Libyan Agriculture Research Center Journal International 1 (2): 115-1, 2010
ISSN 2219-4304

Effect of Pollution on the Physico-chemical Parameters of Water and Sediments of River Galma, Zaria, Nigeria

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Abstract: The River Galma basin around Zaria, was studied in order to determine the whether pollution was responsible for the increasingly low fish catches from the river. This was done by comparing the physico-chemical parameters of water and sediments in the upstream area before the Zaria dam where human and industrial population is low with the downstream area after the dam where human population is high and industries are concentrated. Water and sediment samples were collected from twenty sampling points (ten points each in both upstream and downstream areas) and thirteen physico-chemical parameters of the River water were analysed. Ten physico-chemical parameters of the sediments were also analysed. Results show that values for pH, total solids, total suspended solids, hardness, nitrate and phosphate were higher in the upstream area while values for dissolved oxygen, transparency and conductivity were higher in the downstream area. It was concluded that the physico-chemical parameters of the River water are favourable for fish production and so pollution may not responsible for low fish landings reported by fishermen. The River water is also a suitable source of water for the Zaria municipal water works. All parameters, except alkalinity and phosphate content, had higher mean values in upstream area sediments than in downstream area sediments and this may be due to the higher residence time of water in the upstream area because of the dam

Key words: River Galma % Upstream area % Downstream area % Water % Sediments % Residence time

INTRODUCTION

Fish production from inland water resources (rivers, lakes and streams) is under threat from pollution, habitat alteration and degradation, changes in river flows and over-exploitation [1]. The Lagos State Environmental Protection Agency estimated that pollution and over-fishing combined to reduce fish catches from 1 million kg in 1980 to 100,000 kg in 1990 in the Lagos lagoon [2]. According to Wotton [3], material pollution of rivers is caused by toxic pollutants (heavy metals, phenols, insecticides etc) that have direct adverse effect on aquatic biota and by pollutants that indirectly affect aquatic biota like human and animal waste which are not toxic but due to bacterial action on them, dissolved oxygen is used up which harms aquatic biota. River Galma is the main drainage channel in Zaria since other rivers and streams discharge into it. Zaria is in the North central Kaduna state of Nigeria and is located at latitude 11^{0}3'N and longitude 7^{0}40'E, 128km South-East of Kano and 64km North-East of Kaduna City. Zaria falls into the Guinea Savanna climate which has distinct wet and dry seasons [4]. The Zaria dam is on River Galma. The Galma river basin is a booming agricultural zone. Crops like Irish/Sweet Potato, vegetables (like carrot, garden egg, tomato etc.), cereals (like maize and rice) etc. are planted on both sides of the river bank throughout the year. Fertilizers, herbicides and insecticides are used on these crops and are eventually washed into the river via surface runoff. Petrol powered water pumps are used to irrigate the farmlands in the dry season and this enables petroleum wastes to get into the River. Most of the industries (tobacco, metal smelting, electricity meter manufacturing, ginnery, textile, vegetable oil mill etc.) located in Zaria discharge their wastes directly into the River while others discharge into rivers and streams that empty into it. Trade wastes (from auto-mechanics, metal fabrication/finishing, abattoirs, local tanneries etc.) are also directly or indirectly discharged into the River. Domestic sewage and refuse also find their way into the

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river from the many settlements along the river via leaching, direct discharge and surface runoff. All these wastes point to potential pollution of the River. Indeed, fish caught on part of the River (the study area) where human population and industries are concentrated are usually darker in colour than those caught in areas with lower human and industrial concentration. Fishermen in the River Galma basin also complain of low fish catches. The Global Environment Monitoring System (GEMS), states that sewage, nutrients, toxic metals, industrial and agricultural chemicals are the main river pollutants and river water quality is defined by over fifty water quality parameters [5]. Water quality is the suitability of water for the survival and growth of aquatic organisms like fish [6]. Water quality is defined by the physical, chemical and biological characteristics of water which include Temperature, turbidity, Dissolved oxygen content, Biochemical oxygen demand, pH, alkalinity, Hardness, Nutrient (nitrate and phosphate) content, ammonia and nitrite contents, faecal coliform content etc. The aim of this study is to determine the physico-chemical status of River Galma water and sediments, compare them to national and international standards and determine the suitability of the River for use in drinking and fish production. The study will also provide baseline data for future work on the River.

MATERIALS AND METHODS

(a) Sample collection: The river was divided into downstream and upstream areas (Fig. 1) and 10 sampling points each were chosen on both the study area (points 1 to 10) and control area (points A to J) giving a total of 20 sampling points. In choosing the points, preference was given to such factors as points of effluent discharge into the river, points of confluence between River Galma

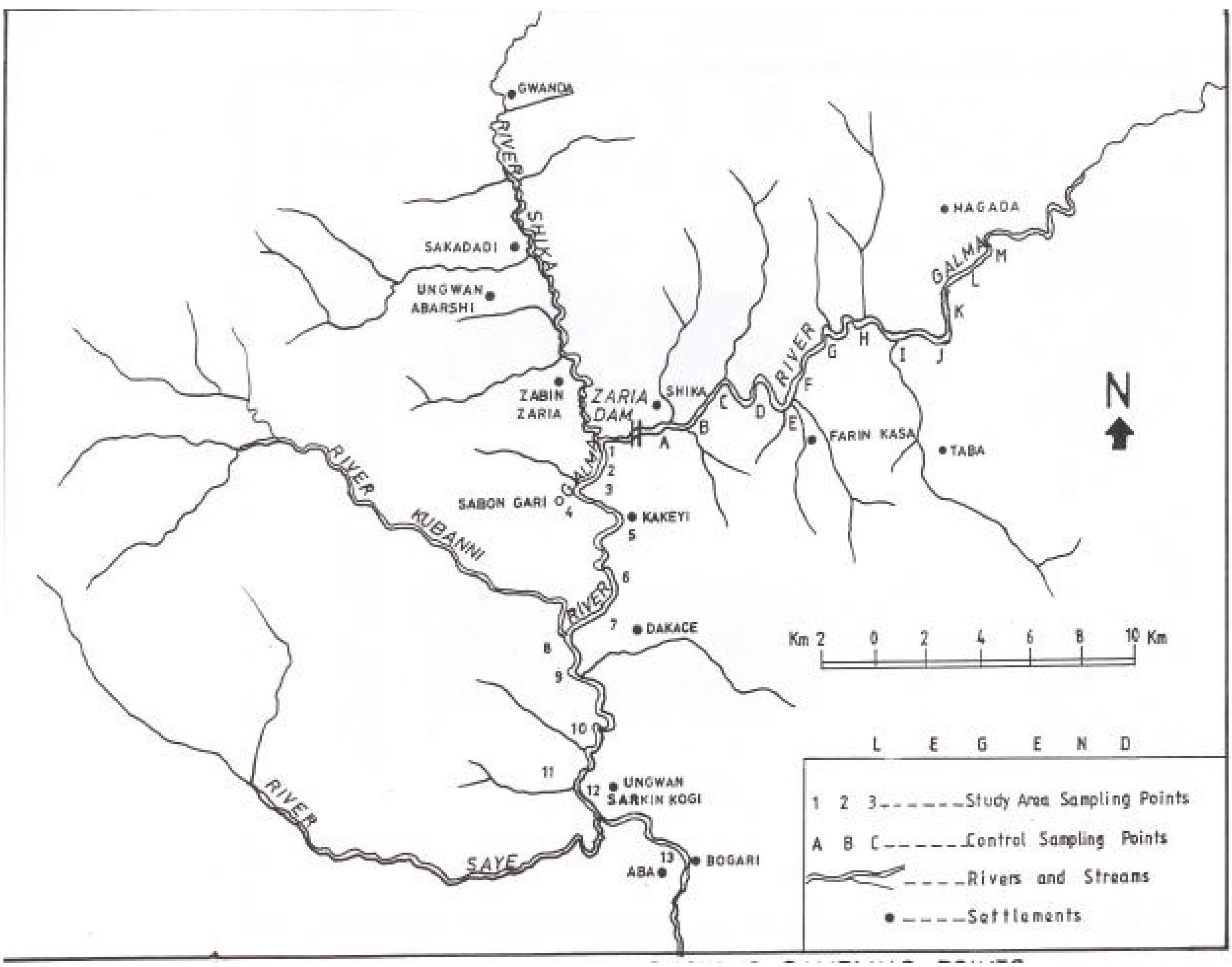

Fig. 1: Layout of Galma River showing sampling points

and other rivers and nearness of sampling point to settlements. A canoe was used as sampling craft and at each point the canoe was stopped for water and sediment samples to be collected. Water samples were collected with 1 litre polyethylene bottles. The bottles were rinsed with river water before collection and temperature /pH measured immediately after collection. Water samples for DO and BOD measurements were collected with 300ml BOD bottles. Sediment samples were collected with Eckman grab sampler at each point. Water samples were acidified with 1.5ml concentrated HNO_3/litre of sample [8] after pH, conductivity and temperature measurements. Sediment samples were wrapped with polythene bags, kept on ice and subsequently, transported to the laboratory. Sediment samples were air dried and sieved with a 200µm sieve before sediment analysis. Sediment samples were analysed in triplicate

(b) Measurement of physico-chemical parameters of water samples: A pre-calibrated HANNA pH/temperature/conductivity meter (model H1991000) was used for pH, temperature and electrical conductivity (EC) measurements. pH of each water sample was measured by inserting the probe into the water immediately after collection. It was rinsed and left standing in double distilled water before being used for further pH measurement. Temperature and conductivity readings were also taken at the same time as pH. Total Solids (TS) and Total Dissolved Solids (TDS) were analysed according to the standard methods [8]. Total suspended solids (TSS) were determined by the difference between TS and TDS. Transparency was measured at each sampling site with a Secchi disc of 30cm diameter [9]. Total Alkalinity was determined by titration of water samples with standard 0.01mol dm^{-3} HCl with methyl orange as indicator [10]. Total Hardness was determined by titrating water samples with standard EDTA titrant with Eriochrome black-T as indicator according to standard methods. The Modified Winkler-Azide Method was used to analyse water samples for dissolved oxygen (DO) while Biochemical oxygen demand (BOD_5) was determined by the difference between DO of samples immediately after collection and DO of samples after incubation at 20 ^{0}C for five days. The phenoldisulphonic acid method was used to analyse water samples for nitrate (NO_3^-) content while ammonium molybdate reagent (Deniges reagent) and stannous chloride were used to determine phosphate (PO_4^{3-}) contents of water samples [8]. In both cases, a CHROMA colorimeter (model 257) was used to measure absorbances..

(C) Measurement of physico-chemical parameters of sediment samples: pH of each sediment sample was determined by weighing 15g of air dried sediment sample into a 50ml beaker and adding 20ml of double distilled water. This was stirred with a glass rod and allowed to stand for 30 minutes. A pre-calibrated HANNA pH meter (model H1991000) was inserted into the slurry and pH taken [11]. Electrical conductivity (EC) of sediment samples was measured with a conductivity meter after the samples were shaken on a mechanical shaker, filtered and sodium metaphosphate added [11]. Organic Matter content of sediment samples were analysed by ignition at 500°C and calculation of the difference between weights before and after ignition [12]. Total Alkalinity of each sediment sample was determined by extraction with double distilled water on a mechanical shaker, centrifugation of the suspension and titration of the supernatant with standard 0.01mol dm^{-3} HCl with methyl orange as indicator. Nitrate (NO_3^-) contents of sediment samples were analysed by extraction with 2 mol dm^{-3} KCl solution, filtration and digestion of filtrate with Magnesium oxide to drive away ammonia, addition of sulphamic acid and Devarda's alloy to destroy nitrite and convert nitrate to ammonium nitrogen respectively. This was followed by steam distillation and titration with standard Sulphuric acid. Nitrite (NO_2^-) content was determined for each sample by repeating the analysis for nitrate above but without the addition of Sulphamic acid. This gives the amount of NO_3^- and NO_2^- in each sample and subtraction of amount of NO_3^- in each sample from this value gives the amount of NO_2-in each sample. Phosphate (PO_4^{3-}) contents were analysed after extraction with a mixture of NH_4F and KCl solutions, mechanical shaking, filtration and addition of ammonium molybdate reagent (Deniges reagent) and drops of stannous chloride followed by the measurement of absorbances at 690 nm using a CHROMA colorimeter (model 257). Chloride (Cl^-) content was determined by extraction with double distilled water, addition of drops of 5% K_2CrO_4 indicator and titration with 0.01 mol dm^{-3} $AgNO_3$ in micro burette. Sulphate (SO_4^{2-}) content of the sediment samples were determined by extraction with KH_2PO_4 solution addition of 1ml of gelatin-$BaCl_2$ solution and double distilled water, thorough mixing and measurement of the absorbance of the solution formed after allowing it to stand for 30 minutes. Cation Exchange Capacity (CEC) was analysed by extraction with ammonium acetate solution, filtration and leaching with NH_4Cl and NaCl solutions followed by distillation over 2% Boric acid and titration of the NH_4-Borate distillate with standard 0.1mol dm^{-3} HCl [11].

(d) Statistical analysis: The results were analyzed using Pearson correlation analysis and single factor analysis of variance (ANOVA). Pearson correlation coefficient, r, is a dimensionless index that ranges from-1.0 to 1.0 inclusive and shows the degree of linear relationship between two sets of data, {X} and {Y} **(Uzairu, 2006)**. If there is perfect linear relationship with positive slope between the two variables, correlation coefficient is 1; if there is positive correlation, whenever one variable has a high (low) value, so does the other. If there is negative correlation, whenever one variable has a high (low) value, the other has a low (high) value. A correlation coefficient of 0 means that there is no linear relationship between the variables. An ANOVA is an analysis of the variation present in an experiment. It is a test of the hypothesis that the variation in an experiment is no greater than that due to normal variation of individuals' characteristics and error in their measurement. ANOVA puts all the data into one number (F) and gives us one P for the null hypothesis. The t-test tells us if the variation between two groups is "significant". P reports the significance level.

RESULTS AND DISCUSSION

Table 1 and 2 show the physico-chemical parameters of water from downstream and upstream areas. There was progressive temperature increase across each area due to the fact that ambient temperature increased as sampling progressed. pH values in the downstream area ranged from 6.02 to 7.40 while those of the upstream area ranged from 7.12 to 8.14. Conductivity ranged from 93μScm^{-1} to 120μScm^{-1} in the downstream area and from 80μScm^{-1} to 103μScm^{-1} in the upstream area. Total solids were generally lower in downstream area (mean 74.2±33.79mg/L) than in the upstream area (mean 94.8±22mg/L). Indeed, it was observed that upstream area water was more turbid than downstream area water and this is confirmed by the higher values for total suspended solids (TSS) obtained for upstream area water (mean, 47.4±20.52mg/L) compared to downstream area water (mean, 30.1±27mg/L). The values for transparency in the downstream area ranged from 15.2 to 46.5cm while those of the upstream area ranged from 10 to 30.5cm and this confirms the fact that upstream area water is more turbid than downstream area water. Mean dissolved oxygen in the downstream area was 5.78±0.54mg/L while that of the upstream area was 5.62±0.78mg/L. BOD ranged from 4.5 to 6.0 mg/L in the downstream area and from 4.0 to 5.7mg/L in the upstream area. Hardness ranged from 60 to 72mg/L in the downstream area while that of the upstream area was 65.9 to 76.7 mg/L. Alkalinity in the downstream area ranged from 61 to 69 mg$CaCO_3$/L (mean, 64.0±1.85mg$CaCO_3$/L) and from 29.0 to 73 mg$CaCO_3$/L (mean, 65.9±3.71mg$CaCO_3$/L) in the upstream area. Values for NO_3-content ranged from 1.4 to 2.4mg/L in the downstream area (mean, 1.95±0.3mg/L) and from 1.85 to 9mg/l (mean, 4.61 ±2.47mg/L) in upstream area. Values for PO_4^{3}- were also higher in upstream area water (mean 5.16 ±1.25mg/L) than in downstream area (mean 4.03±0.72 mg/L). Correlation analysis shows that values for electrical conductivity, alkalinity and NO_3^- and PO_4^{3-} contents from both areas were negatively correlated while other parameters had positive correlation. Single factor ANOVA shows that there's significant difference ($P<0.05$) in temperature, pH, transparency, BOD, Hardness, NO_3^- and PO_4^{3-}contents between both areas. However, no significant difference exists ($P>0.05$) for other parameters when values from both areas are compared. Fakayode [13], studied the physic-chemical parameters of Alaro River, Ibadan and found that mean PO_4^{3}-content in the downstream section of the river was 4.62±_2.07 mg/L. Mean PO_4^{3-}in the downstream area of this investigation is below that of Fakayode [13] while that of the upstream area is above it. Yisa [14], in an analysis of upstream water from River Challawa, obtained the following ranges for physico-chemical parameters: pH, 6.72-8.50; EC, 58-946 μScm^{-1}; TDS, 34-520 mg/L; BOD, 100-935 mg/L etc. these values are considerably higher than the values from this investigation due to the higher industrial and human population in the River Challawa area compared to River Galma area. Ranges for physico-chemical parameters (DO, 1.4-4.8 mg/L; pH, 6.7-7.2 and alkalinity, 24.2-25.4 mg$CaCO_3$/L) obtained by Fafioye *et al*. [15] for water from Omi waterbody are generally lower than values obtained in both downstream and upstream areas of this investigation. Adakole *et al*. [16] obtained the following values for physico-chemical parameters of River Galma water collected from one sampling point within the downstream area of this investigation: pH, 7.3±0.27; Conductivity, 126.0±122; Transparency, 32.16±2.09; DO, 6.9±2.34; BOD, 1.5±1.98; Total Hardness, 97.3±50.8 and total alkalinity, 24.8±10.06. These values are all higher than the mean values for physico-chemical parameters obtained for the downstream area of this investigation except the value for BOD and alkalinity. Tukura *et al*. [17] obtained a mean pH of 6.59±0.10 for River Kubanni dam water (identical to the upstream area of this investigation) which is lower than the mean pH (7.5±0.27) obtained for the upstream area of

Table 1: Physico-chemical Parameters of Water-Downstream area

SP	Temp (°C)	pH	EC (µscmG^{1})	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	Trans-parency (cm)	DO (mg/L)	BOD (mg/L)	Hardness (mgCaC0$_3$/L)	Alkalinity (mgCaC0$_3$/L)	NO_3^- (mg/L)	PO_4^{-3} (mg/L)
1	23.6	7.08	107	75	48	27	25.0	5.1	4.5	62	61	1.9	4.0
2	27.6	6.99	109	66	52	14	22.7	5.3	5.0	64	64	2.4	4.6
3	28.8	7.14	99	70	50	20	28.2	5.6	5.1	58	62	1.4	3.5
4	28.5	6.86	117	63	41	22	33.7	5.9	5.4	70	65	2.1	4.1
5	27.8	7.01	104	40	31	9	46.5	6.6	5.8	56	67	2.2	3.8
6	27.8	6.97	93	44	31	13	40.3	5.2	4.8	68	62	1.7	3.0
7	28.3	7.02	100	78	45	33	40.0	6.3	5.7	57	61	2.3	3.9
8	30.2	6.02	114	85	53	44	30.8	6.0	5.5	70	69	2.0	4.8
9	30.1	7.35	120	89	51	38	24.9	6.2	6.0	72	63	1.6	3.6
10	29.6	7.40	111	132	51	81	15.2	5.6	5.2	60	66	1.9	5.0
Mean	28.5	6.98	107.4	74.2	45.3	30.1	30.73	5.78	5.30	63.7	64.0	1.95	4.03
SD	±1.16	±0.36	±8.87	±33.79	±9.97	±27	±11.63	±0.54	±0.46	±5.66	±1.85	±0.3	±0.72
Standards	23-35[a]	6.5-9[b]	350[c]			30 mg/l[a]	20-50[d]	$\geq$5[e]	10[a]	20-200[d]	80-200[d]	<10[a]	
WHO[f]		7.0-8.5	750	500	1500				100	100		45	

a [18]; b [27]; c[19]; d [20]; e [21]; f [22]. SP = sampling point; SD = standard deviation °C = degree centigrade; µscm^{-1} = micro siemens per centimetre; mg/L = milligram per litre; cm = centimetre; mgCaC0$_3$/L = milligram Calcium Carbonate per litre

Table 2: Physico-chemical Parameters of Water-Upstream area

SP	Temp (°C)	pH	EC (µscmG^{1})	TS (mg/L)	TDS (mg/L)	TSS (mg/L)	Trans-parency (cm)	DO (mg/L)	BOD (mg/L)	Hardness (mg CaC0$_3$/L)	Alkalinity (mgCaC0$_3$/L)	NO_3^- (mg/L)	PO_4^{-3} (mg/L)
A	23.6	7.65	93	113	45	68	13.6	5.3	4.6	68.0	73.0	1.85	5.0
B	24.0	7.48	90	100	49	51	15.4	5.0	4.5	72.4	69.4	2.4	3.6
C	24.5	7.31	80	85	40	45	19.2	5.1	4.3	76.7	72.9	5.1	6.1
D	24.8	7.45	89	62	43	19	30.5	6.5	5.0	80.1	67.0	9.0	6.8
E	25.2	7.44	100	81	42	39	23.3	5.9	5.4	70.0	67.1	6.3	7.6
F	25.7	7.63	92	90	50	40	20.4	5.1	4.2	65.9	64.3	3.7	4.7
G	26.2	7.12	103	96	52	44	18.0	4.7	4.0	68.0	75.0	4.5	5.2
H	26.8	7.19	98	80	47	33	24.0	5.5	4.5	76.7	29.0	2.9	4.05
I	27.3	8.14	94	118	55	63	16.1	6.3	5.5	74.6	70.6	4.8	5.5
J	28.9	7.63	103	123	50	73	10.0	6.8	5.7	71.0	71.0	5.5	3.05
Mean	25.7	7.5	94.2	94.8	47.4	47.4	19.1	5.62	4.77	72.3	65.9	4.61	5.16
SD	±1.56	±0.27	±6.74	±22	±3.26	±20.52	±7.37	±0.78	±0.57	±4.72	±3.71	±2.47	±1.25
Standards	23-35[a]	6.5-9[b]	350[c]			30 mg/l[a]	20-50[d]	$\geq$5[e]	10[a]	20-200[d]	80-200[d]	<10[a]	
WHO[f]		7.0-8.5	750	500	1500				100	100		45	

a [18]; b [27]; c[19]; d [20]; e [21]; f [22]

this investigation. This may be due to the fact that Kubanni dam water receives more pollutants since it is the main drainage channel for the Samaru/Ahmadu Bello University area. Downstream area water was generally more acidic (mean pH 6.98±0.36) than upstream area water (mean pH 7.5±0.27). pH of water in both areas were within the limits set by UNEP [18] for freshwaters. Downstream area water seems to contain more ions than upstream area water which translated into higher conductivity values. Conductivity values from both areas were below the upper limit of 350µScmG^{1} set by ANZECC and ARMCANZ [19]. The higher turbidity of upstream area water may be due to the higher clay content of upstream area sediments. Transparency values from both areas were all lower than the 50mg/L upper limit recommended by Nath [20]. Apart from sampling point G in the upstream area, DO levels in both areas were above the lower limit of 5mg/lit recommended by Swingle [21]. The values for hardness were within the upper limit of 200 mg/L recommended by Nath [20]. The higher alkalinity values from the upstream area explain why upstream area water is more basic than that of downstream area. Values for NO_3-from both areas were all lower than the upper limit of 10 mg/L set by UNEP [18]. The higher values for both nitrate (NO_3^-) and phosphate (PO_4^{3-}) in the upstream area may be due to the higher use of fertilizers and herbicides

Table 3: Mean (±SD) Physico-chemical Parameters of Sediment-Downstream area

Sampling points	pH	EC (μScmG^{1})	Organic Matter (%)	Alkalinity ($mgCaC0_3/kg$)	NO_3^- (mg/kg)	NO_2- (mg/kg)	PO_4^{3}- (mg/kg)	SO_4^{2-} (mg/kg)	Cl^- (mg/kg)	CEC Cmol/kg
1	5.66±0.01	393.5+1.±5	2.93±0.1	12±2	0.91±0.01	0.43±0.025	6.13±0.025	4.725±0.025	0.77±0.03	6.5±0.2
2	5.44±0.02	195±1.0	3.44±0.02	13.5±1.5	0.87±0.22	0.215±0.015	9.24±0.01	3.685±0.035	0.47±0.03	3.25±0.15
3	6.86±0	77±3.0	4.09±0.016	23±1	0.74±0.01	0.16±0.01	8.72±0.025	3.64±0.06	1.10±0.1	4.1±0.1
4	5.84±0.01	159±2.0	3.935±0.005	16±0	0.80±0.01	0.34±0.02	4.98±0.016	2.975±0.025	0.89±0.01	3.6±0.1
5	6.65±0.03	230.5±0.5	3.875±0.025	11±1	1.145±0.045	0.61±0	10.38±0.039	4.8±0	0.82±0.02	2.2±0.1
6	6.01±0.02	128±1.0	2.97±0.01	19±1	1.13±0.045	0.51±0.01	12.09±0.08	4.74±0.03	0.62±0.02	2.4±0.1
7	5.285±0.005	109±1.0	4.25±0.05	26±2	0.775±0.035	0.17±0.02	9.5±0.02	4.35±0.15	1.19±0.01	11.95±0.05
8	5.69±0.01	125±3.0	4.01±0.01	20±0	0.755±0.025	0.19±0.01	6.65±0.06	1.395±0.015	0.99±0.03	3.4±0.2
9	6.07±0.06	293±3.0	4.375±0.045	14±0	0.80±0	0.27±0.02	5.61±0.064	4.56±0.03	1.00±0	4.7±0.2
10	6.35±0	267±2.0	3.935±0.035	16±0	0.85±0.016	0.275±0.025	5.89±0.016	2.65±0.05	0.49±0.01	5.4±0.1
Mean	5.99	197.7	3.781	17.05	0.878	0.317	7.919	3.752	0.834	4.75
SD	±0.51	±98.5	±0.503	±4.88	±0.147	±0.154	±2.386	±1.127	±0.248	±2.85

mg/kg = milligram per kilogram; Cmol/kg = centimole per kilogram

Table 4: Mean (±SD) Physico-chemical Parameters of Sediment-Upstream area

points	Sampling pH	EC μscmG^{1}	Organic Matter (%)	Alkalinity ($mgCaC0_3/kg$)	NO_3^- (mg/kg)	NO_2^- (mg/kg)	PO_4^{3-} (mg/kg)	SO_4^{2-} (mg/kg)	Cl^- (mg/kg)	CEC Cmol/kg
A	5.05±.045	570±9	5.55±0.05	13±1	0.93±0.03	0.365±0.015	6.93±0.06	4.78±0.02	0.83±0.03	8.1±0
B	5.67±0.01	233±1.0	4.03±0.03	12±2	1.14±0.01	0.505±0.045	6.88±0.03	4.87±0.030	0.89±0.01	8.3±0.1
C	6.93±0.016	71±4	6.05±0.07	10±2	0.95±0.04	0.43±0.02	4.44±0.04	2.085±0.045	1.325±0.005	7.2±0.1
D	6.64±0.0	172.5±1.5	7.73±0.07	14±0	1.075±0.025	0.50±0	5.32±0.01	4.36±0.03	1.7±0.02	5.9±0.1
E	5.34±0.005	66±12	8.145±0.045	16±0	1.045±0.045	0.455±0.015	8.48±0.02	5.09±0.11	1.62±0.02	7.2±0.1
F	5.68±0.025	299±1	10.76±0.06	12±0	1.235±0.025	0.435±0.005	12.34±0.04	4.965±0.045	1.655±0.025	12.6±0.3
G	7.65±0.035	257±1	8.25±0.03	11±1	1.025±0.075	0.525±0.025	10.075±0.075	5.945±0.015	1.34±0.06	16.8±0.4
H	6.26±0.035	142±0	6.20±0.00	14±0	0.935±0.055	0.34±0.02	7.32±0.02	3.31±0.01	1.48±0.04	9.25±0.25
I	5.905±0.005	116±1	4.225±0.025	9±1	0.85±0.02	0.24±0.01	6.205±0.015	2.18±0.02	1.36±0.04	8.25±0.15
J	5.26±0.016	145±2	3.815±.015	12±0	0.82±0.01	0.405±0.005	3.885±0.035	4.065±0.035	1.23±0.01	6.85±0.15
Mean	6.04	207.15	6.476	12.3	1.00	0.42	7.188	4.165	1.343	9.045
SD	±0.83	±148.82	±2.239	±2.058	±1.129	±0.087	±2.574	±1.273	±0.299	±3.273

in the upstream area than in the downstream area since the R. Galma basin is a booming crop farming zone in both dry and rainy seasons. The higher nutrient content (indicated by NO_3-and PO_4^{3-}) of upstream area water may be responsible for the lower DO and BOD values compared to the downstream area due to more microbial action and higher consumption of DO in upstream area water. Comparison of these physico-chemical parameters limits set by UNEP or recommended by different authors, show that River Galma water is favourable for growth and reproduction of fish since most physico-chemical parameters are within the limits. Upstream area water seems to be richer in nutrients (though more turbid) than downstream area water. Comparison of the results to WHO [22] desirable limits in drinking water show that while the pH of downstream area water was below the lower limit, that of upstream area water was within the limit and one can conclude that River Galma water is fit for use as source water for the Zaria municipal water works which supplies tap water to Zaria and its environs.

Table 3 and 4 show the physico-chemical parameters of downstream and upstream area sediments respectively. pH of downstream area sediment was highest at sampling point 3 and lowest at point 7 (mean, 5.29) with a mean of 5.99±0.51 while that of upstream area was highest at point G and lowest at point A (mean, 6.04±0.83). Conductivity ranged from 77 to 393.5 μScmG^{1} in the downstream area sediment samples and from 66 to 570 μScmG^{1} in upstream area sediments. The lowest sediment organic matter content in the downstream area was recorded at point 1 (2.93%) and the highest at point 9 (4.375%). Organic matter content in the upstream area ranged from 3.185% at point J to 10.76% at point F. The range of values for alkalinity in the downstream area was from 11 to 26 $mgCaCO_3/L$ while that of the upstream area was from 9 to 16 $mgCaCO_3/L$. NO_3-and NO_2- contents in the downstream area ranged from 0.74 to 1.145 mg/kg and from 0.16 to 0.51 mg/kg respectively. In the upstream area, the ranges were 0.82 to 1.235 mg/kg for NO_3-and 0.24 to 0.525 for NO_2^-. PO_4^{3}- ranged from 4.98 to 12.09 mg/kg in the downstream area and from 3.885 to 12.34 mg/kg in the upstream area. A range of 1.395 to 4.74 mg/kg was recorded for SO_4^{2}-in the downstream area while that of the upstream area was 2.085 to 5.945 mg/kg. Range of values for Cl-and CEC were 0.49 to 1.19 mg/kg and 2.2 to 6.5 Cmol/kg, respectively, in the downstream area. Values for both parameters in the upstream area ranged from 0.83 to 1.7 mg/kg for Cl-and from 5.9 to 16.8 Cmol/kg for CEC. All parameters except alkalinity and PO_4^{3-}, had higher mean values in upstream area than in downstream area. There's significant difference ($P<0.05$) in pH, organic matter, alkalinity, Cl-content and CEC between samples collected from downstream and upstream areas. However, no significant difference existed between values for EC, NO_3^-, NO_2^-, PO_4^{3}-and SO_4^{2}-from both areas. Correlation analysis shows that pH, organic matter, alkalinity values from both areas were negatively correlated while other parameters showed positive correlation.

Lee *et al*. [23] found that the bed sediments of Anyang River, Korea collected at eight sampling points were mostly acidic (pH range, 4.0-7.0). Downstream area sediments of this investigation were generally more acidic than those of upstream area possibly due to the more acidic nature of study area water compared to upstream area water (section 4.3.1). Electrical conductivity was higher in upstream area sediment possibly due to the higher content of NO_3^-, SO_4^{2}-and Cl-ions. Range for Cl^- content in both areas were lower than the range (3.5 to 15.3mg/kg) obtained by Odokuma and Abah [24] in a study of sediments of New Calabar River. Organic matter content of upstream area sediments were generally higher than those of the downstream area which can be attributed to the longer residence time of water in the dam basin where the upstream area is located and which leads to more organic matter being collected in this area than in the downstream area. This is also reflected in the higher mean values for NO_3-and NO_2-in the upstream area. Cation exchange capacity (CEC) of the upstream area is higher than that of the downstream area which can be attributed to higher sites for exchange and possibly, higher amount of cations in upstream area sediments. A look at the four tables shows that there's hardly any relationship between, physico-chemical parameters of water and those of the sediments. It is known that sediments act as sink and source of supply of pollutants to the overlying water column in aquatic systems [25, 26], but no positive correlation has been established between physico-chemical parameters of water and sediments of River Galma in this in this study.

CONCLUSION

The study revealed that despite the unregulated discharge of wastes into River Galma, the river water is suitable for fish production since the water quality parameters determined were generally within desirable limits. Thus, pollution may not be the reason for low fish landings reported by fishermen and other reasons like over fishing may be responsible. However, pollution from substances like heavy metals and organic micro pollutants need to be studied in order to reach a conclusion on the effect of pollution on River Galma. The River water is also suitable for use by the Zaria water works for supply of water to Zaria city after treatment. Most sediment parameters measured were higher in the control area than in the study area. However, no distinct relationship was observed between water and sediment parameters.

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