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Seasonal Variation in Water Quality During Dredging of Brackish Water Habitat in the Niger Delta, Nigeria

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ABSTRACT
Seasonal variation in water quality during dredging process in typical brackish water from the Bonny River (Rumuolumeni axis) located around Eagle Island was analysed. This was done in different seasons using January/November as dry season and July/September as wet season. The following physico-chemical parameters were studied; temperature, pH, conductivity, Total Dissolved Solids (TDS), sulphate, phosphate, nitrate, alkalinity, chloride, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), fecal coliform count, Total hardness, Ammonia, Iron II and Turbidity. Standard methods of measurement and analysis were employed. Some graphical techniques and tabulations were also used to explain variations. The brackish water had significant temporal variations (monthly) recorded for sulphate, Total Hardness, Iron II, phosphate, nitrate and chloride, but spatial variation (up/down stream flow) affected fecal coliform count, sulphate, BODs, Total Hardness, Chloride, alkalinity and turbidity concentrations. Temporal and spatial seasonal variation during dredging affects some physico-chemical parameters.

Key words: Brackish water, habitat, Niger delta, seasonal variation, dry and wet, temporal and spatial variation

INTRODUCTION
Dredging operations entail the removal of bed materials and associated vegetation from a river channel. According to Jones (1986), it is an underwater excavation to re-establish a channel as to improve navigation or for commercial activities. The dredged materials may be deposited in uniform layers over wet land vegetation or open bay bottom (Turner and Streever, 2002). In Nigeria, manual dredging by natives has been in operation since early part of the 19th century. This according to Aroh (2000) was to get sharp sand (for construction purposes) and prevent sinking of boats.

Dredging of brackish water habitat is not an uncommon activity but empirical evidences to show how the physico-chemical parameters vary from one dredging site to another remains a lacuna and great challenge. Similarly, the need to understand the differences in ranges of these physico-chemical parameters of brackish water habitat is of great concern. The need to also comprehend the essential parameters and their limits for academic and practical references cannot be over-emphasized.

Dredging at the Rumuolumeni axis of the Bonny River is for both reclamation and construction purposes. Physical impacts of dredging are quite numerous (IMG-Golder, 2004). Anaerobic layers of sediments are exposed by dredging which potentially disturbs and remobilizes toxic sediments and hence releasing contaminants (Nayar *et al.*, 2004).

The brackish water habitat chosen for the study is the River between Aka Village in Rumuolumeni and the Eagle Island all in Obio-Akpo Local Government Area of Rivers State (Niger Delta) in Nigeria. It is located between longitudes 7°05' and 7°20' E and Latitudes 4°10' and 4°40' N (Chindah and Braide, 2004). It is about 1 km to the confluence of the Bonny and Rumuolumeni Rivers. This area is under severe dredging for land reclamation by Master Energy Oil and Gas Company Limited hence removing a lot of Mangrove forest. The Rumuolumeni River, a tributary of Bonny River is a brackish water habitat bothering the upper reach of the Bonny and New Calabar Rivers which interferes with municipal development. The Bonny River has a maximum width of 2km and maximum depth of 15 meters and has the largest tidal volume compared to other Niger Delta Rivers (NEDECO, 1961). This zone is a semi hot equatorial climate with a mean annual rainfall of 2,405 mm (Gobo, 1988). The transition zone of the Niger Delta according to Fubara *et al.* (1988) coincides with the mangrove brackish water zone with its numerous inter-tidal flats and mangrove vegetation (IGST, 2000) to which the study location belongs. Towns around this Bonny River and transition zone are Bakana, Buguma and Abonnema all in Rivers State of Nigeria.

RESEARCH METHODOLOGY

Sampling locations: Six sample stations were chosen for this work. The stations were chosen based on a systematic sampling design. The six stations were labeled A, B, C, D, E and F. These were measured relative to the dredger position. The sample stations and distance interval is shown in Table 1 below.

Stations D and E are considered as the control stations since dredging effect goes downstream due to the flow regime (unidirectional). Sample collection from the six stations was done using DO bottles, BOD bottles and 1-litre plastic containers for measurement of the other water quality parameters. The water samples were collected at a depth of about 5-10 cm below surface level. The sample collection bottles were rinsed with the water samples to be collected 2-3 times before actual sample collection to prevent contaminants. The samples were fixed using the Winkler I and II solutions for DO while others were fixed and also preserved on site. The BOD samples were stored in a cooler of ice packs. These were all taken to the laboratory for analysis except those involving *In situ* measurements like temperature, pH and conductivity.

Sample preparation and analysis: The pH was measured using 691 pH meter type 169, 100 *In situ*. Conductivity was also done using the conductivity meter, model 5013/000/3768. Total

Table 1: Sampling site description

Sample station (M)	Site description
A	100 m downstream
B	200 m downstream
C	0 m (dredger position)
D	100 m (upstream)
E	200 m (upstream)
F	Dredge water from suction pump

Dissolved solid measurement was achieved using the TDS meter (JENWAY Brand). The modified oxygen depletion method (MOD) also called Winkler method was used for DO and BOD5. Total hardness, Iron II, Chloride, Ammonia and Alkalinity employed the use of titrimetry. Similarly phosphate and turbidity were analysed by the spectrophotometric method suitable at 880 nm. Nitrate involved the use of Brucine method (involving spectrophotometry of spectronic 20 (8 and L at 420 nm). Sulphate concentration was measured using the visual turbidometry. The standard most probable number (MPN) method was used to analyse the concentration of fecal coliform count in the various samples. TDS was measured using the TDS meter, while Turbidity was the spectrophotometer of UV160A, Cat No. 204-04550-1 and UV-visible recording spectrophotometer.

RESULTS AND DISCUSSION

The results of the physico-chemical parameters during dredging of the brackish water of Bonny River are given in Table 2 and 3.

Similarly, seasonal variations in percentages are shown in Table 4 and brackish water status before and during dredging are in Table 5.

From the results in Table 4 and 5, Temperature variation indicates very small change. Hence dredging effect on temperature is quite negligible and was within the DPR (1991) and FEPA (2001) set limits. Similarly, pH, TDS, conductivity, BOD5, Alkalinity, NH_3 and turbidity were not affected seriously by temporal variation during the dredging process. This may be due to some other reasons not due to the dredging. Though, the above parameters were within the DPR (1991) and FEPA (2001) set limits, ammonia was above this limit (DPR = 5). This may be due to anthropogenic activities from surface run-off and agricultural activities but not due to the dredging (Nightingale and Simenstad, 2001). The relatively low BOD level observed seasonally is an indication of low pollution potential due to lack of major effluents and waste into the water.

Though the wet season had relatively higher coliform count than the dry season, both had temporal variations that exceeded recommended standard limits of <10P MN 100 mL^{-1} (December

Table 2: Summary results for mean brackish water measurements for dry season

Parameters	A	B	C	D	E	F	Standard limits
pH (units)	6.86	6.84	6.81	6.74	6.84	6.77	7-8.5 (FEPA, 1991)
Sulphate (mg L^{-1})	6.43	5.52	6.21	4.87	5.47	5.18	500 (FEPA, 1991; WHO, 1993)
TDS (mg L^{-1})	666.7	666.7	666.7	666.7	666.7	666.7	500 (FEPA, 1991)
Conductivity (µS cm^{-1})	1000	1000	1000	1000	1000	1000	10, 000 (DPR, 1991; FEPA, 2001)
DO (mg L^{-1})	11.20	11.41	10.82	11.56	10.81	10.48	10 (FEPA, 1991) 7.5 (WHO, 1993)
BOD_5 (mg L^{-1})	6.82	7.01	6.60	5.74	6.52	6.58	10 (DPR, 1991; FEPA, 2001)
Chloride (mg L^{-1})	284	170	227	256	227	185	200 (FEPA, 1991)
Alkalinity (mg L^{-1})	1.23	13.5	13.2	1.23	24.22	22.86	200 (FEPA, 1991)
Total hardness (mg L^{-1})	27.43	28.15	26.50	29.35	0.340	0.340	1000 (FEPA, 1991)
Iron II (mg L^{-1})	0.112	0.112	0.340	0.223	3.60	2.32	0-0.3 (FEPA, 1991)
Phosphate (mg L^{-1})	3.46	3.70	3.94	3.81	0.0014	0.0015	0-0.5 (WHO, 1993; FEPA, 1991)
Nitrate (mg L^{-1})	0.002	0.0033	0.003	0.0017	1.96	2.07	0-0.5 (FEPA, 1991)
Ammonia (mg L^{-1})	2.72	2.48	2.13	2.35	3.49	4.53	10 (WHO, 1993; FEPA, 2001)
Turbidity (NTU)	2.51	2.74	3.81	3.63	26.08	25.00	5 (FEPA, 1991)
Temperature (°C)	25.25	25.43	25.05	25.43	10.80	25.00	24-28 (FEPA, 1991) 35 (DPR, 1991; FEPA, 2001)
Fecal coliform (MPN)	10.8	15.05	11.85	10.07	10.80	5.50	<10 (FEPA, 1991)

Table 3: Summary result of the mean Brackish water measurement for wet season

Parameters	A	B	C	D	E	F
pH (units)	6.92	6.96	6.94	8.86*	6.95	6.87
Sulphate (mg L^{-1})	3.56	4.74	4.82	4.97	3.86	4.66
TDS (mg L^{-1})	666.7	666.7	666.7	666.7	666.7	666.7
Conductivity (μS cm^{-1})	1000	1000	1000	1000	1000	1000
DO (mg L^{-1})	10.77	12.08	9.89	12.06	11.58	11.64
BOD_5 (mg L^{-1})	4.47	7.50	3.69*	7.11	6.57	5.88
Chloride (mg L^{-1})	369	398	348	355	347	391
Alkalinity (mg L^{-1})	8.1	10.2	5.4	8.4	10.8	30.6*
Total hardness (mg L^{-1})	50.30	48.12	70*.56	47.32	50.53	44.11
Iron II (mg L^{-1})	0.34*	0.11	0.11	0.11	0.11	0.11
Phosphate (mg L^{-1})	1.69*	1.47	1.33*	1.51	1.49	1.33*
Nitrate (mg L^{-1})	0.009	0.003	0.004	0.002	0.02*	0.001
Ammonia (mg L^{-1})	2.09	2.68*	1.64*	2.40	2.44	2.05
Turbidity (NTU)	2.20	1.83*	3.48	3.78	3.29	4.40*
Temperature (°C)	25.25	25.43	25.05	25.43	26.08*	25.00
Fecal coliform (MPN)	4.75*	9.80	15.15*	9.80	8.85	8.50

Table 4: Seasonal rivers variation during dredging

Parameters	Dry	Wet	Variation (%)
Temperature (°C)	25.45	25.29	0.63
Chloride (mg L^{-1})	10.68	9.48	11.24
pH (units)	6.81	6.92	1.59
Sulphate (mg L^{-1})	5.62	4.44	21.00
T.D.S (mg L^{-1})	666.70	666.70	-
Conductivity (μS cm^{-1})	1000.00	1000.00	-
DO (mg L^{-1})	19.52	11.34	41.91
BOD_5 (mg L^{-1})	6.55	5.87	10.38
Chloride (mg L^{-1})	25.00	370.00	39.19
Alkalinity (mg L^{-1})	5.25	12.25	571.00
Total hardness (mg L^{-1})	26.57	51.83	48.74
Iron II (mg L^{-1})	0.26	0.15	42.91
Phosphate (mg L^{-1})	3.43	1.47	57.14
Ammonia (mg L^{-1})	2.29	2.22	30.06
Turbidity (NTU)	3.11	2.16	30.55
Nitrate (mg L^{-1})	0.0022	0.0066	66.67

and June). The use of River as toilet may have contributed rather than dredging especially around the suction point (station C) as supported by Lohrer and Wertz (2003) in a similar work. Sulphate had significant variation within the dry season (higher) which may be due to high anaerobic oxidative processes in the water during the dredging (Leonov and Chicherina, 2008). There were both temporal and spatial variation in sulphate concentration may be due to the mixing property of dredging around anthropogenic wastes as agreed by the work of Seyfried *et al.* (1997) in similar research. Total Hardness had a high temporal variation of about 43.53% which showed that during the dredging certain materials which can increase the hardness may have been excavated as corroborated by Dallas and Day (1993) in a similar environment. Though thevatiation id Fe^{2+} concentration was relatively higher during the dry season before dredging, it became lower after dredging. This may be due to dilution effect of the rains but dredging did not significantly affect the Fe^{2+} concentration as supported by Dallas and Day (1993) earlier. The concentration of

Table 5: Status of brackish water before and during dredging in both seasons

	AB before dredging		DE during dredging		Variation (%)			
Parameter	Drt	Wet	Dry	Wet	Before dreging (dry)	During dreging (wet)	Seasonal variation (%)	Temporal variation
Temperature (°C)	25.78	25.73	25.50	25.18	1.09	2.14	1.05	1.25
pH (units)	6.79	6.90	6.85	6.94	0.88	0.58	0.30	43.70
Coliform (MPN)	10.44	9.33	12.93	7.28	19.26	21.97	2.71	1.30
Sulphate (mg L^{-1})	5.17	4.42	5.98	4.15	13.55	6.11	7.44	30.60
TDS (mg L^{-1})	667	667	667	667	Constant	Constant	Constant	-
Conductivity (μS cm^{-1})	1000	1000	1000	1000	Constant	Constant	Constant	-
DO (mg L^{-1})	11.19	11.82	11.31	11.43	1.06	3.30	2.24	1.05
BOD_5 (mg L^{-1})	6.13	6.84	6.92	5.99	11.42	12.43	1.01	13.44
Alkalinity (mg L^{-1})	1.22	6.90	7.37	9.15	83.45	24.59	58.86	40.73
Total hardness (mg L^{-1})	26.79	48.93	27.79	49.21	3.60	0.57	3.03	19.45
Iron II (mg L^{-1})	0.28	0.11	0.0027	0.0061	40.74	44.55	3.81	55.74
Phosphate (mg L^{-1})	3.71	1.50	3.58	1.58	3.50	5.06	1.56	55.44
Nitrate (mg L^{-1})	0.0061	0.011	0.0027	0.0061	40.74	44.55	3.81	55.74
Ammonia (mg L^{-1})	2.16	2.42	2.60	.39	16.92	1.24	15.68	0.08
Turbidity (NTU)	2.63	2.02	3.56	4.04	35.56	99.00	5.55	11.88
Chloride (mg L^{-1})	241	351	227	383	5.81	8.36	2.55	40.73

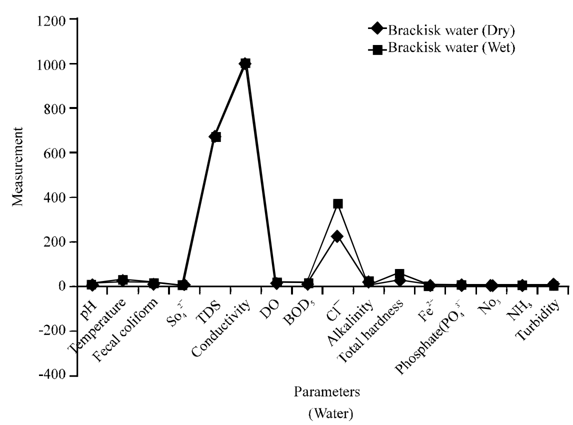

Fig. 1: Seasonal variation of physico-chemical parameter during dredging

phosphate showed that they were above the DPR (1991) and FEPA (2001) recommended limits of 0.5 mg L^{-1} hence potentials of eutrophication. This is a sequential decrease in available phosphate with distance suggesting the reception of inputs from cultural activities (Gambrell *et al.*, 1983). There was no spatial variation rather only temporal variation but not due to dredging. The relatively higher level of nitrate in June at station A may be due to anthropogenic activities which might have contributed certain human and natural wastes to water (HRWQ, 2010). This agrees favourably with the works of Manila and Tamuno-Adoki (2007), Emoyan *et al.* (2006) and Okoye and Chukwuneke (2008) on a similar recent publication. The nitrate concentration was below the recommended standard limit (DPR, 1991; FEPA, 2001). Turbidity was affected by the dredging comparatively but not due to seasonal effects. Seasonal variation of the physico-chemical parameters during the dredging is shown in Fig. 1.

Fecal coliform count was relatively above the standard limit (station C). Iron II had higher values during the dry season but highest in stations C and = D. The chloride concentration was relatively higher in the wet season which may be due to salt-water intrusion but not dredging.

Similarly, phosphate was above DPR (1991) and FEPA (2001) limit, it was higher during the dry season downstream in stations C and D (due to human activities). Ammonia was also above the limit DPR (1991) and FEPA (2001) but highest upstream during dry season which may be due to the presence of substances which may reduce ammonia content from the dredging operations. Turbidity was found highest at station F (suction point). BOD5 was also above DPR (1991) and FEPA (2001) limit, no serious seasonal changes due to dredging. Alkalinity was below the limit but high at station B and C. Dissolved oxygen (DO) was above the DPR (1991) and FEPA (2001) limit but found highest during the wet season in stations B and D.

CONCLUSION

The relatively higher values of sulphate, total hardness, Iron II, phosphate, nitrate and chloride observed seasonally shows temporal impact but not necessarily due to dredging but mostly anthropogenic inputs and spatial variation. Most of the parameters measured showed that they were within permissible limits as stipulated by DPR (1991), FEPA (2001) and WHO (1993). Though the concentrations are relatively low, human inputs should be monitored to avoid bio-accumulation and biomagnifications processes on zooplanktons. The pH, temperature, T.H, nitrate, turbidity, alkalinity and sulphate were below the recommended standard limits of safety.

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