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WATER QUALITY CHARACTERISTICS OF ACCRA-TEMA COASTLINE, GHANA

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ABSTRACT

Studies on the physicochemical parameters, major ions and the interrelationships between them in the surface waters of Accra-Tema coastline were made between August and October 1996. The mean values of physicochemical factors determined were 27.3 ± 0.93 °C, 32.85 ± 0.13 ppt, 7.9 ± 0.1 , 53.6 ± 0.30 ms/cm and 6.98 ± 0.8 mg/l for water temperature, salinity, pH, conductivity and dissolved oxygen respectively. The concentrations of major ionic species determined and the corresponding inter-ionic ratios were found to be higher than expected for a coastal environment except Mg/Cl (0.06698). The low ratio for Mg/Cl corresponds to the decrease in Mg concentrations with increase in salinity of the coastline. A pair wise correlation analysis gave strong and highly significant r^2 values for the relationships: salinity/ DO, 0.92; Mg/salinity, 0.94; pH/Mg, 0.77; temperature/Mg, 0.85 and temperature/Na, 0.85 at $P < 0.001$ and $n = 48$. The observed relationships were attributed to influx of saline water from the Goa lagoon (salinity 37.0 ppt), resulting in elevated concentrations of Na^+ , Cl and SO_4^{2-} along the coastline which ultimately affected the ion pairing of the dissolved constituents.

Key words: Physicochemical factors, ionic ratios, inter-relationships, Accra-Tema coastline, Ghana

INTRODUCTION

Coastlines of the world are important areas useful for economic activities such as recreation, harbour works, transportation, industrialization, tourism and fishing. Arising from the utilization of the coastal resources, a lot of waste matter are released into the system. In the developing nations, reports abound of prolong contamination of coastal areas as a result of uncontrolled discharges from industrial formations, inland drainage, municipal dumpings of solid waste, oil spillages and sewage discharges leading to environmental stress (Asuquo, 1997; Clark *et al*, 1997; Michel & Zengel, 1998). Strategic monitoring and research programs are reliable

environmental tools applied in assessing the quality of the environment, especially when the area is under severe threat arising from anthropogenic pollution.

The handling of coastal zone problems is an arduous task due to its complexity. The concentrations of various dissolved and particulate components can be highly variable since surficial mixing occurs between allochthonous (land-derived) and autochthonous (oceanic) materials (Bassey & Asuquo, 1999) distributing the components into the different interfaces (flora, fauna, water and sediment). On the other hand, the concentration of the dispersed and dissolved components depend intrinsically on the composition of pollutants, rate of mixing of water masses in the nearshore, prevailing winds and magnitude of longshore current velocity which could lead to a remarkable deterioration of the coastal water quality or may result in elevated concentrations of organic and inorganic pollutants along the particular coastline.

Ghana's coastline (ca 550km long) is flanked on the west by Ivory Coast and on the east by the Republic of Togo. The coastline is evenly inhabited with inter town/village distances seldom exceeding 5km. In the near shore area, the waters are characterized by high turbidity, fine to medium sand in the littoral and rocky outcrops to straight low gradient beach in the foreshore. Various human activities ranging from sand mining, agriculture, recreational activities, berthing areas (ports) and civil engineering works abound contributing to the high level of ecosystem perturbation/destabilization. The extent to which these activities affect the water quality of the coastline is yet to be fully established. The intermittent rocky outcrops serve as substrates for various biological species. Detail descriptions of the coastline geomorphologic characteristics have been documented (Armah, 1991).

The Accra-Tema segment where the study was carried out is approximately 20km long (Fig. 1). Materials discharged into the near shore waters are retained by the water column and recirculated during tidal incursions (semidiurnal tides, 2-3m high). Scientific information on the chemistry and mixing characteristics of Ghana coastline are scanty. The levels of temperature and salinity at Tema between 1963 and 1972, the physicochemical quality of estuaries along the Gulf of Guinea in Ghana and the concentration of heavy metals in the pink shrimp *Penaeus notialis* have been reported (Derbrah, 1973; Biney, 1983; Biney, 1984; Biney & Ameyibor, 1992). Recently, it has been observed along the Ghana coastline that interstitial fine grain sediments of pore size less than 0.4mm accumulate more heavy metals than coarser sediments with particle size greater than 0.4mm (Akpabli, *et al*; 1998).

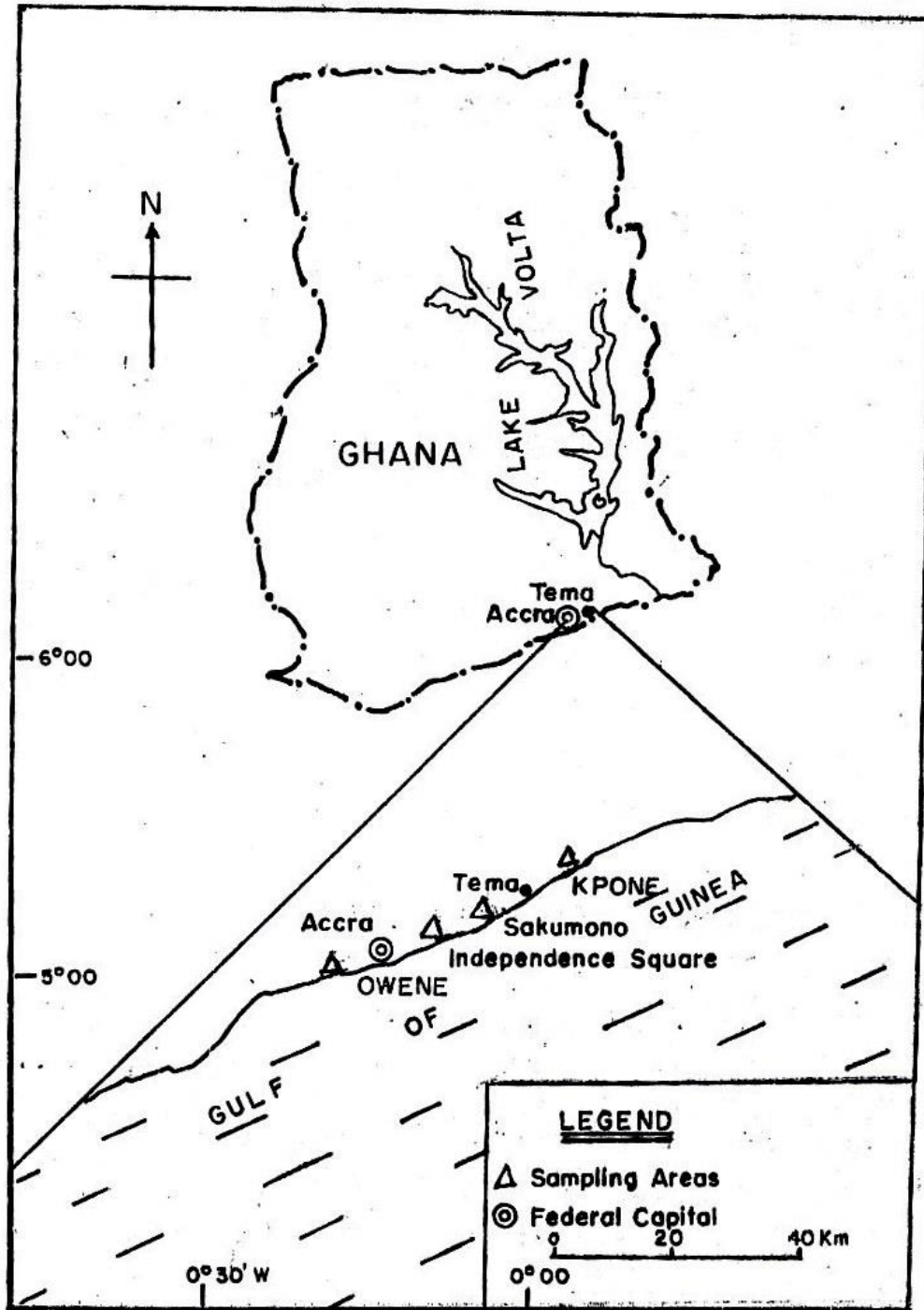


Fig.1 Map of Ghana coastline showing the study areas

This paper however reports the water quality of the coastline, distribution of the major ions and the inter-ionic relationships between the various chemical components investigated. The influence of Goa (salt) lagoon on the ionic composition of the shoreline is also discussed.

METHOD

The investigation was carried out in the nearshore waters of Accra-Tema coastline, approximately 5-10 meters deep during the long warm season of hydrographic stability (Houghton & Mensah, 1978) for two months. Four sampling stations were chosen between Accra and Tema and monitored hourly for water quality. These include Kpone (lat. $5^{\circ} 41' N$, long. $0^{\circ} 04' E$) as Station 1, Sakumuno (lat. $5^{\circ} 37' N$, long. $0^{\circ} 30' E$), Station 2; Accra (lat. $5^{\circ} 32' N$, long. $0^{\circ} 12' W$), Station 3 and Owene (lat. $5^{\circ} 30' N$, long. $0^{\circ} 17' W$) as Station 4. Water temperature and dissolved oxygen were determined in situ using OX1 921 Meter (Aqualitic). pH was measured with pH/mv meter (Crison Instruments) after calibration with buffer solutions of NBS primary standards (KH_2PO_4 and $KH_2Pthalate$). Salinity values were computed from conductivity measurements based on standard salinity-conductivity relationship table for sea water (UNESCO, 1976). Major element concentrations in water were determined using a flame photometer for Ca^{2+} , K^+ and Na^+ and a Pye Unicam Model PU-9200 Flame Atomic Absorption Spectrophotometer (AAS) for Mg and other metals. SO_4 by turbidimetric method, PO_4 by molybdenum blue method and HCO_3 by titrimetric methods (Grashoff *et al*, 1983). Quality assurance was achieved by duplicating each analytical determination. Coefficients of variation for duplicate analyses were less than 10%. The relationships between the ionic species were assessed using regression analysis and inter-ionic ratios (Asuquo, 1998).

RESULTS

Table 1 shows the levels of physiochemical parameters in the surface water samples. The measurements made showed that the water was well oxygenated ($6.98 \pm 0.80 mg/l$) at all the locations. The coastal water salinity was relatively stable (ca 32 ppt), except at Kpone (34.87 ppt) while pH (7.6 ± 0.10) and temperature ($27.3 \pm 0.93^{\circ}C$) values were normal as expected for coastal waters. Fig. 2 shows the diurnal variation of some of the physiochemical parameters in the surface water and Fig. 3 the composition of the major elements along the coastline. Temperature increased gradually during the day to a peak at 15 hours with increase in insolation and dropped at eventide. Oxygen fluctuated within the same range (5.1 – 8.6 mg/l) with no abnormal values at all the stations. The pH at Sakumuno (pH 7.87 units) was higher than other locations (<7.7 units) and the conductivity was highest at Kpone ($53.6 \pm 0.3 ms/cm$). While slight fluctuations occurred with pH,

Table 1. Levels of physicochemical factors and major ions in nearshore waters of Accra-Tema coastline

Parameters	Kpone	Sakumono	Accra	Owene
Temp °C	27.2 ± 1.2	27.2 ± 1.3	27.2 ± 1.3	27.1 ± 0.95
SO ₄ g/kg	2.70 ± 0.02	2.54 ± 0.01	2.55 ± 0.01	2.55 ± 0.01
pH	7.74 ± 0.2	7.87 ± 0.12	7.6 ± 0.06	7.56 ± 0.12
HCO ₃ g/kg	0.14 ± 0.001	0.13 ± 0.001	0.132 ± 0.001	0.13 ± 0.001
Cond. mS/cm	53.6 ± 0.30	51.4 ± 0.24	51.5 ± 0.26	51.3 ± 0.26
Cl ⁻ g/kg	19.26 ± 0.11	18.17 ± 0.07	18.17 ± 0.07	18.14 ± 0.09
Mg ²⁺ g/kg	1.29 ± 0.01	1.22 ± 0.05	1.22 ± 0.01	0.21 ± 0.01
Ca ²⁺ g/kg	0.4178 ± 0.002	0.3942 ± 0.001	0.3954 ± 0.002	0.3936 ± 0.002
K ⁺ g/kg	0.3970 ± 0.002	0.3745 ± 0.001	0.3756 ± 0.002	0.3739 ± 0.002
Na ⁺ g/kg	10.725 ± 0.06	10.118 ± 0.04	10.149 ± 0.04	10.102 ± 0.05
DO mg/l	7.7 ± 0.63	7.9 ± 0.6	6.1 ± 0.62	6.98 ± 0.80
Salinity ppt	34.87 ± 0.19	32.85 ± 0.13	32.95 ± 0.14	32.8 ± 0.17

DO, temperature and conductivity, the major elements Ca²⁺, Mg²⁺, and K⁺ appeared to be relatively stable except Cl and Na at Kpone (Fig. 3).

A useful parameter in describing the ionic stability of marine waters is the ionic ratio (Harvey, 1960; Asuquo, 1998). Most ionic ratios of coastal waters have been determined in relation to the chloride component since the salt content has direct bearing with chlorinity

Table 2. Comparison of ionic ratios of Accra-Tema coastline with the reported values from the Atlantic Ocean (Harvey 1960)

Ionic ratios	Open ocean*	Accra-Tema coastline	Classification of ionic character
Na/Cl	0.5549	0.55711	H
Mg/Cl	0.06801	0.06698	L
Ca/Cl	0.02095	0.02181	H
K/Cl	0.02029	0.02061	H
SO ₄ /Cl	0.13950	0.14019	H
PH	7.5 – 8.5	7.56 – 7.87	-

H - High ionic state, L - Low ionic State *Source: Harvey (1960)

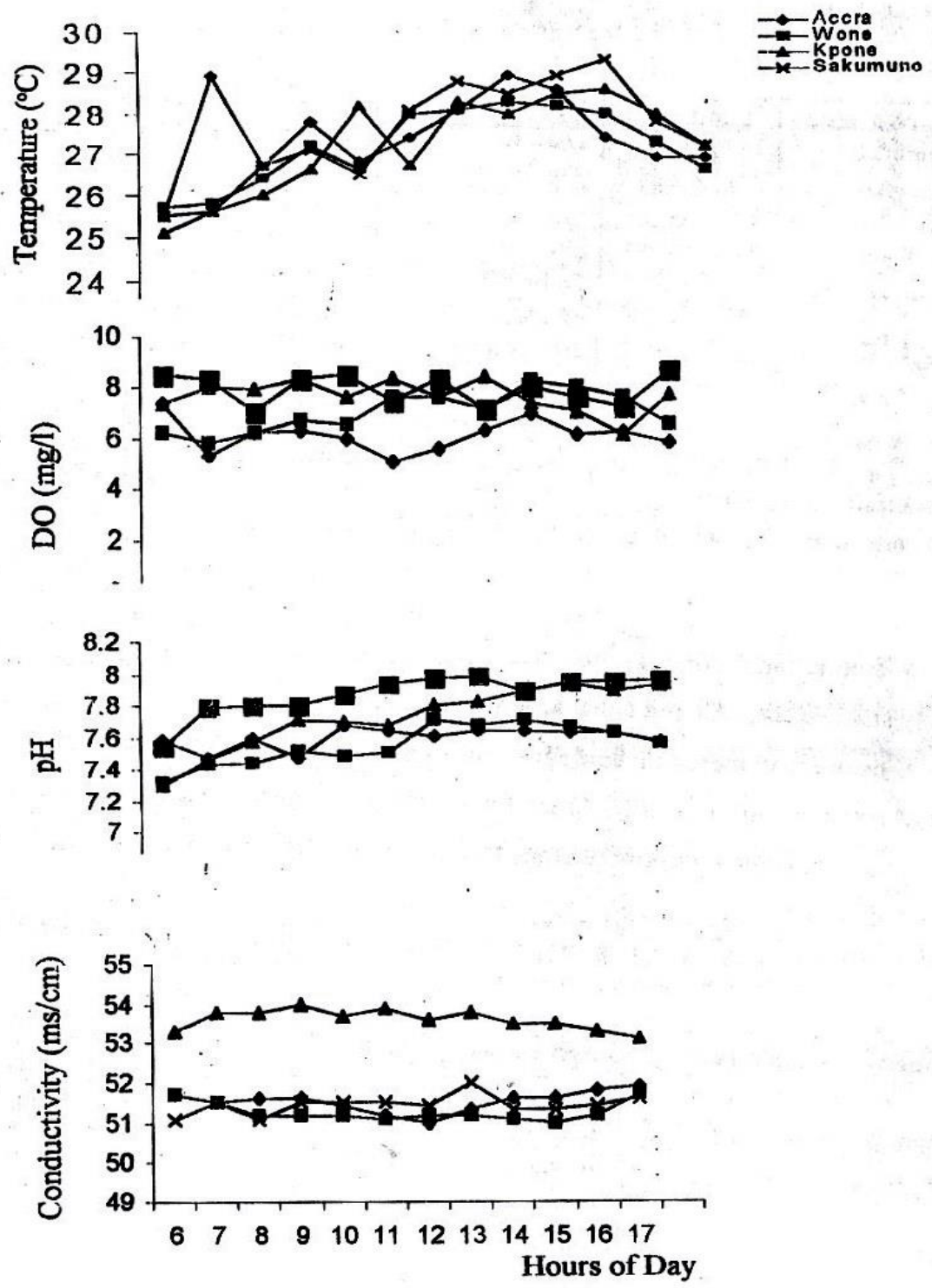


Fig 2 Diurnal variations of physicochemical factors along Accra-tema coastline, Ghana

(Table 2). The use of ionic ratios to assess ionic stability of coastal water is important for two reasons: values obtained from such ratios are fixed and may serve as constants since they are calculated from field data. Secondly, such ionic ratios suggest the degree of stability of the water to external perturbations. The closer the ratio to that of open ocean, the comparable the ionic composition of the coastal water to that of the sea water. Of course, these ratios should remain constant or comparable in the same locality except Ca and Mg ratios which may show slight differences because of their utilization by marine organisms for shell formation.

Characteristic ionic ratios of the coastline were computed and compared with ionic ratios of the Atlantic ocean (Table 2). Except for Mg/Cl ratios, all the other ratios were similar and comparable with the ionic ratios of open ocean. Ionic ratios as a classification tool have been used to distinguish water masses in low salinity waters (Gripenberg, 1937; Miyake & Sakurai, 1952). The low value with respect to Mg/Cl ratio depicts a decrease in the concentration of Mg as salinity increases along the coastline due to the dilution effect of the Volta river.

Table 3. Regression equations and correlation coefficients for the relationship between various parameters along Ghana coastline

Parameters	Regression equation	r ²
Salinity: Mg	$Y_z = 1.62 - 0.013X_z$	0.94**
Salinity: DO	$Y_z = 18.8 - 0.12X_z$	0.92**
Temp. DO	$Y_z = 13.17 - 0.22X_z$	0.10
Temp. Mg	$Y_z = 0.97 - 0.014X_z$	0.85**
Temp. Na	$Y_z = 14.25 + 0.04X_z$	0.85**
SO ₄ : HCO ₃	$Y_z = 0.93 - 0.19X_z$	0.68
SO ₄ : Mg	$Y_z = 1.06 + 0.08X_z$	0.54**
SO ₄ : DO	$Y_z = 15.6 - 2.2X_z$	0.38
pH: Mg	$Y_z = 1.35 - 0.004X_z$	0.17**
pH: Na	$Y_z = 27.31 - 0.49X_z$	0.98**
Ca: K	$Y_z = 1.31 + 0.93X_z$	0.62

** Highly significant correlations (P<0.001)

Linear regression and correlation coefficients between the physiochemical factors along Ghana coastline (Table 3) gave strong and highly significant (P<0.001) relationships. The

regression coefficients refer to the equation $Y_z = a + BX_z$ where Y and X are the physicochemical variables depending on the mode of combination and z represents the zone of interaction (surface water). The observed significant correlations include $r^2 = 0.54, 0.92, 0.85$ and 0.98 for SO_4/Mg , salinity/DO, temperature/Mg, temperature/Na and pH/Na relationships ($n = 48$), Table 3.

DISCUSSION

The spatial variation observed among the parameters were minimal and comparable except conductivity at Kpone due to the contribution from Goa lagoon (Fig. 2). The surface waters of the South Atlantic Ocean have a salinity range fluctuating between 34 – 35‰ (Harvey, 1960). The salinity at the surface is greater in the upper layers due to high rate of evaporation which concentrates the salt at the surface. However, the situation changes with the coastal water which receives high fresh water input from land drainage since the fresh water contains more sulphate than chloride and more Ca than Mg and Na (Harvey, 1960). Along the coastline, the concentration of the ionic species were expected to be high (> 35 ppt) due to additions from Goa lagoon (salt pond with salinity of 37 – 38‰). The relatively low salinity (32 – 34‰) recorded along Accra-Tema coastline is attributed to the influence of discharges from Volta river having an annual yield of 48 tons/km² and a runoff of 91mm/yr (Milliman & Syvitski 1992). Comparatively, the salinity of Ghana coastline is higher than the Nigerian coastline at Ibeno (South-East, Nigeria, 15-20‰) which is also influenced markedly by discharges from adjoining Niger delta, Imo river, Cross river and Qua Iboe river estuaries (Bassey & Asuquo, 1999).

In the nearshore environment, where the ocean water is greatly diluted by discharges from fluvial and land-derived sources, the concentration of ionic species are markedly altered depending on the nature and quality of discharge (Asuquo, 2002). Along the Ghana coastline, the inputs from the salt lagoons (Goa, Korle etc) are high and have greatly contributed to the concentration of species as reflected in the specific ratios of the elements. For instance the higher value of SO_4/Cl (0.14019), than the open ocean (0.1395) and the higher concentrations of Na and Cl at Kpone are indications of marked additions of dissolved elements from the salt ponds to the coastal water. The ionic speciation shows that the higher the ratio, the greater the concentration of species in solution and the more saline the coastline compared to the open ocean.

The strong and highly significant ($P < 0.001$) inter-relationships between chemical variables along the coastline indicate strong dependence of each parameter on the concentration and

distribution of the corresponding parameters. For instance, high temperature could enhance solubility and increase the concentration of Mg and Na ($r^2 = 0.85$) but decrease DO concentration ($r^2 = 0.10$) leading to elevated levels of these ions in the coastal waters (Table 3). The correlations show that SO_4 are pH dependent while only Mg and Na are temperature dependent among others. These relationships could be used to predict variations of the water quality parameters within tidal incursions or during seasonal changes and when there is anthropogenic discharge of dissolved materials or exchange of water masses.

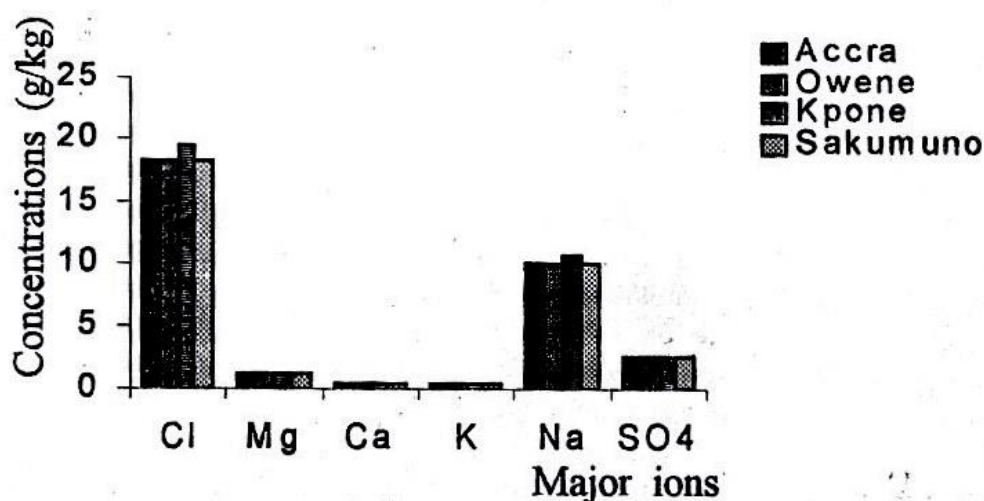


Fig. 3. The Composition of major elements along Accra – Tema Coastline, Ghana

CONCLUSION

The coastal water of Accra-Tema coastline is highly saline (> 32‰) and appears to be the most saline shoreline along the West African coastline being principally influenced by the inland drainage from the coastal lagoons (Goa, Korle lagoons etc). The concentrations of the dissolved chemical species were enhanced as reflected in the marked values of ionic ratios and higher levels of major elements particularly Na and Cl obtained for the coastline. This is similar to the observation that salt water contains more Mg^{2+} , Na^+ and Cl^- than Ca^{2+} and SO_4^{2-} (Harvey, 1960; Rudshi *et al*, 1992) and hence the positive impact observed on the coastal water quality from the salt lagoons.

Fluctuations were observed only during diurnal measurements of DO, temperature, salinity and pH due to the salt water input from lagoon and microbial activities (Fig.2). The high correlations and the inter-ionic ratios are indicators of the strong inter-relationships between the chemical species. Changes in ionic composition could ultimately affect the water chemistry and population dynamics of coastal species in the area.

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