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Variations in oxygen and some related pollution parameters in some streams in ITU Area of Nigeria

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Abstract: The analyses of water from four tributaries of Ikpa River: Afaha Nsai Stream (ANS), Ikot Ekpuk Stream (IES), Afaha Itam Stream(AIS) and Nduetong Stream (NDS) in International Telecommunication Union (ITU) Local Government Area of Akawa Ibom State in Nigeria were carried out using standard analytical procedures. The parameters investigated were temperature (Temp.), hydrogen ion concentration(pH), total suspended solids (TSS), total dissolved solids (TDS), dissolved oxygen (DO) and biochemical oxygen demand (BOD). Correlation analysis carried out between pairs of variables showed that only the correlation coefficients between TDS and DO in ANS($p<0.05$); Temp. and TDS in IES ($p<0.05$) and between Temp. and TDS in AIS ($p<0.01$) were significant. None of the pairs of the variables in NDS showed any significant correlation. The coefficients of variation for the parameters were also computed and used in determining their stability in the water. The possible effects of these variables on each other and on the aquatic ecosystem were discussed.

Key words: pollution parameters; dissolved oxygen; biochemical oxygen demand; streams; Nigeria

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Introduction

Physical and chemical properties are of great significance to the working of any aquatic ecosystem. In most cases, the chemical properties are greatly influenced by the presence of soluble substances while the insoluble materials greatly influence some of the physical properties. A wholesome and palatable water is one that is not only free from disease-producing organisms but from poisonous and undesirable substances (Udosen, 1997). The actual quality of water (physical, chemical and biological) depends on the quality and types of chemical substances present as well as on the geological and biological processes occurring in that water. While all natural water bodies are subject to certain degree of natural pollution arising from decaying plant matter and impurities washed out from the soil and rocks, the greater part of pollution occurring in our rivers and streams may have its origin in the lifestyles of community and the operation of various industries with little or no regard to water quality surveillance resulting in the continuous discharge of toxic substances into these bodies of water (Lees, 1994). It should also be noted that even when there are no manufacturing industries near a water source, such water could still be polluted by runoff through point and non point sources such as mechanic workshops, petrol filling stations, transit sites/camps for road construction companies, agricultural farms, refuse and waste dump sites. It could also be polluted by substances discharged into it upstream. If considerable amount of dissolved solids are contained in the runoff, the receiving river or stream is rendered brackish. Moreover, the wastes from the above sources often contain more organic matter than the treated sewage and when decomposed by aerobic microorganisms could lead to oxygen depletion, toxicity to aquatic biota and subsequent rendering of such water unfit for domestic and some industrial uses. Bio-oxidation of nitrogenous materials could also deplete oxygen (Udosen, 1992).

The presence of dissolved oxygen in water is vital to aerobic organisms and the levels of both oxygen and biochemical oxygen demand are used to assess the degree of pollution of water sources.

Thus when a river or stream becomes devoid of oxygen, bacteria that can live without free oxygen increases. Because these anaerobes obtain their oxygen from sulphate and nitrites, they release H_2S and NH_3 gases and therefore create odour problems (Moriber, 1974; Stoker, 1976).

With the depletion of dissolved oxygen, fish start to disappear while most of the aquatic organisms die and decay, thus causing the water course to turn into a smelling black swamp. At this stage, the water course is said to be grossly polluted. When there are excess phosphorus, potassium, nitrogen, carbon and sulphur in the aquatic environment, eutrophication results (Goldsmith, 1988). Initially this effect leads to rapid growth in fish population and algal bloom. However, when there is excessive algal bloom and overgrowth for aquatic weeds, turbidity increases, leading to gross reduction in visibility. There is also competition for available space, oxygen and sunlight.

Ikpa River is a major source of water in Itu Local Government Area which receives several tributaries including Afaha Nsai, Ikot Ekpuk, Afaha Itam and Nduetong streams before emptying into the Cross River that flows into the Atlantic Ocean via the Bight of Bonny. The investigation into the qualities of these tributaries was therefore necessitated by the desire to find out the influence of rural and urban runoff on the receiving streams and the river and hence of the suitability or otherwise of water from these sources for domestic and other purposes.

1 Materials and methods

All the samples used for analysis were mixtures of surface and bottom water collected at two points (upstream and downstream) from each of the four streams: Afaha Nsai(ANS), Ikot Ekpuk (IES), Afaha Itam(AIS) and Nduetong(NDS), all in Itu Area of Akwa Ibom State, Nigeria (Fig.1). These were later made into composite samples prior to treatment and analysis. Samples meant for the determination of pH and solid matter were collected in clean 1 liter plastic bottles. All the samples were always stored in covered plastic containers and transported with minimum delay to the laboratory for analysis.

Both dissolved oxygen(DO) and the biochemical oxygen demand(BOD) were determined at sites using HACH Kit model DR/2010. Similarly, temperature was determined in situ using a Celsius thermometer graduated in degrees centigrade(0—100℃), while pH was determined using a pH meter model 7010 after standardizing the instrument with standard buffer solutions of pHs 4.00 and 6.85 (Hanson, 1973).

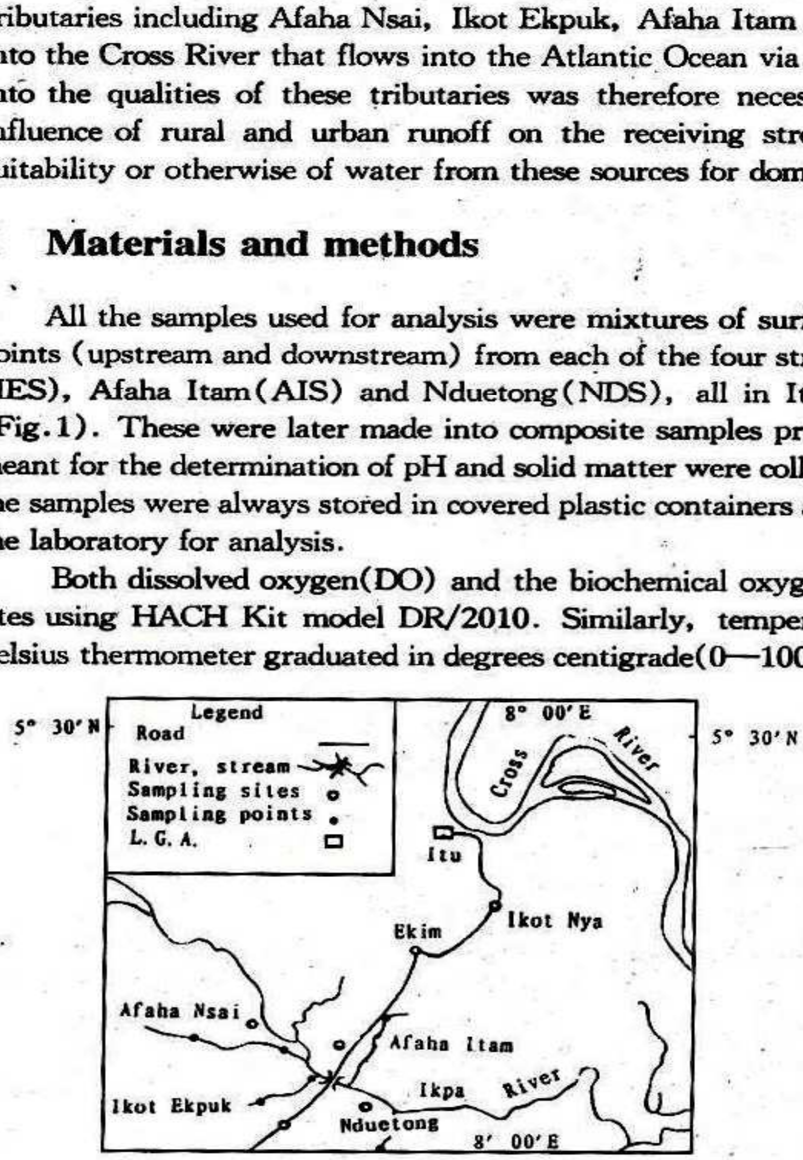

Fig.1 Part of ITU showing sampling sites/points

Suspended matter was determined gravimetrically by finding the difference in weight between TDS and TS. The total solids (TS) on the other hand was determined by drying the sample (100 cm^3) in an oven at 180 ℃ for about 2 hours. After complete evaporation and drying of the samples, the dish was cooled in a desiccator, reweighed and the increase in weight recorded as the total solids.

2 Results and discussion

The mean values of the physicochemical variables and their coefficients of variation based on the sites investigated are presented in Table 1 and 2, respectively. In Table 3, the correlation coefficients between pairs of variables are given. For a learned understanding of the trends in the results obtained, histograms of the mean values of the variables at respective sites are given in Figs. 2 and 3.

Table 1 The mean values of physicochemical variable (ranges are in parenthesis)

Variables	Sampling sites			
	NDS	ANS	IES	AIS
Temp., ℃	24.96±0.16	26.04±0.32	25.90±0.66	25.26±0.43
	(24.20—25.80)	(26.00—26.50)	(25.20—27.00)	(25.00—26.00)
pH	6.77±1.34	5.76±0.32	5.37±0.32	5.37±1.87
	(6.00—9.40)	(5.40—6.20)	(5.40—6.20)	(5.80—6.20)
DO, mg/L	1.31±0.32	1.83±0.26	1.85±0.40	1.99±0.12
	(0.80—1.70)	(0.50—2.17)	(1.10—2.20)	(1.77—2.13)
BOD, mg/L	0.23±0.10	0.35±0.18	0.25±0.06	0.40±0.04
	(0.10—0.41)	(0.20—0.80)	(0.00—0.41)	(0.20—0.43)
TDS, mg/L	53.00±31.99	52.00±20.52	15.00±10.80	35.00±15.57
	(20.00—110.00)	(20.00—220.00)	(10.00—40.00)	(20.00—140.00)
TSS, mg/L	20.78±12.53	29.00±22.34	0.01±0.01	30.00±18.86
	(20.00—70.00)	(10.00—80.00)	(0.00—0.01)	(10.00—60.00)
TS, mg/L	88.00±27.41	81.00±19.78	20.00±11.55	64.00±12.11
	(50.00—140.00)	(30.00—300.00)	(10.00—40.00)	(10.00—20.00)

Table 2 Site-based mean coefficients of variation of physicochemical variables, %

Parameters	Sampling sites			
	NDS	ANS	IES	AIS
Temp., ℃	2.44	1.23	2.55	1.70
pH	19.79	6.25	5.56	34.82
DO, mg/L	24.43	14.21	21.62	6.03
BOD, mg/L	43.48	51.43	1.04	92.86
TDS, mg/L	60.36	116.38	72.01	101.63
TSS, mg/L	60.28	77.02	100.00	62.85
TS, mg/L	31.14	98.50	57.74	81.42

Table 3 Correlation between pairs of variables at different sampling sites, n—10

Pairs of variables	Correlation coefficient, r			
sampling sites	NDS	ANS	IES	AIS
Temp./DO	0.30	−0.07	0.45	0.27
DO/BOD	0.40	−0.30	−0.35	−0.08
TDS/DO	0.19	0.57*	0.35	0.14
Temp./BOD	−0.19	0.06	−0.22	−0.30
TDS/BOD	−0.33	−0.09	0.06	0.11
Temp./TDS	0.21	0.06	0.57*	0.68*

* significant

In all the sites investigated, ranges in the variables were very narrow. For instance, in

NDS, temperature ranged between 24.20℃ and 25.80℃. This was higher than that of ANS. Similarly, IES and AIS samples had temperature ranges higher than that of NDS(Table 1). While ANS recorded the highest mean temperature of 26.00 ± 0.32, NDS recorded the least temperature of 24.96 ± 0.16. Temperature is a very important parameter which control the lives of aquatic organisms. The values obtained fell below the FEPA and WHO recommended standard of 29.40℃—30.30℃ (FEPA, 1991; WHO, 1984). The drop in temperature must have been due to the sampling time, stream gradients, weather condition and rate of flow of the river or stream. For instance, water bodies with high gradient usually have higher temperatures than those with low gradients. The temperature of a particular water system usually affects the solubility of substances in it. However, whereas certain substances dissolved significantly in water at high temperatures, others do so at low temperature. At water temperatures above 35℃ aquatic animals die. On the other hand, at low temperatures, the rate of sedimentation and filtration decrease. Decrease in water temperature could also slow down the rate of metabolism of aquatic animals since temperature controls to a certain extent, chemical reactions in water and the metabolic processes in some fishes. The trends in temperature levels in the four sites investigated was ANS>IES>AIS>NDS.

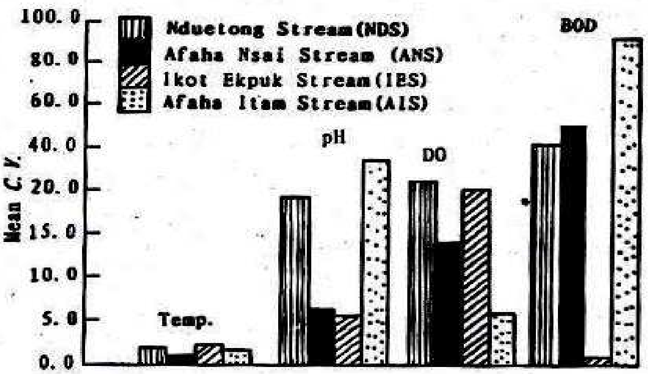

Fig.2 Coefficients of variation of oxygen and related variables in the samples

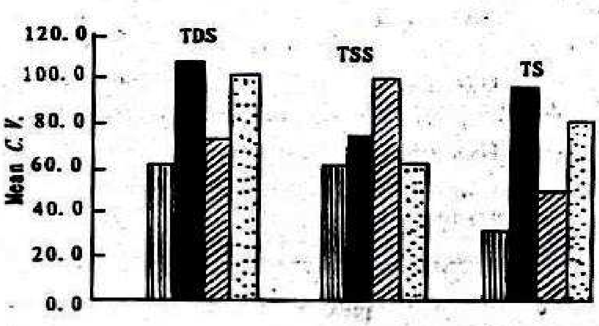

Fig.3 Coefficients of variation of solid matter in the samples (the illustrations are the same as Fig.2)

Dissolved oxygen (DO) is one of the most significant physicochemical variables often used to determine water quality. It often depends on the temperature of that water, therefore the higher the temperature of the water, the lower the dissolved and vice versa. Furthermore, oxygen concentration in water could be lowered by solutes and decrease pressure. In addition to microbial activity which leads to the depletion of DO, washing down of top soil by rain into the water courses could increase the acid content of the water and thus also leads to oxygen depletion. Generally, when oxygen is consumed by respiring organisms in a stream faster than it is replenished, an oxygen deficit results. This is capable of prohibiting the existance of life forms that otherwise would have lived therein. Values for DO were low in ANS, IES and AIS with the highest value of 2.20 mg/L recorded in IES(Table 1). The lowest level of 0.80 mg/L was recorded by NDS. The mean DO levels in ANS, IES, AIS and NDS were 1.83 ± 0.26 mg/L, 1.85 ± 0.40 mg/L, 1.99 ± 0.12 mg/L and 1.31 ± 0.30 mg/L respectively. The ranges for DO levels in these samples were also narrow(Table 1). Generally, a DO level of 5.00 mg/L or above is needed to support fish and vertebrate life. ANS recorded the lowest DO corresponding to the highest temperature recorded in the sample. On the other hand, both IES and AIS samples recorded higher levels corresponding to the lower temperature values. The DO in NDS was slightly higher although its mean temperature was the lowest. The values were generally below the FEPA and WHO standard of 5.00 mg/L and the trend in mean DO level in the four streams was AIS>IES ANS>NDS. This low trend was capable of causing fish scarcity in these streams.

BOD usually indicates the amount of dissolved oxygen used up during the oxidation of oxygen-demanding wastes to produce CO_2 and H_2O. When polluting substances are introduced into water, a natural purification action involving biochemical reaction takes place. This may involve microbial growth capable of utilizing sources of CO_2 while utilizing dissolved oxygen for respiration. The rate of respiration in such cases may depend on temperature and nature of organic matter:

$$CHO + O_2 \longrightarrow CO_2 + H_2O.$$

Similarly, the bio-oxidation of nitrogenous substances may also deplete oxygen present in the water:

$$NH_4^+ + 2O_2 \longrightarrow 2H^+ + NO_3^- + H_2O.$$

The highest mean BOD value of 0.40 ± 0.40 mg/L recorded in AIS sample must have resulted from the breakdown of by-products of aquatic activities. This was closely followed by ANS sample (0.35 ± 0.18 mg/L) and IES sample (0.20 ± 0.06 mg/L) while NDS sample recorded the least value of 0.23 ± 0.10 mg/L. The low BOD levels in all the samples including AIS, may have resulted from less input of industrial, municipal and rural sewage from the nearby towns and villages. Since an excellent water source has an average BOD of between 0.75 mg/L and 1.50 mg/L and a poor, rejectionable source has a BOD of 4.00 mg/L and above (Dangerfield, 1983), the water from the four streams could be said to have been quite good with respect to BOD levels.

The pH of any water system is an important physicochemical parameter. It is the negative logarithm of hydrogen ion concentration and usually determines the acidity or alkalinity of a water system. The chemical and biological states of natural waters are regulated by it. Since the ability of water to support life is a function of pH, toxicity of most compounds in water is affected by the degree of dissociation of weak acids and bases brought about by changes in pH. Surprisingly, whereas NDS had pH within the FEPA and WHO range of 6.00—8.50 (FEPA, 1991; WHO, 1984), ANS, IES and AIS were somehow acidic. This is an unwelcome trend in rural waters since little changes in pH of water could convert a relatively harmless substance into a toxic one, a process that has contributed to the toxicity of some metals to some fish species as water temperature increases (Bervoets, 1996). Moreover, the degree of ionization and concentration of metals present could increase, speciation and precipitation of heavy metals could also occur leading to bioaccumulation and biomagnification of these metals in fish. The World Health Organization (WHO) recommends a pH range of 6.50 to 8.50 for fishing and strongly advises that for streams or rivers to be unpolluted, their pH values should range between 6.00 and 7.00(WHO, 1984).

The pH levels recorded in all the streams were close to the expected range of 6.90—9.00 for fresh water (Grant, 1981). IES and ANS recorded respective mean levels of 5.76 ± 0.32 and 5.76 ± 0.36 while the mean pH level in AIS was 5.37 ± 1.87. NDS however recorded the highest mean pH of 6.77 ± 1.34 with a corresponding high range of 6.00—9.40. The trend in pH was NDS> ANS=IES>AIS. The pH in NDS was highest probably due to the nature of the runoff received by the stream in addition to $CaCO_3$ already present in that stream. Since the pHs recorded in all the samples were not outside FEPA and WHO range, the water from all the streams investigated could be said to have been acceptable for domestic and industrial uses during the period of investigation.

The summation of total suspended solids (TSS) and total dissolved solids (TDS) give total solids (TS). The nature of soil traversed by water and the type of waste discharged into a stream or river determine the quantities of suspended and dissolved solids in that stream or river. When present in high concentration in water, these solid reduce light penetration, increase turbidity and colour and thereby reduce the depth of photozone. This may affect primary product that may decrease the dispersion of DO and nutrient to low portions of the water body. Moreover, since water conductivity depends on dissolved solids, large amounts can lead to increased mineralization of a receiving stream or river with the consequent further depletion of dissolved oxygen.

The mean total solids content in NDS and ANS were 88.00 ± 27.41 mg/L and 81.00 ± 19.78 mg/L respectively (Table 1). On the other hands, AIS recorded a total solid content of 64.00 ± 12.11 mg/L while that for IES was 20.00 ± 11.55 mg/L. Although the levels of particulate matter in all the samples were not significant when compared to WHO standard of 500 mg/L the oxygen levels in all the streams became depleted as a result of activities of microorganisms present in the soils washed into the streams particularly during rainy season. These also rendered the streams turbid.

The coefficients of variation for all the samples fluctuated considerably (Table 2). While temperature tended to be the most stable parameter in ANS ($C.V. = 1.23\%$), total suspended solids in IES with a $C.V.$ of 100. 10% was the most unstable. From the results in Table 3, only the correlation between TDS and DO in ANS ($p<0.05$); temp. and TDS in IES and AIS ($p<0.05$ and $p<0.01$) respectively were significant. None of the pairs of variables in NDS showed any significant correlation. However, correlation coefficients of 0.40 between temp. and DO in IES call for concern.

In conclusion, it could be said that most substances which pollute our streams and rivers are oxygen-demanding, the amount of oxygen available often depending on other physicochemical variables such as temperature, dissolved solids and suspended solids, which in turn affect the pH, odour, taste and turbidity or transparency of the water body. Since the levels of all the parameters when compared with FEPA and WHO standards fell within safety limits for drinking water, the four streams could therefore be used for domestic and other purposes.

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