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Effects of Sewage Pollution on Water Quality of Samaru Stream, Zaria, Nigeria

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1. Introduction

Water bodies are important economically, aesthetically and intellectually. The livelihood of many communities is hinged to the water bodies around them. Water bodies mirror the environment in which they are found and accumulate substances generated in their catchment (Yongendra and Puttaiah, 2008).

Assessment of water quality is very important for knowing its suitability for different uses (Choubey *et al.*, 2008). Urbanization and rapidly growing human population results in an increase in waste water discharge into fresh water ecosystems, thus impairing water quality, sometimes to unacceptable levels, thereby, limiting its beneficial use (Tanimu *et al.*, 2011).

The contaminants in domestic sewage have been categorized by Wang *et al.* (2007) into Suspended Solids (SS) and dissolved solids (DS), organic matter (Chemical Oxygen Demand and Biochemical Oxygen Demand) and nutrients (nitrogen and phosphorus). Raw sewage can carry a number of pathogens including bacteria, viruses, protozoa, helminths (intestinal worms) and fungi (RMCG, Chigoret *et al.*, 2011).

The Samaru stream is the major drain of domestic waste of Samaru village, several researchers have lamented the poor state of water quality in the stream Smith (1975), Tiseer *et al.* (2008 and 2008b), Olubgenga (2009), and Chigor *et al.* (2011). During a field visit to the Samaru stream in May 2010, the water in the stream was observed to be blackish in colour with an offensive odour due to sewage pollution. Therefore this study was carried out to evaluate water quality characteristics of the stream.

2. Materials and Methods

Study Area and Sampling Sites: The Samaru stream is a seasonal stream with its head waters in the Samaru village, a suburban settlement that hosts the main campus of the Ahmadu Bello University, Zaria. The stream is a tributary of the River Kubanni on which the Ahmadu Bello University (Kubanni) Dam is built. The stream flows from Samaru village through a gully into the University community to the reservoir of the Ahmadu Bello University reservoir, which is the major source of water (for drinking, domestic and other uses) to the University community. The Samaru stream receives sewage from the Samaru village and student hostels (UsmanDanfodio, Sassakawa and Icsa/Ramat Halls).

Sample Collection and Analysis: Samples were collected during a field survey at the onset of the wet season (May 2010). Surface Water Temperature, pH, Electrical Conductivity, Total Dissolved Solids were determined in situ with the aid of a portable HANNA instrument (pH/Electrical Conductivity/Temperature/TDS meter model 210).

Samples of water were collected in prewashed sample bottles and transported to the laboratory for analysis of other parameters. Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) were determined using the Azide Modification of the Winkler method, Nitrate-Nitrogen ($\text{NO}_3\text{-N}$) was determined using the phenoldisulphonic acid method, Phosphate-Phosphorus using the Stannous Chloride method (all as described by APHA, 1998).

Sample for metal analysis were digested by Nitric acid (HNO_3) and the concentration of metals in the samples was determined by Atomic Absorption spectrophotometry (AAS) (APHA 1998).

3. Data Analysis

Water Quality Index (WQI) was determined by methods described by Yogendra and Puttaiah (2008).

The WQI of a water sample in which n number of parameters (characteristics) have been determined is expressed as a summation of the product of quality rating for the nth Water quality parameter (q_n) and the unit weight of each parameter (W_n) divided by sum of the unit weights of all the (n) parameters ($\sum W_n$).

Mathematically: $WQI = \frac{\sum (q_n W_n)}{\sum W_n}$

q_n = quality rating for the nth Water quality parameter, corresponding to the nth parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value and is given by $= 100(V_n - V_{io}) / (S_n - V_{io})$

V_n = Estimated value of the nth parameter at a given sampling station.

S_n = standard permissible value of the nth parameter.

V_{io} = ideal value of the n th parameter in pure water (i.e. 0, for all parameters except pH, 7.0 and Dissolved Oxygen, 14.6 mg/L).

W_n = unit weight of n th parameter = K/S_n

Metal Index (MI) for the concentration of n number of metals determined in a water samples given by the summation of the observed concentration of each metal divided by its Maximum Allowable Concentration (MAC).

Mathematically $MI = \sum_{i=1}^n \left(\frac{C_i}{MAC_i} \right)$ (Karami and Bahmani, 2008)

C = the concentration of each element in solution,

MAC is maximum allowed concentration for each element

i = the i th sample.

The higher the concentration of a metal compared to its respective MAC value, the worse the quality of the water.

Pearson Correlation Coefficient was used to determine the relationships between observed water quality characteristics.

4. Results

The mean pH of the water in the stream was found to be 7.68, with a maximum value of 8, minimum of 7.30 and a standard deviation 0.12 (Table 1). EC and TDS showed a similar trend across the stream cross, increasing from concentrations of 1000 to 1049 and 500 mg/L to 525 mg/L in stations 1 and 2, respectively and then decreasing steadily across stations 3, 4 and 5 (Fig 1). The mean EC was 816.20 μ S/cm with a standard Error of 134.71 μ S/cm while a mean of 409.80 mg/L was recorded for TDS with a Standard Error of 134.71 mg/L (Table 1).

Dissolved Oxygen decreased from station 1 (0.85 mg/L) to station 2 (0.25 mg/L) and then increased steadily in stations 3 (0.3 mg/L), 4 (0.4 mg/L) and 5 (0.85 mg/L) (Fig 2). Biochemical Oxygen Demand declined from station 1 (0.4 mg/L), 2 (0.25 mg/L), 3 and 4 (0.05 mg/L) and then a slight increase in station 5 (0.1 mg/L) Fig 2). Table 1 shows mean and standard errors for DO and BOD of 0.53, 0.13 and 0.17, 0.07 respectively.

NO_3 -N increased from station 1 to 2, decreased in 3 and then increased and decreased in stations 4 and 5 in a zigzag manner giving a similar trend with PO_4 -P concentration in the five (5) stations. (Fig.2). the maximum NO_3 -N concentration observed was 3.80 mg/L and a lowest of 0.90 mg/L. PO_4 -P mean concentration observed in the stream was 0.44 mg/L with a standard error of 0.17.

Surface Water Temperature had the highest value of 31°C and lowest of 27°C, Cu and Cr had concentrations below detectable limits (Table 1). Zn, Ni and Cd showed a similar concentrations gradient from station 1 to 5 while Fe showed an opposite trend with the other

metals, decreasing in concentration were the others increase and increasing where they decrease (Fig 3). Among the four (4) metals, only Zn concentration was within the acceptable limits (Table 1).

Parameter	Mean	Standard Error	Minimum	Maximum	Standard	Recommending Agency
pH	7.68	0.12	7.30	8.00	< 8	WHO
EC ($\mu\text{S}/\text{cm}$)	816.20	134.71	298.00	1049.00	1000.00	WHO
TDS (mg/L)	409.80	67.55	149.00	525.00	500.00	WHO
DO (mg/L)	0.53	0.13	0.25	0.85	5.00	WHO
BOD (mg/L)	0.17	0.07	0.05	0.40	5.00	WHO
NO ₃ -N (mg/L)	2.58	0.55	0.90	3.80	10.00	WHO
PO ₄ -P (mg/L)	0.44	0.17	0.02	1.00	5.00	WHO
Temp. (°C)	29.20	0.66	27.00	31.00	NA	NA
Fe (mg/L)	0.47	0.12	0.29	0.89	0.30	SON
Cu (mg/L)	BDL	BDL	BDL	BDL	1.00	SON
Cr (mg/L)	BDL	BDL	BDL	BDL	0.05	SON
Zn (mg/L)	0.39	0.05	0.25	0.56	3.00	SON
Ni (mg/L)	0.40	0.04	0.33	0.50	0.02	SON
Cd (mg/L)	0.09	0.02	0.06	0.16	0.003	SON

EC= Electrical Conductivity, TDS= Total Dissolved Solids, DO= Dissolved Oxygen, BOD= NO₃-N= Nitrate-Nitrogen, PO₄-P= Phosphate-Phosphorus, Temp.= Temperature, BDL= Below Detectable Limit, SON= Standard Organisation of Nigeria, NA= not available

Table 1. Summary Statistic of Water quality characteristics of Samaru stream and standard values for water quality.

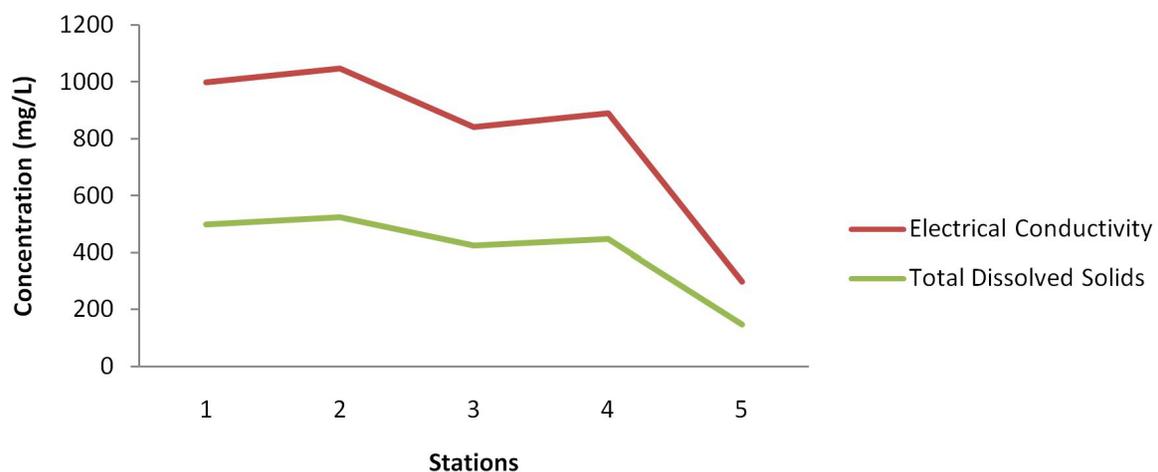


Figure 1. Variation of Electrical Conductivity and Total Dissolved Solids in Samaru stream.

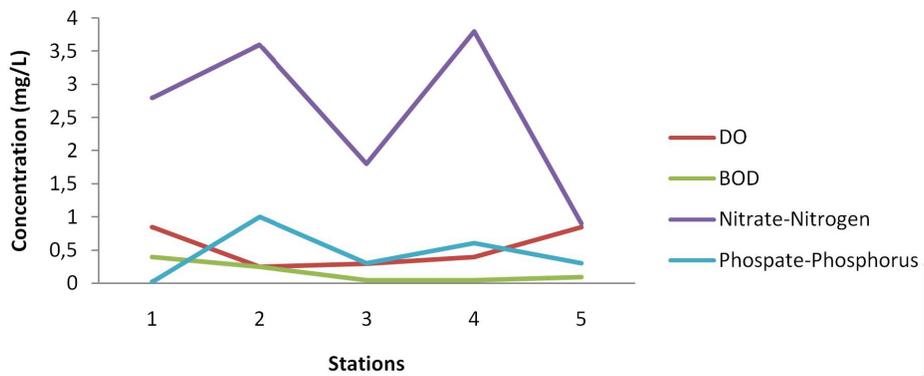


Figure 2. Variation of concentration of Dissolved Oxygen, Biochemical Oxygen Demand, Nitrate-Nitrogen and Phosphate-Phosphorus in Samaru stream.

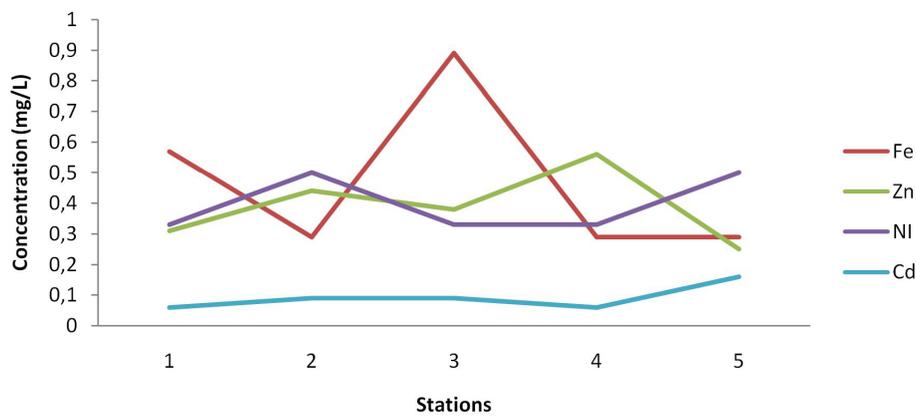


Figure 3. Variation of concentration of Fe, Zn, Ni and Cd in Samaru stream.

The Water quality index and Metal Index showed a similar pattern of distribution in Stations 1 to 4, increasing from 52.45 and 38.1 (station 1) to 58.95 and 56.11 (station 2) decreasing to 55.25 and 49.51 (station 3) and, 48.31 and 37.65 (station 4). In station 5, the lowest WQI of 45.03 was observed while in contrast station 5 recorded the highest MI value of 79.38 (Table 2).

Station	Water Quality Index	Metal Index
1	52.45	38.5
2	58.95	56.11
3	55.25	49.51
4	48.31	37.65
5	45.03	79.38

Table 2. Water Quality and Metal Indices of the five sampling stations in Samaru stream.

Water Quality Index Level	Water Quality Status
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Very Poor Water quality
>100	Unsuitable for drinking

Table 3. Water Quality Index and water quality status (Yogendra and Puttaiah 2008).

Significant positive correlation was observed between Fe concentration and pH ($r=0.76$) ($P<0.01$); Electrical Conductivity and BOD ($r=0.46$) ($P<0.05$), $\text{NO}_3\text{-N}$ ($r=0.83$) ($P<0.01$), Surface Water Temperature (0.68) ($P<0.05$) and Zn (0.57) ($P<0.05$); TDS with BOD ($r=0.45$) ($P<0.05$) and $\text{NO}_3\text{-N}$ ($r=0.83$) ($p<0.01$), Surface Water Temperature (0.69) ($P<0.01$) and Zn ($r=0.58$) ($P<0.01$); DO with BOD ($r=0.40$) ($p<0.05$); $\text{NO}_3\text{-N}$ with $\text{PO}_4\text{-P}$ ($r=0.56$), Temperature ($r=0.69$) ($P<0.01$) and Zn ($r=0.82$) ($P<0.01$); $\text{PO}_4\text{-P}$ with Zn ($r=0.62$) ($P<0.01$) and Ni ($r=0.50$) ($P<0.05$); Temperature with Zn ($r=0.86$) ($P<0.01$); and Ni with Cd ($r=0.74$) ($p<0.01$) (Table 4).

Significant negative correlation was observed between EC and DO ($r=-0.53$) ($P<0.05$), Ni ($r=-0.43$) ($P<0.05$) and Cd ($r=0.89$) ($P<0.01$); TDS with DO ($r=-0.53$) ($P<0.05$), Ni ($r=-0.44$) ($P<0.05$) and Cd ($r=-0.89$) (0.01); DO with $\text{NO}_3\text{-N}$ ($r=-0.50$) ($P<0.05$), $\text{PO}_4\text{-P}$ ($r=-0.73$) (0.01), Surface Water Temperature ($r=-0.64$) ($P<0.01$) and Zn ($r=-0.73$) ($P<0.01$); $\text{NO}_3\text{-N}$ with Cd ($r=-0.80$) ($P<0.01$); $\text{PO}_4\text{-P}$ and Fe ($r=-0.52$) ($P<0.05$); Surface Water Temperature with Ni ($r=-0.74$) ($P<0.01$) and Cd ($r=-0.83$) ($P<0.01$); Fe with Ni ($r=-0.60$) ($P<0.01$); and Zn with Cd ($r=-0.64$) ($P<0.01$) (Table 4).

	pH	EC	TDS	DO	BOD	$\text{NO}_3\text{-N}$	$\text{PO}_4\text{-P}$	Temp.	Fe	Zn	Ni	Cd
pH	1.00											
EC	0.37	1.00										
TDS	0.36	1.00	1.00									
DO	-0.23	-0.53*	-0.53*	1.00								
BOD	0.34	0.46*	0.45*	0.40*	1.00							
$\text{NO}_3\text{-N}$	-0.19	0.83**	0.83**	-0.50*	0.26	1.00						
$\text{PO}_4\text{-P}$	-0.15	0.30	0.30	-0.73**	-0.20	0.56*	1.00					
Temp.	-0.05	0.68*	0.69**	-0.64**	-0.24	0.69**	0.21	1.00				
Fe	0.76**	0.21	0.21	-0.15	-0.05	-0.31	-0.52*	0.27	1.00			
Zn	-0.35	0.57*	0.58*	-0.73**	-0.33	0.82**	0.62**	0.86**	-0.21	1.00		
Ni	-0.10	-0.43*	-0.44*	0.06	0.03	-0.25	0.50*	-0.74**	-0.60**	-0.33	1.00	
Cd	-0.11	-0.89**	-0.90**	0.34	-0.33	-0.80**	-0.03	-0.83**	-0.23	-0.64**	0.74**	1.00

EC= Electrical Conductivity, TDS= Total Dissolved Solids, Temp.= Surface Water Temperature, DO= Dissolved Oxygen, BOD = Biochemical Oxygen Demand, $\text{PO}_4\text{-P}$ = Phosphate-Phosphorus, $\text{NO}_3\text{-N}$ = Nitrate-Nitrogen, *Significant $P<0.05$, **Significant $P<0.01$

Table 4. Pearson Correlation Coefficient of physicochemical characteristics of water of Samaru stream.

5. Discussion

On the basis of water Quality Index, stations 1, 2 and 3 (upstream stations) may be classified to be of poor water quality, whereas stations 4 and 5 may be classified to be of good water quality. The trend where downstream stations are of a better water quality when the source of pollution is upstream may be explained by the role bacteria, algae and aquatic macrophytes play in ultra filtration of polluted water as it flows from upstream-down stream. Similar results have been reported Tiseer *et al.*, (2008a) and Taurai (2012).

The mean metal concentration of Fe, Ni and Cd observed were above the permissible limit in drinking water (SON, 2007), while the high metal index observed in the stream may be a great indication that the sewage entering the stream contains a high concentration of heavy metals. The higher MI observed in station 5 may be as a result of pollution from the University Press and/or the dumpsite behind Icsa/Ramat Halls.

Abolude *et al.*, (2009) reported that concentrations of seven (7) out of the nine (9) studied trace elements (including Fe, Ni and Cd) in the Kubanni reservoir were above the recommended levels for drinking water, the present study implicates the Samaru stream to be an important contributor to the problem.

The significant relationships observed between pH and Surface Water Temperature and parameters such as DO, PO₄-P, NO₃-N, EC, TDS, Fe, Zn, Ni, Cd may be attributed to the reason that the solubility of this chemical substances in water is affected by pH and Temperature.

5.1. Recommendations

Measures are required to be taken to halt the continuous inflow of sewage into the Samaru stream from the Samaru village and the some student hostels (Danfodio, Sasakawa and Icsa/Ramat) of the Ahmadu Bello University, Zaria to reduce or totally eliminate the continuous pollution of water in the Samaru stream and the University reservoir by extension.

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