampling was done once using an Ekman grab. Eight samples each were collected from the Lower Volta River and the Densu Reservoir, six for the Kpong Headpond and four each for the other locations. Air dried sediment samples were analysed for pH in the laboratory by stirring 10 g of each sample in 30 ml distilled water and measuring with a pH meter after 20 min.

Results and discussion

pH

The mean pH values of water and sediment from fresh and coastal waters are presented in Table 2. The freshwaters of the Lower Volta River, the Kpong Headpond and the Densu Reservoir all had neutral values. The Lower Volta River was slightly acidic while the Densu Reservoir was slightly alkaline. Running waters are normally influenced by the nature of deposits over which they flow (Hynes, 1970) while shallow lentic environments which favour the growth of phytoplankton are more influenced by photosynthetic activities which increase pH values (Symoens *et al.*, 1981). However, since neither primary productivity nor chlorophyll measurements were made, it is not possible to explain clearly why the Lower Volta River which runs over lateritic and ochrosol sediments had lower mean pH than its main source, the Kpong Headpond. With the Densu Reservoir the mean pH is further increased because of its proximity to the sea (Fig. 2). In the open ocean the pH of sea water falls within the limits of 7.5 to 8.4 (Riley & Chester, 1971). The influence of sea water on the Densu Reservoir also shows in its ionic dominance pattern of $Na^+ > Mg^{2+} > Ca^{2+} > K^+ : HCO_3^- > Cl^- > SO_4^{2-}$ (Biney, 1987). This is in contrast to the ionic dominance pattern of Na > Mg > Ca > K : Cl > SO_4 > HCO_3 for sea water and Ca > Mg > Na > K : HCO_3 > SO_4 < Cl for fresh water (Burton, 1976). The cationic pattern is similar to that for sea water and the anionic pattern intermediate between fresh and sea water.

Studies of Ghanaian estuaries (Biney, 1985) have shown that in general slightly acidic river waters turn alkaline under the influence of sea water in the lower reaches. This should account for the slightly alkaline nature of the waters of the Volta Estuary.

The waters of the coastal lagoons and along the ocean front were mostly more alkaline than the freshwaters (Table 2). In his studies of dissolved oxygen and primary productivity of two Ghanaian lagoons, the Sakumo II and Mukwe, Kwei (1977) found a daily rhythym of low carbon fixation and

Table 2. Mean pH, transparency and dissolved oxygen concentrations.

Location	pH		Transparency cm	Dissolved oxygen mg l^{-1}
	Water	Sediment		
Lower Volta River	6.8 ± 0.5	6.3 ± 1.1	237 ± 61	7.4 ± 0.8
Kpong Headpond	7.0 ± 0.4	6.9 ± 0.8	181 ± 57	6.3 ± 1.6
Densu Reservoir	7.3 ± 0.2	7.0 ± 2.2	53 ± 14	8.2 ± 3.0
Volta Estuary	7.3 ± 0.6	–	199 ± 21	9.9 ± 2.0
Laiwi Lagoon	8.1 ± 0.1	8.0 ± 0.5	49 ± 10	7.6 ± 0.5
Sakumo II Lagoon	8.2 ± 0.6	7.5 ± 1.2	22 ± 12	8.0 ± 2.5
Korle Lagoon	7.1 ± 1.4	6.6 ± 1.3	25 ± 16	4.4 ± 3.4
Sakumo I Lagoon	7.0 ± 0.4	–	44 ± 15	6.3 ± 1.0
Fosu Lagoon	7.8 ± 0.9	7.3 ± 1.0	26 ± 9	8.3 ± 2.2
Accra–west	7.8 ± 0.2	6.2 ± 0.4	77 ± 7	7.4 ± 0.5
Accra–east	7.9 ± 0.1	6.3 ± 0.7	89 ± 7	7.2 ± 0.4

dissolved oxygen concentration during the mornings which rose to a peak around 1,300 hours and dropped afterwards. Thus, apart from their proximity to the sea, photosynthesis by phytoplankton may also significantly increase the pH of lagoon waters during the day. The neutral pH of the Sakumo I Lagoon could be due to the effects of the Densu River which flows through the lagoon into the Gulf of Guinea (Fig. 2). Studies of the physical and chemical properties of this river (Amuzu, 1975; Biney, 1985) have shown it to have a mean pH of about 7. With the Korle Lagoon, the great diversity of industrial and domestic discharges which reach it (Mensah, 1976; Biney, 1982) may account for the comparatively low pH.

The mean pH values of sediments were normally lower than those of corresponding waters. No clear pattern could be identified in the differences between the pH of sediments from coastal and freshwater ecosystems. This may be explained by the differences in the composition of sediments from different areas. Thus, while sediments from the Lower Volta River were acidic, sediments from the Korle Lagoon and the ocean front in Accra were also acidic. Depositions from industrial and domestic discharges may also have contributed to the acidic nature of the sediments of the Korle Lagoon and the ocean front.

Transparency

The waters of the Lower Volta River, the Kpong Headpond and the Volta estuary were particularly clear with mean Secchi disc transparencies of 200 cm or more (Table 2). This is due to the effects of the Akosombo Dam behind which the bulk of the waters of the Volta collects and sediments resulting in clear and silt-free waters downstream. For the Lower Volta River, this effect is doubled since waters downstream of Akosombo are also retained in the Kpong Headpond before being discharged downstream. These clear freshwaters contrast very much with those of the Densu Reservoir with a mean disc transparency of about 50 cm. The Densu River, the principal source of freshwater to this reservoir normally has low transparency with a range of 20–30 cm, the result of large discharges from a densely populated catchment zone where agriculture is the mainstay.

River borne silts and other suspended matter settle from suspension as they are transported to more saline waters because of flocculation and aggregation (Burton, 1976). This phenomenon would normally be expected to increase the clarity of coastal waters including those lagoons which serve as estuaries. In general, however, the coastal waters had low transparencies (Table 2) mainly because of the influx of turbid waters from rivers and land runoff. Phytoplankton abundance also contributed to the low transparencies. In the Fosu and Sakumo II lagoons, for example, algal proliferation accounted in part for their slightly greenish colouration and resulting low transparencies (Table 4). Of the coastal waters, those along the ocean front had higher mean transparencies because these are being constantly renewed through wave action. However, during the rainy season, they may become more turbid as a result of the influx of turbid land runoff.

Dissolved oxygen

Both fresh and coastal waters had high mean dissolved oxygen concentrations with a range of 6–8 mg l^{-1} (Table 2). Generally, differences in dissolved oxygen concentrations between coastal and freshwater ecosystems had more to do with whether the environments were riverine or lacustrine and the type of discharges a particular water body received. As they flow along rivers are oxygenated by wave action. Waters of the ocean front are also oxygenated because of their constant renewal through wave action. In the lacustrine environments, whether fresh or saline, their stagnant nature encourages the growth of both micro- and macrophytes which oxygenate the waters by their photosynthetic activities.

Supersaturation of oxygen occurs in the Volta Estuary, because apart from the water flow, the clarity of the waters coupled with high temperatures have encouraged the growth of large quantities of submerged aquatic weeds such as *Vallisneria aethiopia*, *Ceratophyllum demersum* and *Potamogeton octandrus* (Biney, 1983). The lowest dissolved oxygen concentration occurred in the Korle Lagoon which is regarded as grossly polluted (Biney, 1982).

Nutrients

Like most coastal states, the coastal region of Ghana is the major area for industrial development. About 55% of all industries are located in the Accra-Tema metropolis (Fig. 2). Under these conditions the coastal environment has been subjected to increased stresses and polluting influences from over population, excessive domestic and industrial discharges and human-induced erosion. For instance, the Korle Lagoon which is located in the centre of the capital city of Accra is the most polluted water body in Ghana at present. The highest concentrations of orthophosphate and ammonia-nitrogen occurred in the Korle Lagoon (Table 3). Other coastal waters such as the Sakumo II and Fosu lagoons also had high concentrations. With freshwaters, the Densu Reservoir, which is also located in the Accra-Tema metropolis, had the highest concentrations of orthophosphate and ammonia-nitrogen. While phosphorus may be introduced as a result of domestic and industrial activities, the high levels of ammonia-nitrogen in these waters may result from nitrogen fixation by blue-green algae which occurred in high populations (Table 4). Zooplankton and fish excretion may also contribute to the elevated levels of ammonia-nitrogen.

The waters of the Lower Volta River and Estuary had very low concentrations of orthophosphate (Table 3). It is likely that biological processes in the form of phytoplankton growth reduce the levels of orthophosphate in the lake behind the Akosombo Dam. The algae might then settle out of the water column resulting in nutrient-poor waters downstream. Man-made lakes are also known to act as sedimentation tanks for the suspended sediments of their feeder rivers (Symoens *et al.*, 1981). This process may also remove some of the inorganic phosphorus before the waters are discharged downstream into the Kpong Headpond and Lower Volta respectively. Studies in the Volta Estuary have shown that at certain periods orthophosphate is not even detectable (Biney, 1983). Unlike the concentrations of orthophosphate, appreciable amounts of ammonia-nitrogen occurred in freshwaters (Table 3). However, these were mainly confined to bottom waters as a result of the decomposition of organic matter in the sediments.

For both coastal and freshwater environments, lower concentrations of nitrate-nitrogen occurred in waters with relatively high concentrations of orthophosphate and ammonia-nitrogen such as the Densu Reservoir, Sakumo II and Fosu

Table 3. Mean water concentrations of orthophosphate, ammonia-nitrogen and nitrate-nitrogen in mg l^{-1}.

Location	PO_4^{3-}-P	NH_4^+-N	NO_3^--N
Lower Volta River	0.018 ± 0.016	0.12 ± 0.2	0.25 ± 0.10
Kpong Headpond	0.025 ± 0.03	0.17 ± 0.09	0.25 ± 0.10
Densu Reservoir	0.12 ± 0.04	0.21 ± 0.11	0.13 ± 0.14
Volta Estuary	0.012 ± 0.01	0.053 ± 0.05	0.74 ± 0.31
Laiwi Lagoon	0.041 ± 0.02	0.016 ± 0.017	0.27 ± 0.10
Sakumo II Lagoon	0.17 ± 0.05	0.15 ± 0.05	0.18 ± 0.08
Korle Lagoon	0.56 ± 0.22	1.46 ± 0.95	0.30 ± 0.09
Sakumo I Lagoon	0.027 ± 0.019	0.072 ± 0.10	0.48 ± 0.15
Fosu Lagoon	0.094 ± 0.05	0.26 ± 0.08	0.011 ± 0.02
Accra–west	0.067 ± 0.02	0.084 ± 0.09	0.41 ± 0.09
Accra–east	0.056 ± 0.04	0.034 ± 0.01	0.37 ± 0.05

lagoons. Here, most of the oxygen available may be used for the decomposition of organic matter and not for nitrification of ammonia to nitrate. The Volta Estuary and Sakumo I Lagoon, which had lower concentrations of orthophosphate and ammonia-nitrogen, had comparatively higher nitrate-nitrogen concentrations. In these waters, phytoplankton growth is limited by phosphorus availability, thus allowing nitrate to accumulate.

Phytoplankton

The variation in algal type and population in different water bodies constitutes one of the indices that can be applied to determine the presence or absence of polluting organic wastes. Blue-green algae and flagellates are groups frequently encountered in the presence of organic wastes while green algae and diatoms occur in non-polluted waters (Patrick, 1950). It is also known that environmental stress frequently reduces community diversity (Stirn, 1981). Despite the many changes that may be revealed by the measurement of physical and chemical parameters, the most critical effects of pollution on water environments are those on living organisms. Any significant introduction or removal of substances or energy involved in biological processes inevitably induces ecosystem modifications. Of the ecosystem characteristics, community structure and diversity are relatively easy to measure. Thus changes in diversity index (I) defined as $I \neq \sqrt{\frac{S}{N}}$, where S is the number of species present and N the total number of individuals may be used with other parameters to assess the degree of environmental stress or intensity of pollution (Hellawell, 1978).

Inspection of Table 4 indicates that irrespective of the type of water body, high phytoplankton counts, dominated by blue-green algae, occurred in waters such as those of the Densu Reservoir, the Sakumo II, Korle and Fosu lagoons in which orthophosphate and ammonia-nitrogen concentrations were high. The major groups of blue-green algal populations found here were *Anabaena*, *Nostoc*, *Microcystis*, *Oscillatoria* and *Lyngbya*. According to Fogg (1962) many of the nitrogen-fixing species belong to the genera *Anabaena*, *Nostoc* and *Cylindrospermum*. Because some of the groups found are capable of nitrogen fixation, this suggest that phosphorous loading may have driven these waters to nitrogen limitation. Also the relatively high concentrations of ammonia in these water bodies may be attributed to nitrogen fixation by blue-green algae.

Diversity indices were high in water bodies with low orthophosphate and ammonia concentrations such as the Lower Volta River and Sakumo I Lagoon and decreased with increasing nutrient levels in the Sakumo II, Korle and Fosu lagoons (Table 4). This may be explained by the fact that introduction of easily biodegradable organic substances contained in domestic sewage and some industrial wastes may provide energy in

Table 4. Phytoplankton numbers, diversity and ratio of green algae, blue-green algae and diatoms.

Location	Counts ml^{-1}	Diversity index	Green algae	Blue-green algae	Diatoms
Lower Volta River	6 ± 2	2.0	1	0.6	1.38
Densu Reservoir	1306 ± 905	0.38	1	0.9	2
Laiwi Lagoon	36 ± 9	0.83	0	1	30
Sakumo II Lagoon	7800 ± 2000	0.034	0	7800	0
Korle Lagoon	1145 ± 725	0.13	1	111	0
Sakumo I Lagoon	110 ± 45	1.53	1	2.7	2.5
Fosu Lagoon	6872 ± 950	0.097	1	48	0
Accra–west	53 ± 10	0.82	1	9	0.25
Accra–east	103 ± 16	1.60	1	5.5	2

the form of nutrients that will initially increase the productivity of a water body leading to high species diversity. However, beyond a certain level, additional inputs become a stress and productivity is decreased resulting in low diversity. Thus the dominance of blue-green algae in the phytoplankton populations of the Sakumo II, Korle and Fosu lagoons (Table 4).

In general, phytoplankton occurrence was low in lotic environments. Thus, the lowest numbers occurred in the Lower Volta River while in coastal waters lower counts occurred in the waters of the ocean front. While differences may occur in phytoplankton species between fresh and coastal waters, their abundance and diversity are subject more to the influence of pollution, than to whether the water bodies are lotic or lentic.

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