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A COMPARATIVE STUDY ON WATER QUALITY CRITERIA OF DELIMI RIVER IN JOS, PLATEAU STATE OF NIGERIA

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ABSTRACT

A survey to compare level of environmental law compliance using Delimi River, Jos in Plateau State was carried out. The study isolated major pollutants, resulting from waste water seepage from mines. Toxic substances implicated include iron (0.6-3.0 mgl^{-1}), cadmium (1.5-2.1 mgl^{-1}), lead (0.8-1.25 mgl-'), copper (2.6-3.8 mgl-l), Zinc (8.5 - 18.0 mgl-1) and cyanide (0.05-0.4 mgl-1). These values significantly ($p < 0.05$) violate the internationally recommended water quality criteria for drinking purposes, domestic use and aquatic life.

The implications of these observations on the health of resource - dependent users, the aquatic biota and water environment are discussed.

Keywords: Aquatic environment, water quality, Delimi river

INTRODUCTION

The biotic component of the aquatic ecosystem is an indispensable economic resource. It consists of the fishery, a natural resource that includes fin fishes, the shell fish and crustaceans (shrimps, prawns, crabs, lobsters, etc); the mollusks (calms, scallops, periwinkles, Oysters etc) and edible aquatic needs.

Exploitation of these resources in deep maters such as seas and oceans is an exclusive preserve of the industrial fisheries sector which is essentially capital intensive and beyond the scope of the resource - poor producer. Rural artisans thus concentrate on shallow water bodies, including rivers, creeks, lakes, lagoons, etc for their fishing expedition. In Nigeria this artisanal fisheries sector produces the bulk of fish consumed by the people, serving as source of food, income, employment, raw material and foreign exchange to Nigerian populace and the nation.

In recent times however, Nigerian inland water bodies have been subjected to various forms of degradation due to pollution. Sources include industrial effluents domestic wastes, agricultural run-offs, oil spillage, mine effluents and obnoxious fishing methods. The resultant effect is that the associated fishery, the biota and the ecosystem upon which fishers and fishing families depend for a living are destroyed. Consumption of fish caught from water bodies so polluted also poses severe danger to the consumer. For example, FEPA (1991) has reported cases of methyl mercury poisoning of people who ate fish polluted by mercury in which 120 people died in Japan and 144 in Ghana. A case of accidental discharge of waste water containing high levels of ammonia from NAFCON, a fertilizer company in Onne, River State into the Okrika river has also been reported (FEPA, 1991) in which massive fish kills were recorded for which compensation was paid for the socioeconomic deprivations of the resource dependent fishers.

One of such endangered inland water bodies is the Delimi River, in Jos Plateau State of Nigeria. Delimi River is the main drainage system in Jos (Anadu & Akpan 1986) and serves dual roles as source of water for drinking, domestic use and fishing. Mining is the second most important occupation of the people after farming. Lack of effective control and management of wastewater seepage from these mines and mine washings into the river are major problems, resulting in sporadic reports of fish kills especially around points of entry.

Anadu and Ejike (1981) have reported a significant reduction in the number and species diversity of macro-invertebrates and fish fauna of Delimi River as a result of mine washings, adding that the stream bed is also significantly altered. Mine effluent is a veritable source of heavy metals in the aquatic environment (FEPA, 1991). The presence of these metals and non metallic radicals potentiate serious problems at certain concentrations because of their toxic properties. FAO (1975) suggested that monitoring and evaluation of effluents and waste water discharges from mines are very important in order to obtain an appropriate indication of the concentrations of a substance likely to be hazardous to fish and fisheries in the' natural environment. Water quality criteria are available as the recommended international minimum standards for drinking purposes by the World Health Organization, WHO (1971, Table 1); for domestic use by the Federal Environment Protection Agency of Nigeria, FEPA (1991, Table 2) and for aquatic life by Roberts (1978, Table 3), together with the associated legislation, but these standards and laws are hardly enforced for the protection of our inland waters, the biota and the poor resource users.

In the present study, attempt is made to determine the level at which some toxic elements are present in the Delimi River as a result of waste water seepage/discharges from mines. Values of substances identified were compared with the internationally recommended maximum permissible levels in portable water for drinking, domestic use and for aquatic life.

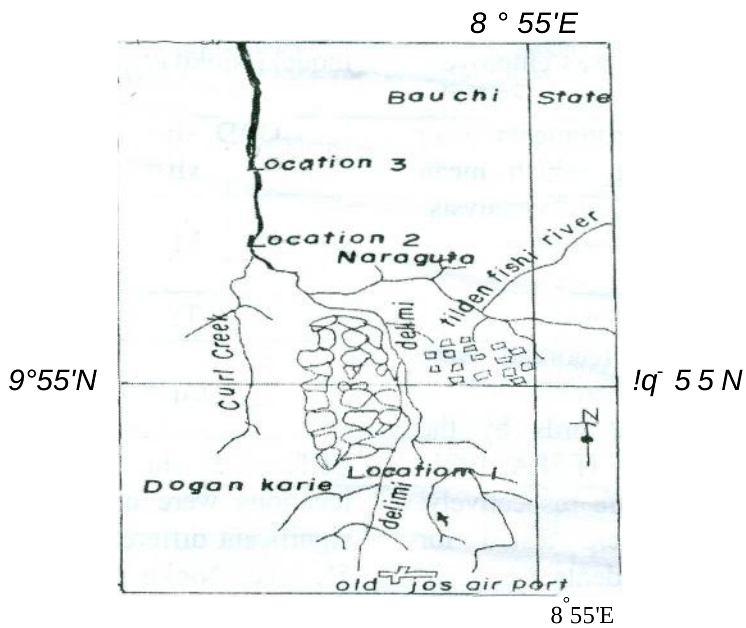
MATERIALS AND METHODS

The Study Area

The Delimi River (Fig. 1) has been described by Anadu & Akpan (1986). It is the main drainage system of Jos and a major tributary of the Shari River system which flows North-east and drains into Lake Chad, covering a distance of about 900km. For the purpose of this study three sampling locations were chosen as designated in Fig 1.

Analytical Procedure

Data collection and analytical procedure were carried out in accordance with standard procedure described by APHA (1985), AOAC (1994) and Krylova *et al* (2003). Water samples were collected from several sites on each of the three designated sampling locations of the river, using clean reagent bottles screened from sunlight. Sampling was carried out weekly between March 1996 and February 1997. Specimens were labeled and transported to the laboratory in temperature - controlled Styrofoam boxes for analysis. An ambient temperature of 28° was maintained during transportation. Colour of water was visually compared using platinum - cobalt method. Calibrated special glass colour discs were employed. The pH was determined using



KEY
river System
-t direction of water flow
at,b settlement
scale:-1.25,000

Fig 1. Map of Delimi System Showing the Sampling Locations

the BDH electronic pH meter with temperature adjustment.

The conductivity of the recipient water at 28°c (in mscm^{-1}) was determined using the platinum - electrode-type conductivity cell while hardness (mgl^{-1}) employed the EDTA titrimetric method.

The metals (Cadmium, Copper, Iron, Lead and Zinc) were determined using the atomic absorption spectro-photometer (OHAU ISO - 09000 model). After pre-treatment by additional acid to preserve any organic matter present, (APHA 1985), a sample of the test water was aspirated into an air-acetylene flame and atomized with high beam, directed through the flame. Metal concentration in the test water were recorded in mgl^{-1}.

Cyanide concentration was determined by titrimetric method, using the standard sliver nitrate solution as the titrant and sliver-sensitive par a dim ethyl amino-benzal-rhodanine as the indicator. Values were recorded in mgl^{-1}.

The concentration of chlorine (in mgl^{-1}) in the upstream (clear water) location was measured by the Argentometric method while at the point of effluence discharge (downstream) pre-treatment was used. Crylova *et al* (2003). Values were recorded in mg^{-1}.

For the nitrate-nitrogen, the ultraviolet spectro-photometer was used for samples from upstream location. Samples from downstream locations (entry sites) were analyzed using the nitrate-electrode method (APHA, 1985).

For sulphate redicals, the gravimetric method with residue drying was employed. Values were recorded in mgl'. For all the parameters evaluated, measurements were replicated four times from which mean estimates were obtained for Anova analysis.

Statistical Analysis

Water quality parameters recorded were compared with values recommended as international minimum standards by the World Health Organization (FEPA 1991) for domestic and aquatic life respectively. Differences in values were tested for significance, using the students t-test for two sample classification. The statistical model, (Roger, 1979; Njoku, 1991) was of the form:

$$t = \frac{(x_A - X_B) - (\mu_A - \mu_B)}{S_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \quad \text{with } (n_1 + n_2 - 2) \text{ df}$$

Where x_A = mean value of the water quality criteria for recipient river
x_B - mean value of recommended international standard
s_1 = estimated standard deviation of the recipient stream from the internationally set minimum standard for the specific uses.
df = degree of freedom

S_P is defined as $$\sqrt{\frac{(n_A - 1) S^2_A + (n_B - 1) S^2_B}{(n_A + n_B - 2)}}$$

Mean values of the water quality parameters (elements) for the three designated locations on the recipient stream were compared using the one-way Anova (completely randomized experimental Design, CRD) test. The mathematical model (Njoku *et al, 1998) is* thus:

CRD, $x_{ij} = M + T_i + E_{ij}$

Where x_{ij} = values of independent observations
M = unknown population variance
T_i = effect of mine effluent on mean observations
E_{ij} = Error term

Differences in mean values between locations were compared using the least significant difference (LSD) method at the 5% level (Njoku, *1998)*.

RESULTS

Table 4 shows the concentration of major pollutants from mine seepage on three locations of the recipient river. The result shows that all the substances identified (except p") varied between locations. Upstream location (site 1) recorded the least concentration while the highest were observed in the downstream location 1 (site 2). This is followed by the downstream location 11 (site 3). Differences in mean values between locations were found to be quite significant ($p<0.05$). Values for the three locations were then pooled and the mean values (Table 5) compared with the recommended international quality criteria for portable (drinking) water by WHO (FEPA, *1991)* domestic use (FEPA, *1991)* and aquatic life (Roberts, *1978)*.

The Extent of compliance of Delimi River with recommended international standards.

Virtually no single parameter out of the 14 substances evaluated conformed with the prescribed standards as revealed in Table 5.

Allowable Levels of Pollutant Concentration in Drinking (Portable Water as the International Standards by WHO (after FEPA 1991)

Table 1:

Parameter (Quality indices)	; Recommended water quality i Criteria (mgl⁻¹)	Maximum Permissible Level (mgl⁻¹)
Colour		15 Hazen Units
pH	7.0-8.5	6.5-9.2
Total Solids	500 €	1500
Total hardness	j 100	500
Calcium (Ca)	75	200
Dissolved Oxygen (DO)	15 (minimum)	
Chloride (CI)	200 1600	
Copper (Cu)	0.05	1.5
Iron (Fe)	1	1.0
Magnesium (mg)	30 (At most if S042- lis up to 250) 150 (if S042- is less)	
Managenese (Mn)	0.05	0.5
Sulphate (SO4-2)	200	400
Zinc	5.0	15.0
1 Sodium (Na)	200	400
Fluoride (F)	1.5	2.0
Nitrate (NO,)	10.0	100
Turbidity	5 FTU	25 FTU
Nitrate-nitrogen		2.27
Nitrite ($N0_2$)	10-56	100
Lead (pb)		0.05
Chromium (cr)		0.05
j Cadmium (Cd)		0.01
Barium (Ba)		1.0
Cyanide (CN)		0.2
Phenolic Substance		0.002
COD		10.0
BOD		6.0
NH3 (Ammonia)	-	0.5
1 Grease and Oil		1.0
j Mercury (Hg)		0.002

Table 2. International Water Quality Standards for Domestic Use as Recommended by the World Health Organization (WHO, 1971 after FEPA, 1991) and Adopted by the Federal Environmental Protection Agency of Nigeria (FEPA).

i Substances _	Water quality criteria mg'	Maximum permissible range (mg')
Phenolic Compounds (as Phenol)	10.001	10.00-0.001 I
j Fluoride (F)	< 1.0-1.7	0.2-1.7
1 Nitrate (NO;)	50.1	
*pH	-	6.5-9.2
*Copper (C +	1 0.5	0.5-1.5
Iron (Fe")	€0.1	10.1-1.0
4 Manganese (mn^2) N	10.005	0.05-0.5
*Zinc (Zn^{2+})	5.0	5.0-15.0
Mangnesium (Mg^-')	150.125	50.0-150
I Sulphate (S04 21)	€150	200-400
1 Hydrogen Sulphide (HS)	'0.05	
*Chloride (CI)	{ 200-600	j 200-600
Chlorine (Free)		
'_=Ammonia (NH_4)	10.5	
Carbon dioxide (Free)	-	
? Calcium (Ca'^+)		75-200
Mineral Oil		0.01-0.5
Mineral Oil with High sulphur	-	0.01-0.1
Turbidity		5-25
Organics	0.2-0.5	

* FEPA adopts the WHO Criteria as standard.

For example, where as the pH of the recipient stream was 5.9 (acidic) the maximum permissible levels were 7.85 (alkaline) for drinking purposes 7.75 (alkaline) for domestic use, and (8.75 - 7.85) for aquatic life. Among the toxic metals isolated at various concentrations from the river are iron, cadmium, lead, copper, zinc and cyanide. Lead occurred in the concentration of 1.13mgl-' in the river as against (0.05 mgl^{-1}) recommended for drinking purposes, (0.03 mgl-') for fresh water organisms and (0.01 mgl-') for marine life. The concentrations of copper (3.63mg1-'), zinc (17.20mgl"') and cyanide (0.17mgl-') in the recipient stream significantly deviated ($p<0.05$) from the recommended maximum permissible concentrations of (1.50mgl-', 15.0mg1-' and 0.20mgl-') respectively for portable

Table 3: Recommended Water Quality Standards for Aquatic Life in Different Aquatic Environment as Recommended by Roberts (1978)

Parameter	Fresh water habitat	Sea-water habitat
pH	6.0-9.0	6.5-8.5
Suspended solids, mg-1	25-80	80-100
Cadmium Ng-1	0.003-0.004	0.002
Chromium mgl-1	0.005	0.05
Copper, mgl-1	0.1	0.01
Lead, mgl-1	0.03	0.01
Mercury, mgl-V	0.05	Unknown
Nickel, mgl'l	0.02	0.002
Zinc mgl-1	0.05	Unknown
Ammonia (undissociated), mgl-1	0.02	0.01
Cyanide, mgl-1	0.005	0.005
Hydrogen sulphide (Undissociated, mgl-1)	0.002	0.005
Nitrite, mgl-1	0.1	0.1

(drinking) water and (1.0mg1^{-1} for copper and 10.0mgl^{-1} for zinc) in water for domestic uses. For aquatic life, (0.10mgl^{-l} and 0.005mg1$^{-'}$) respectively were recommended for fresh water life while (0.O l mgl^{-1} for copper and 0.005mgl^{-1} for cyanide) were recommended for marine life. There was not stipulated quality criteria for the deadly substance, cadmium with respect to water for domestic use, but the value recorded in the river (2.Omgl^{-}) was observed to be significantly higher ($p<0.05$) than 0.01 mgl^{-1} recommended for drinking purposes, 0.022mgl$^{-'}$ for fresh water habitat and 0.002mgl^{-1} for saltwater environment.

DISCUSSION

The concentration level *of* these toxic substance in Delimi river which exceeded the minimum recommended standards is a matter of worry because *of* their toxic properties (FEPA, 1991) , not only to fish, but to man that consume this fish (Robert, 1978). Oronsaye (1990) has reported that *Gasterosteus* was killed by cadmium at the concentration of 0.001 mgl' ^{1} in water. Zinc has also been reported to exert noxious effects in fish (Weatherly *et al* 1980 in which it causes structural damages to the gills thereby affecting respiration. Oronsaye (1990) has also observed lethal zinc toxicity at concentrations of 0.5 - 1.0mgl$^{-'}$ to strickle backs within 1-3 days of exposure. In a 96 hour static broassays, Annune (1989) obtained an LC_{50} at 13.24mg1^{-1} for *Clarias gariepinus* figerlings and LC50 of 24.59mgl^{-1} of zinc for *Oreochrimics niloticus.* Observed toxicosis ranged from loss of equilibrum to air-gulping and death.

However, toxicity of heavy metals is known to be reduced in hard water. For example, Lloyd (1978) has demonstrated that zinc was more toxic to fish in water of hardness, 12mgl$^{-'}$, than in water with a concentration of 320mg1$^{-'}$ of calcium carbonate. Perhaps the high concentrations of calcium carbonate (total hardness) in the river of 427 mgl^{-1} explains why there has not been massive fish kills in the river despite the high concentrations *of* Cadmium (2.00 mgl^{-1}) and other metals in the river. Another possible explanation for the survival *of* fish in the highly polluted Delimi River may be high rate *of* mater exchange. Crylova *et al* (2003) working on the toxicity *of* organo-chloride DDT pesticide in polluted lake Ladoga, attributed fish survival to water exchange. Waste water drainage from coal and metal mines are not only toxic to fish, but also pose serious health danger to humans that drink from the river or eat fish caught from such

Table 4: Comparison Of The Concentration of Pollutants on Three Locations of Delimi River, Jos Due to Mine Effluents and Washings.

Pollutant	Upstream location (Site 1)		
Colour	Clear^{s}	Turbid ^{b}	Turbid`
PH	8.50^{a} + 0.05	4.50^{6} + 0.01	4.80^{6} + 0.01
Conductivity at 28°C	10 i cm^{-ia} +0.08	216C3cm_^{,b} + 15	125C3cm` + 815
Total hardness	550.00`' + 12.50	380.00^{6} + 10.50	350.00^{6} + 8.5
Total organic matter	3.50^{3} + 0.15	12.96^{6} + 0.10	8.62+0.2
Iron (Fe)	0.60^{3}+003	6.27^{6} + 0.05	3.00^{c} + 0.04
Cadmium (Cd)	*1.50^{0}+0.01*	2.60^{6} +0.08	2.10^{6} + 0.06
Lead (pd)	0.80^{1,} + 0.02	1.35^{6} +0.05	1.25" + 0.001
Cooper (Cu)	2.60^{3} *+0.05*	4.50^{6} + 0.4	3.80` + 0.02
Zinc (Zn)	8.50`' + 0.02	25.00^{6} + 0.6	18.00` + 0.80
Cyanide (CN)	0.05" + 0.001	0.50^{6} +0.01	0.40^{b} +0.02
Chloride (Cl)	75.00' + 1.5	280.00^{6} +3.6	340.00` + 5.3
Nitrate (No,)	12.00' ± 0.80	45.00^{6} + 1.5	86.50` + 2.0
Sulphate (So.,')	215.00 ^{a} + 6.80	560.00^{b} + 15.0	435.00` + 10.0
Mean	68.30'	217.0	106.00`
LSD (0.05)	6.80	4.50	
CV (%)		18.50	15.00

abc = means in the same row with different superscripts one significantly different at p = 0.05.

rivers. FEPA (1991) reported a case of methyl-mercury poisoning in Japan which killed several people who had consumed fish caught from a river that received untreated lead effluents from surrounding factories. Botkin and Keller (1998) reported a high incidences of cancer among organisms exposed to high concentrations of copper. zinc and lead. adding that these heavy metals usually stored in tissue fats and oils are concentrated in body as they pass through the food chain. The higher the organism is on the food chain, the higher the heavy metal concentration in its tissue (known as bio-magnification). Such metal toxicity is more deadly in the tropics (Artfi, 2003) due to accelerated temperature and chemical reaction in the tissue.

Predisposition to diseases and the extent of damage done to water consumers of Delimi River call for serious research, as contaminants are far above the internationally recommended maximum permissible level for National Drinking Water Standards (Table 6) advocated by the US Environmental Protection Agency USEPA (Botkin & Keller, 1998).

CONCLUSION/RECOMMENDATION

The observed bio-chemical degradation of Delimi River is a general one affecting the majority of inland waters of Nigeria. A survey of manufacturing companies in Nigeria and municipal sewers will reveal that resultant effluents and sewages are discharged into nearby rivers with such recklessness and without treatment as

Table 5: The Water Quality of Delimi River Jos, Compared With Internationally Recommended Water Quality Criteria for Drinking Purposes (WHO, 1971, After FEPA, 1991) Domestic Use (FEPA, 1991) and for Aquatic Life (Roberts 1978).

[Pollutants (Mgi')	Delimi River X ± S.D	Water quality Criteria for Drinking purposes W Recommended quality criteria	Maximum permissible Level	Water quantity Criteria for Domestic use (FEPA, 1991) Recommended quality criteria	Maximum permissible Level	Aquatic Life (Roberts, 1978) Fresh water habitat	Salt water habitat
Colour	turbid	-	15 Hazen Unit	6.50		--	--
pH	5.9^{2} ± 0.001	7.00-8.50	6.5-9.2		[6.50-9.20 (7.	(7.85)^{b}	6, 5 0
Conductivity at 28°C	117.0^{1} + 5.0						
Total hardness	427.0^{a}+ 10.0		500.00^{6}	0.10			
Total organic matter	8.36^{3}+0.40						
Iron (Fe)	3.29^{3}+0.04		1.00^{6}		(0.55)\` 0.10-1.00	(0.22)\` 0.003-0.004	
Cadmium (Cd)	2.00^{a} + 0.06		0.01^{6}			0.03^{6}	
Lead (pd)	1.13 ^{a} +0.01		0.05^{6}	0.50		0.10^{1}	
Copper (cu)	3.63^{a} +0.02	0.05	1.50^{6}	5.00	(1.0)^{C} 0.50 - 1.50		
Zinc (Zn)	17.20^{a} + 0.80		15.00^{6}	(400)	4 (10.0)°	0.05\`	Unknown 0.005\`
Cyanide (CN)	0.17^{a} + 0.02		0.20^{1}		I --	0.005\`	4
Chloride (Cl)	231.7 ^{a} +5.30		600.00^{6}	200.00 -	(400)^{b} 200.00 - 600.00		--
Nitrate (No)	47.8" + 2.0		100.00^{b}	50.10			--
Sulphate (SO.;)	403.3^{a} + 10.5 1 200.00		400.00^{a}	150.00	(300)^{b} 200.00 - 400.00		-

(Water quality Criteria for (

abcd Means in the same row with different superscripts are significantly differently different (P = 0.05)

( ) Values in parantheses are means calculated from the upper and lower limits of the parameter for the purpose of this comparison.

X

S.D = Standard Deviations.

stipulated by law: Any factory without the requisite waste treatment plant should be made to shut down. The Federal Environmental Protection Agency (FEPA), has the statutory role to ensure strict compliance with the existing legislation on water quality criteria. It would be wise to create a national awareness to these laws, and to commission a nation-wide survey on inland-water pollution, monitoring and evaluation. Such study should take cognizance of the need for lethal toxicity bioassays, not only on Delimi River alone, but also on all similar water bodies prone to

Table 6. National Drinking Water Standards

Contaminant	Maximum Contaminant Level (mg/L)
Inorganics	
Arsenic	0.05
Cadmium	0.01
Lead	0.015 action level[s]
Mercury	0.002
Selenium	0.01
Organic chemicals	
Pesticides	
Endrin	
Lindane	0.0002
Methoxyclor	0.004
Herbicides	*0.1*
2,4-D	
2,4,S-TP	0.1
Silvex	0.01
Volatile organic chemicals	*0.01*
Benzene	
Carbon tetrachloride	0.005
Trichloroeghylene	0.005
Vinyl chloride	0.005
Microbiological organism	*0.002*
Fecal coliform bacteria	
	I cell / 100 ml

Source: U.S Environmental Protection Agency (After Botkin & Keller, 1998)

[a] Action level is related to the treatment of water to reduce lead to a safe level. There is no maximum contaminant level for lead.

biochemical degradation. Commercially exploited fish stocks instead of the traditional non-exploitable small fish species should be used for such bioassays upon which minimum water quality criteria should be further redefined.

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