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Water quality assessment of the Densu River: studies on *physicochemical* parameters and nutrients

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ABSTRACT

This present investigation aimed at assessing the water quality of the Densu delta. Data on some ions namely Na^+, HCO_3^-, Cl^-, K^+, SO_4^{2-}, NO_3^--N and PO_4^{3-}-P were measured. The pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen, biochemical oxygen demand were also determined to assess the chemical status and pollution levels of the river. The ranges for BOD (3.40-4. 21), Na^+ (104-29800), Cl^-(67.98-19194), K^+ (16.90-4630),PO_4-P(0.0063-0.032), NO_3-N(0.19 - 0.60) and SO_4^{2-}(224.67-23700) were found to be higher than the natural background levels for surface water. This indicates pollution of the river water samples from the areas studied. Our findings highlighted the deterioration of water quality of the river due to anthropogenic activities.

Introduction

The effect of poor water quality on human health was noted for the first time in 1854 by John Snow, when he traced the outbreak of cholera epidermic in London to the Thames River water which was grossly polluted with raw sewage. Since then, the science of water quality has progressed. In third world countries, 80% of all diseases are directly related to poor drinking water quality and insanitary conditions (Sharma et al., 1995).

Only 0.76 % of water on the Earth is fresh and available for use. Finite supplies are under stress due to increasing agricultural, industrial and domestic demands. Due to these anthropogenic activities, water quality monitoring has become an essential tool used by environmental agencies to gauge the quality of surface water and to make management decisions for improving or/and protecting the intended uses. Environmental pollution issues adversely affecting water quality arise from the improper management and control of domestic, municipal, agricultural and industrial wastes which find their way into such water bodies, as well as from erosion in river catchments as a result of clearing for farming, timber, and extraction of firewood, among others (WRC, 2000). One of the major sources of pollutants to this portion of the Densu basin is the Leachate flow from a Landfill site at Oblogo, a town within the catchment of the Densu delta where sampling was carried out. The ever-increasing demands that the society places on the ecosystem of the Densu River basin, coupled with the need to generate useful and convincing information in the design of socially optimal decisions for public intervention, gives good reason for this study. The overall aim of the study was to determine the status of the Densu river water quality. The specific objectives of the study were however to study the physico-chemical and nutrient characteristics of the Densu River and to propose recommendations for the efficient management of the river ecosystem.

Methodology

Study area

The Densu River system is one of the coastal drainage basins of Ghana. The river lies between latitudes 5°30'N to 6°20'N and longitudes 0°10'W to 0°35'W. The basin area is about 2488.41km2 with an average length of 225.6km (Fig.1.0). Its floodplain and river channel have been dramatically altered by building and construction, installation of a dam, salt mining, grazing, channel incision and other fluvial processes.

The Densu basin has Rivers Adeiso, Nsakyi, Dobro, and Kuia. It enters the Weija reservoir, one of the two main sources of water supply for the city of Accra The Weija reservoir discharges into Sakumo II lagoon which, subsequently, drains into the Gulf of Guinea near Bortianor to the west of Accra (Kusimi, 2008).

Fig 1: A map of the study area describing the sampling area

Excess flow from the Weija reservoir discharges into the Densu delta (Sakumo) lagoon and salt pans complex, which constitutes one of Ghana's internationally recognised protected

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areas (Abrahams and Ampomah, 2007). The Densu delta with the Sakumo II lagoon and its associated estuary is among the nation's many wetland ecosystems spread along the coast. Major socio-economic activities within the wetland are the large-scale commercial salt operation and small scale lagoon fishing, mainly for tilapia and crabs and subsistence agriculture especially in the dry season is also a common activity within the wetland.

Sample collection and Treatment

Five sampling stations within the Densu delta catchment were selected for this work. These were Oblogo (OB), Tettegu (TG), Aplaku (AK), Faana (FN) and Bortianor(BT). The sampling points are indicated on Fig 1. Surface water samples were taken from the river (i.e. top 50 cm) into a pre-labelled (with sampling location and dates) 500mL screw capped plastic container that had been pre-rinsed and acid leached. Sampling was done between December, 2009 and February, 2010. Sampling bottles were rinsed three times with portions of the river water before the water samples were collected. The water samples, after collection, were stored in a cooler at 4^oC and transported to the laboratory. Temperature (T), conductivity(C), dissolved oxygen (DO) salinity, Total Dissolved Solids (TDS) and pH of the samples were measured in situ. All the analyses were done by standard methods according to APHA, AWWA (1992). In the laboratory the following chemical parameters were measured; nitrate, phosphate, sulphate, alkalinity, chloride, Sodium, Potassium, biochemical oxygen demand and total dissolved solids. The methods used for these measurements are indicated in table 1.

Analytical precision

The reproducibility of the analytical procedures was ascertained by carrying out a duplicate analysis. Duplicate results did not differ by more than 5% of the mean. Replicability of sampling was also determined by collection of multiple samples at each of the five sampling stations. The overall variability ranged from 2.53% relative standard deviation (r.s.d) for temperature to 15.9% r.s.d. for phosphate ion concentration with the average sampling variability being 10.1%.

Results And Discussions

Physical and chemical parameters

A summary of the results obtained for the analyses of physical and chemical parameters of surface water samples taken in this work is presented in Table 2.0. The codes OB1, OB2, TG, AK, FN and BT represent Oblogo1 (a point before leachate enters river), Oblogo2 (a point after leachate enters river), Tettegu, Aplaku, Faana and Bortianor respectively. The Table also includes, in instances where available, WHO standard values of the parameters measured in natural surface water.

pH

The Densu River largely exhibited slightly alkaline pH of natural waters in the range of 7.36 to 7.89 with an average value of 7.57. The lowest and highest pH values were observed at Tetegu and Bortianor respectively (Table 4.1). The pH values were within the "no effect" range of 6.0–9.0 for drinking water use (WRC, 2003) and the WHO range for drinking and potable water of 6.5 to 8.5 (WHO, 2003). Though the selection of raw water as a drinking water source is never based solely on pH, these results show that no significant adverse health effects, due to toxicity of dissolved metal ions and protonated species were expected. In addition no aesthetic effects (e.g. taste), were also expected. It was however slightly above the natural background level of 7.0. This increase in pH of the water samples above the normal background levels may be due to the presence of dissolved carbonates and bicarbonates present in the water, which are known to affect pH of almost all surface water (Chapman, 1992).

Electrical conductivity (EC)

The electrical conductivity is a valuable indicator of the mineralization in a water sample (Jain et al. 2005). The conductivity values ranged from a minimum of 509.67µS/cm to a maximum of 53500µS/cm with a mean value of 19961.56µS/cm. The WHO limit for EC for drinking and potable water is 700 µS/cm (WHO, 2003). It can be observed from table 2.0 that from Oblogo1 to Aplaku the conductivity increased gradually, however there was an astronomical rise from 12453µS/cm at Aplaku to a value of 52000µS/cm and 53500µS/cm at Faana and Bortianor respectively. This trend is largely due to the inflow of sea water into the river at Faana and Botianor which are in close proximity to the estuary. The contribution of total dissolved solids to the electrical conductivity values can also not be neglected. The EC values for the river at TG, AK, FN and BT were greater than the WHO limit of 700 µS/cm. This suggests its unsuitability for domestic use. Health effects in humans for ingesting water with high EC may include disturbances of salt and water balance; and adverse effect on certain myocardic patients and individuals with high blood pressure (Fatoki and Awofolu, 2003).

Total dissolved solids (TDS)

Total dissolved solids (TDS) indicate the general nature of water quality or salinity. The background TDS value is 1000 mg/L in surface water. Though the observed concentration at Oblogo 1, Oblogo 2 and Tetegu were below the background value, at Aplaku, Faana and Bortianor however, the TDS values were above the background value indicating surface water pollution. The introduction of anthropogenic substances such as agrochemicals, fertilizers, municipal sewage, leachate and solid waste into surface water is likely to contribute to an increase in TDS. This is so, because these pollutants contain organic matter and inorganic salts. Pollution by human activities may not be the major reason for the elevated levels encountered but rather the influence of seawater intrusion on the river in the wetland.

Since conductivity and TDS are all influenced by ionic content of the water, these two parameters tend to follow the same trend when measured. The results obtained in this study confirmed this, as shown on Fig.2.0. The fluctuations in electrical conductivity correlated positively with the total dissolved solids (TDS) concentration.

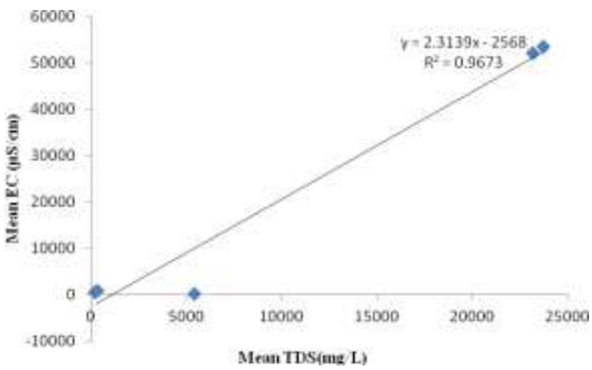

Figure 2.0: Correlation plot of mean EC against mean TDS across all sampling locations.

Bicarbonate concentration (HCO_3-) and Alkalinity

From table 2.0, the HCO_3- in the water ranged from 137.35 mg/L (at Bortianor) to 199.94 mg/L(at Tettegu). The HCO_3- content remained fairly constant within the range of 197.91

mg/L and 199.94 mg/L at the first three sampling locations (table 2.0). It however, declined drastically at Aplaku with about 45 units from 199.94 mg/L at Tetegu to 152.80 mg/L. The decline continued further from Faana (138.98) to Bortianor (137.35 mg/L).

Alkalinity of the sampling locations varied between 112.66 mg/L and 164.00 mg/L (Table 2.0). The highest alkalinity (i.e.163.00) was recorded at Oblogo1. From Oblogo1 to Tetegu the alkalinity was fairly constant within a narrow range of 162.33 mg/L - 164.00 mg/L; however a sharp decrease was observed from 164.00 to 125.33 at Aplaku and continued to decrease to a value of 112.66 mg/L at Bortianor. The seemingly identical pattern of decline in both bicarbonate content and alkalinity could be attributed to the fact that alkalinity of water is directly linked to the bicarbonate concentration (APHA, 1998). The existence of this direct relationship was confirmed by the very strong correlation (R^2 = 1) between the bicarbonate and alkalinity values measured in this work (Fig. 3.0).

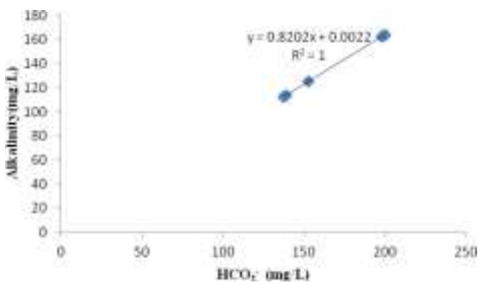

Figure 4.2: Correlation plot of alkalinity and bicarbonate concentration across all sampling locations.

Ionic dominance pattern

The Densu delta at TG, AK, FN and BT exhibited an overall ionic dominance pattern of $Na^+ > HCO_3^- > Cl^- > K^+ > SO_4^{2-} > NO_3^- > PO_4$-P, $Cl^- > Na^+ > K^+ > SO_4^{2-} > HCO_3^- > NO_3^-$-N $> PO_4^{3-}$-P , $Na^+ > Cl^- > K^+ > SO_4^{2-} > HCO_3^- > NO_3^-$-N $> PO_4^{3-}$-P, $NO_3^- > PO_4^{3-}$-P and $Na^+ > Cl^- > K^+ > SO_4^{2-} > HCO_3^- > NO_3^-$-N $> PO_4^{3-}$-P respectively. The ionic dominance of the Densu basin was in contrast with the ionic dominance pattern of Ca > Mg > Na > K and $HCO_3 > SO_4 >$ Cl for fresh water and Na > Mg > Ca > K and Cl > $SO_4 > HCO_3$ for sea water (Burton & Liss, 1976). The observed dominance of chloride over sulphate could be due to the large amount of domestic wastes being discharged into the delta and its tributaries Studies conducted by Biney in 1990 on characteristics of fresh water and coastal ecosystems in Ghana confirmed this observation.

Sodium (Na+) and Potassium (K+)

Sodium recorded the highest concentration of 29800 mg/L at Bortianor while the lowest concentration of 104.0 mg/L was measured at Oblogo2 (Table. 2.0). The concentration of sodium at 106.6 mg/L and 104.0 mg/L measured at Oblogo1 and Oblogo2 respectively were all within the natural background level of 200 mg/L. Extremely high values were however recorded at Aplaku, Faana and Bortianor. A similar trend of excessive rise in concentration was also observed for K+ in water samples from locations close to the estuary. This high concentration of K+ and Na+ ion pattern can be largely attributed to the influence of seawater on the river at the sampling locations in question rather than the effects of pollution by anthropogenic activities, though activities such as farming, livestock rearing, discharge of sewage and dumping of refuse along the banks of the river occurs in the wetland.

A look at Fig 4.0 also confirms this assertion and further lays credence to the fact that the sodium and potassium ions originate from a common source (the sea) as can be seen from the very strong positive correlation displayed.

Chloride (Cl-) and Sulphate ($SO4^2$-) concentrations

Chloride concentrations were in the range of 67.98 mg/L and 19194.05 mg/L (Table 2.0). The lowest value of 67.98 was measured at Oblogo2 (after leachate entry) and the highest value of 19194.05 mg/L occurred at Bortianor. Three of the sampling locations (i.e. Oblogo1, Oblogo2 and Tetegu) which are remote from the estuary had chloride concentrations which were well below the natural background level value of 250 mg/L, while Aplaku, Faana and Bortianor registered very high values which were several folds higher than the natural background level.

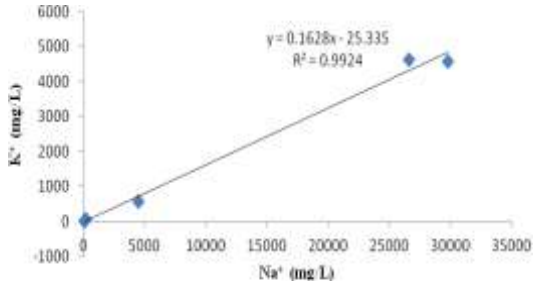

Figure 4.3: Correlation plot of potassium and sodium concentration across all sampling locations.

The concentrations of sulphate measured varied from 13.00 mg/L to 423.36 mg/L (Table 2.0). The pattern of increase in the sulphate values across all the sampling locations was similar to the pattern observed for the chloride concentrations. The margin of increase of the sulphate at Aplaku, Faana and Bortianor above the natural background level of 200 mg/L was however not as high as that observed for the chloride. The rise in concentration of both the chloride and sulphate ions at the sampling locations close to the estuary can be attributed to intrusion of seawater into the river and sea spray in the atmosphere. The release of the chloride ions is bound to increase the chloride concentration of the river thereby making it brackish in nature.

Apart from the natural sources of entry of sulphate into water such as decomposition of organic matter, the use of sulphate fertilizer on farms along the banks of water bodies, seawater and sea spray is also another major source of sulphate in surface water. This is because seawater is typically known to contain about 2700 mg of sulphate per litre (Hitchcock, 1975). The assertion that the chloride and sulphate ions in the water share a common source which is the sea, is further strengthened by the strong positive correlation that exists between the two anions (Fig. 5.0)

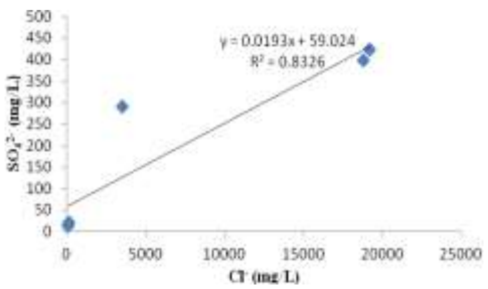

Figure 5.0: Correlation plot of sulphate and chloride ion concentrations across all sampling locations.

Nutrient Concentration

NITRATE (NO_3- -N)

The concentrations of nitrate determined at the various sampling points ranged from 0.28 mg/L to 0.60 mg/L (Table 2.0). The highest nitrate concentration of 0.60 mg/L was registered at Faana followed by Oblogo 2 where the level detected was 0.35mg/L. Though the concentrations of nitrate at all the sampling locations are well below the natural background level of 10 mg/L, the extent of rise in concentration is due to the landfill site at Oblogo. Oblogo 2 site is located about 100 meters downstream from the point where leachate from the Oblogo landfill site flows into the Densu River. Though Faana (a small island community in the wetland) is quite removed from the landfill site, the surrounding water was heavily polluted with solid waste and domestic sewage introduced by the inhabitants due to the absence of a proper refuse dump site. The high level of nitrate also observed at Oblogo 2 and Faana may also be attributed to the discharge of solid waste and domestic sewage (WHO, 1985; Egboka, 1984).

Phosphate (PO_4^{3-}-P)

Phosphate concentration in the water ranged from 0.0063 mg/L to 0.0324 mg/L (Table 2.0) with a mean value of 0.019 mg/L. All the values measured were well within the natural background level range of 0 - 0.3 mg/L. The highest phosphate concentration of 0.0324 mg/L was measured at Tetegu. This high concentration could be due to the presence of settlements which are very close to the river bank. Dumping of refuse and discharge of domestic sewage into the river was observed during the sampling campaign. Phosphate ions like nitrate ions are introduced into surface water via decaying organic matter, agricultural fertilizers, manure, domestic sewage and landfill leachate. However it cannot be concluded that nitrate and phosphate at the various sampling points originated from the same source since the correlation between the two nutrients is not strong (Fig.6.0).

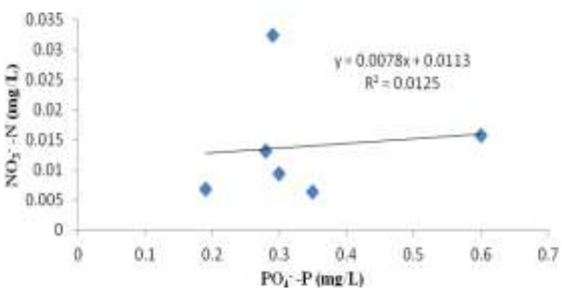

Figure 6.0: Correlation plot of nitrate and phosphate concentrations across all sampling locations.

Biochemical Oxygen Demand (BOD)

The biochemical oxygen demand for the Densu River ranged from a minimum value of 3.66 mg/L to a maximum value of 4.21 mg/L (Table 2.0). All the BOD values recorded at the various sampling sites exceeded the natural background level of 3.00 mg/L. This indicates high organic matter pollution along the Densu delta in the wetland where sampling was done.

The highest values of 4.00 mg/L and 4.21 mg/L were recorded at Oblogo2 and Tetegu (Table 2.0).

In table 3.0, the result of this work was compared to previous works done in Ghana "(Osei *et al.,* 2010 and Denutsui *et al.,* 2011)" and "(Abida *et al.,* 2009)" respectively. From the mean pH obtained for the water samples in this work (i.e. 7.63), the water samples were observed to be slightly basic. This agreed well with previous work done by Osei *et al.,* 2010., Denutsui *et al.,* 2011 and Abida *et al.,* 2009 whose water samples were also found to be slightly basic (table 3.0). Apart from the electrical conductivity (EC), the values obtained for K, Cl, SO_4, HCO_3 and NO_3- -N in this work were greater than that recorded in Osei *et al.*, 2010. This indicates that mineralization in the water of the present study was less compared to that of Juliet et al. However the values obtained for Na, K, Cl, SO_4 and HCO_3 in this work were observed to be lower than that from the Cauvery River. The mean level of SO_4 (218.18) and that of Cl- (9631.02) in this work indicates a rise in the levels of SO_4 and Cl over the years when compared to that obtained from Dzifa et al, 2011. This is an indication of more seawater intrusion into the Densu River.

Conclusion:

Physico-chemical parameters of surface water from the Densu River in the Densu Delta wetland were measured. From the results obtained, the Densu River water was slightly alkaline. The EC values suggested the unsuitability of the Densu River for domestic use. Dominance of chloride among the ions measured was observed from the ionic balance studies. Though Na+ recorded concentrations within the natural background values, higher values were observed at Aplaku, Faana and Bortianor. The levels recorded for nitrates and phosphates were below the natural background values. The Densu River can however be considered to be polluted with high organic matter since the BOD values recorded were above the upper limit of the natural background levels. The Densu River can be said to be largely of good quality to support aquatic life but should not to be used for drinking purposes.

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Table 1.0: Physico-chemical parameters determined in the laborator

Parameters	Analytical Method Used
Alkalinity (mg/L)	Titration method
Biochemical Oxygen Demand (mg/L)	5-day BOD test
Chloride (mg/L)	Argentometric method
Sodium(N^+) and Potassium (K^+)	Flame photometer
Nitrate (mg/L)	U.V spectrophotometric screening method
Phosphate (mg/L)	Ascorbic Acid method
Sulphate (mg/L)	Turbidimetric method

Table 2.0 Mean values for physico-chemical parameters of surface water measured at various sampling sites

PARAMETERS	Sampling sites						NATURAL BACKGROUND LEVELS
	OB1	OB2	TG	AK	FN	BT	
Temp (ºC)	26.2	26.2	25.7	25.6	25.2	25.0	22-29
pH	7.41	7.40	7.36	7.60	7.74	7.89	7.00
EC (µS/cm)	509.67	514.33	792.33	12453	52000	53500	700
Salinity (ppt)	0.20	0.20	0.40	6.83	33.77	34.57	
TDS (mg/L)	224.67	226.67	350.33	5423	23166	23700	1000
Alkalinity(mg/L)	163.00	162.33	164.00	125.33	114.00	112.66	400
Na^+ (mg/L)	106.6	104.0	260	4546	26600	29800	200
K^+ (mg/L)	16.9	19.0	53.3	570	4630	4560	30
Cl^- (mg/L)	71.31	67.98	150.62	3515.58	18794.17	19194.05	250
$HCO3^-$ (mg/L)	198.72	197.91	199.94	152.80	138.98	137.35	
PO_4^- -P (mg/L)	0.0068	0.0063	0.0324	0.0094	0.0157	0.0131	<0.3
NO_3^- -N (mg/L)	0.19	0.35	0.29	0.30	0.60	0.28	10
SO_4^{2-} (mg/L)	15.73	13.00	20.66	289.77	397.46	423.36	200

Table 3.0. Results of this work compared to that obtained in other research works.

	pH	EC	SO_4	Na	K	Cl	PO_4^--P	BOD	HCO_3	NO_3^--N
This work	7.36-7.89	509.67-53500	224.67-23700	104-29800	16.90-4630	67.98-19194	0.0063-0.032	3.40-4.21	137.35-199.94	0.19-0.60
Densu basin 2010	6.2-9.5	235-60000	0.28-45.8	51.7-6670	1.3-1340	53.18-2428	0.009-0.63	0.25-63.33	31.2-67.2	0.0009-0.44
Cauvery River	6.5-8.9	3.2-45.4	207.66-55036.43	59.60-6023.80	72.50-21926.4	153.7-50586.33			345.89-11247.45	
Densu basin 2011	6.4-8.1	150-3412	5.98-157.5	37.2-5719	0.80-390.0	212-8600	0.005-1.30	0.10-7.01	34.8-329.4	0.09-71