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An Assessment of the Physio-Chemical and Bacteriological Parameters of Water Quality in River Chanchaga, Minna, Niger State, Nigeria

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ABSTRACT

The study aimed to assess the effects of anthropogenic activities on water quality in River Chanchaga. Specifically, the objectives were to assess the quality of water parameters in the study area and examine the influence of human activities on the depletion of natural vegetation cover of the river. Landsat 7 Enhanced Thematic Mapper (ETM) imageries were used to detect the net changes in vegetation cover for two time periods (1986 - 2000 and 2001 - 2015). Also, water samples from 11 sites at 90 cm depth below the water surface were taken along River Chanchaga during the wet and dry seasons. The samples were analyzed for key physico-chemical properties to determine the water quality. A total of Nineteen (19) physico-chemical parameters were analyzed to determine the level of water pollution. The results revealed a 31.62%, decline in vegetation cover between 1986 and 2001 and a further decrease of 40.50% between 2001 and 2015 in the study area. The vegetation changes were attributed to agricultural activities and growing human settlements along River Chanchaga. The mean differences between water quality in dry and rainy seasons was 0.168 of the total value in the study area. The values were considered significant where the calculated value is less than α value of 0.05. The parameters' threshold indicates that River Chanchaga is polluted when compared to Nigeria National Standard for Drinking Water Quality (NSDWQ). The study recommends that dwellers along River Chanchaga be educated on getting their water treated before consumption. It is also recommended that government and other relevant authorities organize public enlightenment programmes against activities which pollute water sources.

Keywords: Anthropogenic, pollution, water quality, vegetation cover.

1. INTRODUCTION

Water sources such as harbors, bays, creeks, canals, swamps, lakes and streams form small network of the river system (Adakole and Annune, 2003). In Nigeria, waterways (rivers) have been the medium to an increasing pollution load from contaminated runoff. The contaminated runoff comes from agriculture, domestic (residential), industrial, commercial, recreational land uses (Adakole and Annune, 2003). Ogbogu and Hassan (1996) observed that contaminants usually carried into water bodies (stream/rivers), especially by heavy anthropogenic activities, degrade the aquatic habitat and water quality. Macro-invertebrate organisms form an integral aquatic environment and are of ecological and economic importance as they maintain different stages of interaction between the environment and the community (Anderson and Sahel, 1999). When the physical and chemical conditions of ecosystem alter, this may affect individual organisms, populations, and communities (Lenat, *et al.,* 1980).

The management of wastewater in Nigeria has been ineffective; as it does not receive the attention it deserves (Tiseer, 2008). The release of domestic wastewater through drainages into streams and reservoirs which supply drinking water without subjecting it to any treatment is becoming an enormous water threat to the people (Tiseer, 2008). Agrochemical substances such as fertilizers, herbicides, nutrients and heavy metals from farmlands and other land uses are leached and discharged into upstream and downstream catchment reservoirs (WHO, 2006).

Nigeria has numerous environmental laws such as National Environmental Standards and Regulations Enforcement Agency law (Establishment Act of 2007 (NESREA act), Environmental Impact Assessment Act of 1992 (EIA Act), Nigerian Radioactive Waste Management Regulation 2006, Harmful Waste Special Criminal Provision Act of 1988 (Harmful Wastes Act), the National Oil Spill Detection and Response Agency (NOSDRA) Establishment Act 2006 Act and Nigerian Radioactive Waste Management Regulation 2006. However, the law's enforcement is ineffective (Onaruwa and Fakayode, 2002; Adegoroye, 2008).

Field observations show that River Chanchaga receives huge volumes of effluents, sediments, raw sewage and solid wastes during the rainy season which influence the biological and chemical characteristic of the river. Similar observations were made by Qadir *et al.,* (2008) which found that many pumps are used to suck in polluted water for irrigation purposes in surrounding crop-lands. This put the agriculture and soil resources at risk. The challenges of water used have raised concerns for farmers, herdsmen and those engaged in fishing. The surrounding environment of River Chanchaga has been subjected to massive artificial alteration (Muhammad, 2012) and there are concerns of periodic outbreaks of water-borne diseases and buildup of mud in the water channel (Maureen, 2002).

Several studies such as Augustine *et al.,* (2015) and Ayobahan *et al.*, (2015) have documented findings on water quality and impact of human activities on the aquatic environment across the world. Although studies exist across the world, paucity of data on the impact of human activities on the aquatic environment was found in the study area under consideration. Therefore, this study assessed the physico-chemical and bacteriological parameters of water quality in river Chanchaga, Minna, Niger state. The specific objectives include assessing the changes in the vegetation cover of the study area from the multi-temporal landuse and land cover data (1986 - 2015) and identifying the responses of the physico-chemical and bacteriological parameters of water quality to the spatio-temporal changes in the environment.

2. MATERIALS AND METHODS

2.1 Study Area

River Chanchaga lies between longitude 6º 33'- 6º38'E and latitude 9º37'- 9º 40'N (Figure 1) and transverses Munya, Shiroro, Paikoro, Bosso and Katcha Local Government Areas. The total land area covered by the river basin is 159,259 km^2 (Muhammad, 2012). Geologically, the study area belongs to the Basement Complex rocks. The rainy season starts from April and lasts till October with a mean annual rainfall of 1,334 mm (52 inches) with September

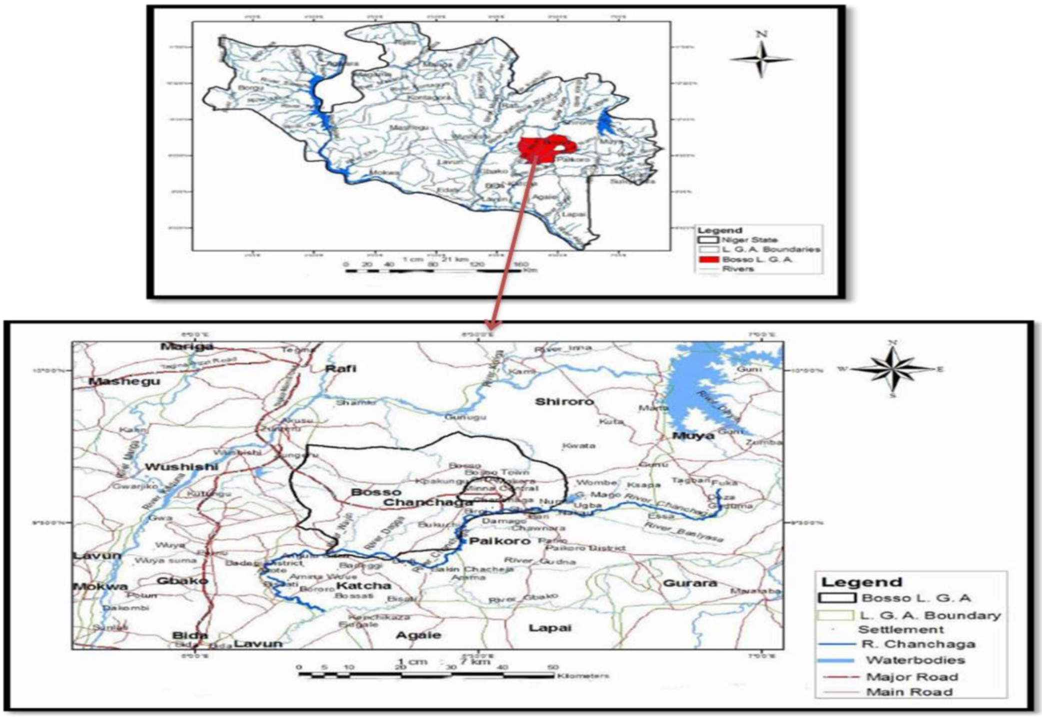

Figure 1: Geographical Location of the Study Area

recording the highest rainfall of 300 mm. The mean monthly temperature is highest in March at 30ºC – 50ºC (85ºF) and lowest in August at 22.3ºC (Muhammad, 2012).

The vegetation occupies about 10.65 km^2 with fresh grasses. The transition zone between the fringing forest in the south and Savanna is not too obvious as it is characterized by mixed woodland and deciduous trees with considerable regional variation in the types of wood land. Major tree species include shea, mango, and acacia trees. Subsistence agriculture is the predominant occupation of the population along River Chanchaga. Cultivation is at the upper and middle courses of River Chanchaga and at the banks of the watershed and depressions (fadama lands).

2.2 Methods of Data Collection and Analysis

2.2.1 Changes in Vegetation Cover

In this study, vegetation transition for two time periods between 1986-2002 and 2002-2015 was assessed using Landsat 7 imageries and Enhanced Thematic Mapper (ETM). The data for the two time periods was extracted for the study area in ArcGIS 10.0 environment. The satellite images were subjected to pre-processing of imageries, radiometric correction, image enhancement and display. The vegetation changes were classified as areas of losses, persistent (unchanged) and gained. The Maximum Likelihood Classifier (MLC) was adopted for its popularity, simplicity and high degree of accuracy. Results of vegetation transition were summarized using descriptive statistics such as mean and frequencies.

2.2.2 Analysis of water physicochemical parameters

Following a reconnaissance survey of the study area, representative sampling points were selected along accessible tributaries of River Chanchaga (Figure 2). The sampling points were distributed with unequal distance ranging from 4km - 10km because of inaccessibility in some river bank areas. The

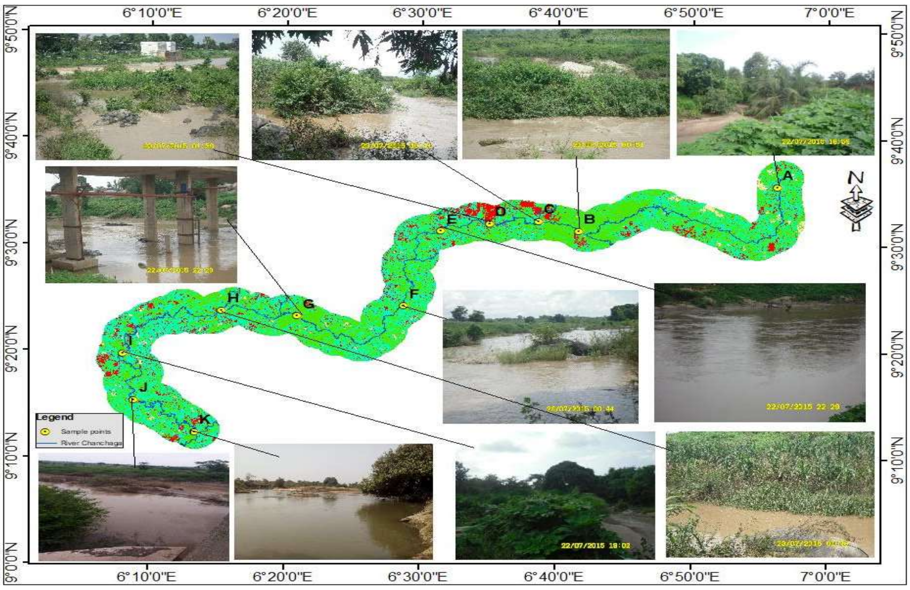

Figure 2: Sampling Sites and their Respective Plates along River Chanchaga

sampling period was divided into two: the dry season (March) and the rainy season (July).

Water sampling was carried out at eleven (11) sites with one control point at site A. The washed plastic bottles covered by rubber coating in which glass containers were washed with nitric acid and rinsed with water at all sites. The water samples were taken at 90 cm below the water surface. All the sampling containers were drained into sampling bottles without trapping any bubble. The method of sampling was similar to the study of Qadir (2009). The water samples were preserved in iceboxes and conveyed to the laboratory according to the prescribed standard method (APH, 1998). The water parameters as presented in Table 2 were separated for the dissolved metal concentrations and particulate matter in Clear Production Center (CPC) of Niger State Water Board Headquarters, Minna. The analysis of water physicochemical parameters (turbidity, suspended solids, electrical conductivity, total dissolved solids, temperature, pH, total hardness, total alkalinity, nitrite, phosphate, manganese, copper, iron, cyanide, nitrate, phosphorus, E-coli and total coliform) was conducted and results compared to that of the National Standard for Drinking Water Quality (NSDWQ). Independent t-test was used at α level of 0.05 to test for significant difference in water parameters and the NSDWQ standard.

3. RESULTS AND DISCUSSIONS

3.1 Vegetation Transition over the Study Area

The results of the vegetation transition from 1986-2015 in the study area are presented in this section. Figure 3(a, b and c) show the vegetation cover for 1986, 2001 and 2015. Figure 4a and 4b show net vegetation

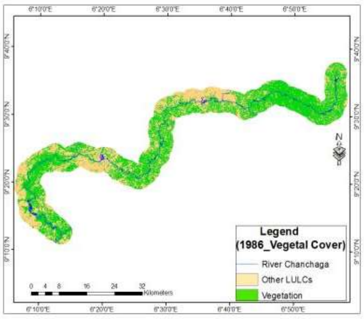

Figure 3a: Vegetation cover map of 1986

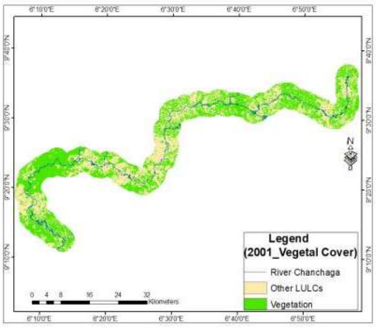

Figure 3b: Vegetation cover map of 2001

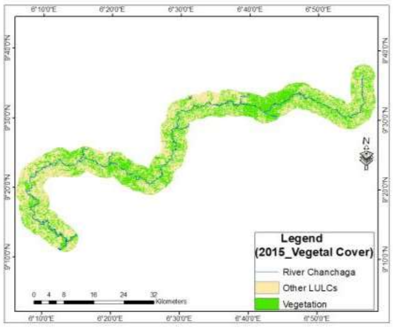

Figure 3c: Vegetation cover map of 2015.

changes for the period studied, while Table 1 shows the associated statistics.

Table 1: Vegetation Transition Area Coverage from 1986 to 2001

S/N	Vegetation status	1986 to 2001		2001 to 2015	
		Area Coverage (Hectare)	%	Area Coverage (Hectare)	%
1	Losses	24190.08	31.62	28941.8	40.50
2	Persistence (Unchanged)	31260.36	40.87	23389.1	32.73
3	Gains	21046.08	27.51	19126.7	26.77
	Total	**76496.52**	**100.00**	**71457.6**	**100**

Source: Author's Data Analysis (2016)

The results indicate a 31.6% decrease (loss) in vegetal cover from 1986 to 2001, 40.9% of the vegetation cover (31260.36ha) remained unchanged while it gained 21046.08ha (27.51%). However, between 2001- 2015 there was a 40.50% loss in vegetation cover, about 33% unchanged (23389.1ha) and 26.8% (19126.7ha) gained. The study revealed that the rate of vegetation depletion was higher between 2001 and 2015 and could be as a result of population increase with the attendant increase in anthropogenic activities. Previous studies (Onojeghuo and Blackburn, 2011; Alex and Ajoke, 2015) have attributed such changes to population increase and its attendant increase in anthropogenic activities. In addition, Moussa (2016) added that unsuitable land-use practices such as bush burning are possible factors of vegetation changes. Furthermore, vegetation changes have been linked to extreme El Nino Southern Oscillation (ENSO) anomalies (Aweda and Adeyewa, 2011). According to Esio and Igba (2014), a long term impact of such vegetation changes include poverty and hunger, environmental degradation, loss of biodiversity, accelerated climate change effects and the outbreak of medication-defying sicknesses and diseases.

3.1.1 Comparison of Vegetation Cover Transition (1986- 2015)

Figures 4 (a) and (b) show results of vegetation cover transition for the period under study, while Table 2 shows the statistics. Table 2 shows the vegetation changes between 1986 and 2015. The results show decreasing vegetation coverage in the study area through increases in agriculture and agricultural activities as well as built-up areas. A similar study by Frank *et al.*, (2017), established that the increased intensity of agriculture and deforestation results in high surface runoff, increased pesticide contamination and sedimentation rates in streams and rivers. Observations from the various sampling sites indicate depletion of biological assemblages in the River Chanchaga ecosystem. The biological depletion could mean a possible link with the vegetation depletion in agreement with Frank *et al.* (2017), who established that as vegetation covers decline, there is a corresponding decline in other natural

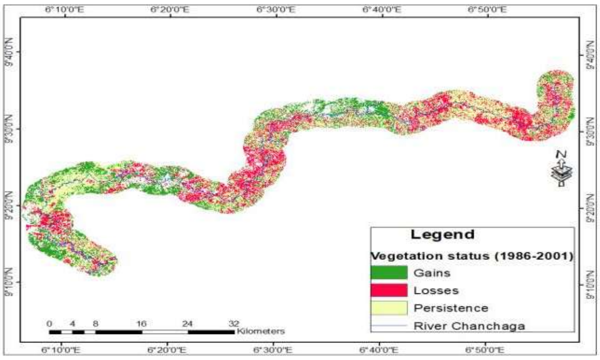

Figure 4a: Vegetation Transition Image from 1986 to 2001

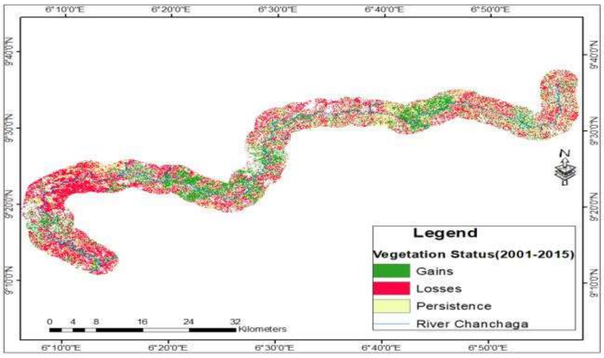

Figure 4b: Vegetation Transition Image from 2001 to 2015

Table 2: Vegetation Change for Two Periods (1986-2015)

S/N	Vegetation status	1986-2001 Area Coverage (Hectare)	2001-2015 Area Coverage (Hectare)	Percentage change
1	Losses	24190.08 (31.62%)	28941.8 (40.50%)	8.88%
2	Persistence/unchanged vegetation	31260.36 (40.87%)	23389.12 (32.73%)	8.15%
3	Gains	21046.08 (27.51%)	19126.68 (26.77%)	0.74%
	Total	**76496.52**	**71457.6**	

aquatic resources like fishes, amphibians, reptiles, water birds and riverside animals thereby affecting river ecosystems. In another study, Alam *et al.,* (2021) found that establishment of settlements for the increasing population, indiscriminate use of pesticides, environmental pollution and climate change were the factors for LULC. The implications of the vegetation changes are general decline in biodiversity of swamp areas and adjacent environment (Seki *et al*., 2018) and declining trends of wetland biodiversity (Alam *et al*., 2021).

3.2 Physicochemical analysis of Water Samples

Results of physicochemical analysis of water samples are presented in Tables 3 and 4 (see Attached) for dry and rainy seasons. The tables indicate a variation between the water in the river Chanchaga at the two seasons and the National Standard for Drinking Water. This suggests that the river Chanchaga is not safe for drinking. According to Wilbers *et al.*, (2014), large quantities of fertilizers transported in solute from agricultural fields into the river could be responsible for such variation.

3.3 Variations of Physiochemical Water parameters in Dry and Rainy Seasons

The percentage variations of physiochemical water parameters in dry and rainy seasons compared to NSDWQ is presented in Table 5 as computed from Table 3 and 4 (see Attached). The results show the three parameters with percentage variations greater than their recommended NSDWQ. These three parameters include turbidity with 5.23% (NSDWQ value of 5.0), total dissolved solids with 645.45% (NSDWQ value of 129.09) and total coliform with 111.77% (NSDWQ value of 10). Several activities were detected in and along the river during the field survey, such as agricultural and domestic wastes, mud from irrigation farming, demolition and mining, solid waste dumps, bathing and washing materials. The increased level of degradation of the study area through alteration of land use/land cover types by deforestation, land clearance and construction along River Chanchaga is

Table 5: Mean Distribution of Water Parameters in Dry and Rainy Seasons

SN	Parameters		Dry Season		Rainy Season	
		NSDWQ	MWP	Percentage Variation from NSDWQ (%)	MWP	Percentage Variation from NSDWQ(%)
1.	Turbidity	5.0	104.54	5.23	116.54	5.83
2.	Colour	15.0	63.09	9.46	75.18	11.28
3.	Suspended Solids	NS	68.4	NS	73.81	NS
4.	Electrical conducting	1000.0	83.0	830.00	316.63	316.63
5.	Total dissolved solids	500.0	129.09	645.45	159.81	799.05
6.	Temperature	Ambient	29.22	Ambient	28.36	Ambient
7.	pH	6.5-8.5	6.81	0.58	6.95	0.59
8.	Total Hardness	150	89.85	134.78	108.52	162.78
9.	Total Alkalinity	NS	65.59	NS	81.81	NS
10.	Nitrite	0.20	0.03	0.00	0.03	0.00
11.	Phosphate	NS	2.28	NS	2.05	NS
12.	Manganese	0.20	0.26	0.01	0.27	0.00
13.	Copper	1.0	0.07	0.00	0.10	0.00
14.	Iron	0.30	0.63	0.00	0.57	0.00
15.	Cyanide	0.01	0.16	0.00	0.09	0.00
16.	Nitrate	50.0	3.88	1.94	5.10	2.55
17.	Phosphorus	NS	0.81	NS	1.62	NS
18.	E-coli	0	48.5	0	29.81	0
19.	Total Coliform	10	1117.72	111.77	1234.09	123.41

Source: *Laboratory Result, (2017)*

responsible for a high level of turbidity, total dissolved solids and total coliform.

Field observations indicate that agricultural wastes such as yam stalks, corn stalks, maize stalks, shrubs, animal dung and mud from farmlands flow into the river Chanchaga. This could explain the observed elevated turbidity concentrations of total coliform and dissolved solids in the river. The finding is in line with Safari *et al.*, (2012), who found that the impact of human activities was responsible for the degraded quality of water and aquatic resources in Nyaruzinga, Uganda. The high level of turbidity, total dissolved solids and total coliform above the recommended values result in increased living nematodes that could cause an outbreak of water-borne diseases such as malaria, cholera, dysentery and typhoid fever (Safari *et al.,* 2012). In addition, the mud water alters the transparency and chemical property of the water, which is detrimental to aquatic plants, animals and human health.

The other parameters that reveal percentage variations less than the recommended NSDWQ (permissible limit) in the dry season include colour, electrical conductivity, total hardness, nitrate, manganese, copper, cyanide, nitrate, water pH, manganese and iron. These parameters are within the permissible limits of drinking water quality. The parameters with no stated NSDWQ values include suspended solid SS, total alkalinity, phosphate and phosphorus and temperature with ambient value. The rainy season indicated four parameters with percentage variations greater than the recommended NSDWQ values. These include turbidity with 5.83% (NSDWQ value of 5.0), total dissolved solid with 799.05% (NSDWQ value of 129.09), total hardness with 162.78% (NSDWQ value of 150) and total coliform with 123.41% (NSDWQ value of 10). The parameters that have a percentage greater in the rainy than the dry season are turbidity, colour, electrical conductivity, total dissolved solids, water pH, total hardness, nitrate and total coliform. The surface runoff from different land uses along the river is responsible for a huge inflow of parameters that degrade water quality. The other parameters with less or no percentage variations include suspended solid, nitrite, manganese, copper, manganese, iron, cyanide and E-coli. The parameters with no stated NSDWQ values include suspended solid SS, total alkalinity, phosphate and phosphorus and temperature with ambient value as indicated in Table 4.

The increased level of turbidity from 5.23% to 5.83%, total dissolved solids from 645.45% to 799.05%, total hardness from 89.85% to 162.78% and total coliform from 111.772 to 123.41 (Table 4) indicate a higher level of inflow in the rainy season than that of the dry season into the river. This agrees with Usoro *et al.,* (2013), who concluded that physiochemical parameters of water and sediments inflow into the Iko River from heavy anthropogenic sources were responsible for pollution stresses of the river. As indicated in Table 5, the percentage variation is higher in the rainy season than that of the dry season for most of the parameters. This is due to the transportation of huge volumes of pollutants by surface runoff from different land uses into the river in the rainy season.

3.4 Mean Difference between Water Quality Parameters and NSDWQ

The mean difference between water quality parameters and NSDWQ for the dry and rainy seasons is presented in Table 6. The mean difference between water quality in dry and rainy seasons was 0.168 of the total value in the study area. The values are considered significant where the calculated value is less than an α value of 0.05. The table indicates that sites B, F and I representing 27%, had a significant mean difference in water qualities in the dry season. About 73% of the sample sites showed an insignificant difference in the water qualities with the NSDWQ. The rainy season sample sites showed insignificant difference between the mean water quality parameters and NSDWQ. The finding suggests a difference in the quality of water parameters between dry and rainy seasons.

Table 6: Mean Difference between Water Quality Parameters for Both Seasons and NSDWQ

Cites	Dry Season	Rainy Season
A	0.5131	0.8547
B	0.4478	0.9438
C	0.8998	0.8893
D	0.7607	0.7618
E	0.9975	0.8487
F	0.2708	0.8464
G	0.8463	0.9359
H	0.7431	0.9762
I	0.2901	0.5097
J	0.9051	0.8873
K	0.7998	0.8691

The finding is consistent with the previous studies which established differences in water parameters between seasons (Ling *et al.*, 2017; Muñoz-Nava *et al.*, 2018; Silas *et al.*, 2018). The excavation for sand and gold mining is common in the dry season. The mining causes the accumulation of leftover sand, mud and debris that could be washed or transported during the rainy season by runoff water. The constant flow of river water that moves debris, mud and sand from anthropogenic activities is responsible for the rainy season's significant level.

4. CONCLUSION AND RECOMMENDATIONS

The study assessed the effects of anthropogenic activities on water quality in River Chanchaga. The results show degradation in the natural vegetation from 1986-2015. The study established that water quality is below the National Standard for Drinking Water Quality (NSDWQ). Water quality degradation in the river is associated with a high inflow of pollutants from contaminated runoff in the rainy season from different anthropogenic sources. Therefore, the study concluded that River Chanchaga is polluted, particularly in the rainy and dry seasons. The study recommends that dwellers along River Chanchaga be educated on getting their water treated before drinking and used for other domestic purposes. It is also recommended that government and other relevant authorities organize public enlightenment programmes against activities which pollute water sources.

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Table 3: Result of Physiochemical Analysis of Water Samples for the Dry Season

S/N	PARAMETER	UNIT	SITE A	SITE B	SITE C	SITE D	SITE E	SITE F	SITE G	SITE H	SITE I	SITE J	SITE K	Mean	NSDWQ
1.	Turbidity	(NTU)	49.0	80.0	130.0	95.0	126.0	90.0	123.0	70.0	121.0	109.0	157.0	104.54	5.0
2.	Color	(Pt/Co)	20.0	66.3	77.2	83.0	80.5	80.0	70.0	38.0	96.0	28.0	55.0	63.09	15.0
3.	Suspended Solids	(Mg/L)	15.0	24.0	98.0	130.0	70.0	25.0	120.0	98.5	45.0	60.0	67.0	68.4	NS
4.	Electrical conductivity	(US/cm)	105.0	80.0	118.0	125.0	86.0	40.5	38.5	15.0	110.0	110.0	85.0	83.0	1000.0
5.	Total dissolved solids	(Mg/L)	40.0	78.0	68.0	290.0	180.0	90.0	200.0	176.0	86.0	124.0	88.0	129.09	500.0
6.	Temperature	(ºC)	30.5	28.0	25.5	32.5	31.0	29.0	30.0	29.0	28.5	30.5	27.0	29.22	Ambient
7.	Ph	-	7.0	7.8	6.5	7.9	5.0	7.0	7.1	5.8	6.9	7.5	6.5	6.81	6.5-8.5
8.	Total Hardness	(Mg/L)	28.5	96.0	68.0	154.0	70.0	65.5	100.4	93.0	65.0	120.0	128.0	89.85	150
9.	Total Alkalinity	(Mg/L)	18.0	45.0	65.0	149.0	63.0	38.0	138.0	35.0	26.0	60.0	84.5	65.59	NS
10.	Nitrite	(Mg/L)	0.001	0.003	0.002	0.082	0.001	0.003	0.005	0.020	0.100	0.004	0.057	0.03	0.20
11.	Phosphate	(Mg/L)	1.25	2.75	0.45	2.90	2.78	1.55	2.60	2.65	2.45	2.95	2.75	2.28	NS
12.	Manganese	(Mg/L)	0.0	1.5	0.3	0.4	0.0	0.20	0.1	0.1	0.0	0.1	0.2	0.26	0.20
13.	Copper	(Mg/L)	0.0	0.10	0.0	0.2	0.1	0.1	0.2	0.0	0.0	0.02	0.0	0.07	1.0
14.	Iron	(Mg/L)	0.0	0.2	0.65	1.98	0.1	0.2	0.1	0.0	1.80	0.05	1.95	0.63	0.30
15.	Cyanide	(Mg/L)	0.0	0.15	0.11	0.10	0.00	1.30	0.0	0.00	0.10	0.001	0.0	0.16	0.01
16.	Nitrate	(Mg/L)	0.95	1.00	1.50	10.50	3.96	2.50	7.20	4.48	4.75	2.00	3.85	3.88	50.0
17.	Phosphorus	(Mg/L)	0.15	0.60	0.63	1.92	0.50	0.90	2.00	0.30	0.5	0.65	0.80	0.81	NS
18.	E-coli	(cfu/10 ml)	15.0	21.0	25.0	83.0	88.0	60.0	75.0	45.0	30.0	60.0	32.0	48.5	0
19.	Total Coliform	(cfu/100ml)	900	610	1420	1925	1560	150	1910	1140	125	1405	1150	1117.72	10
	Site Mean		64.75	60.12	110.78	162.76	124.57	35.88	148.64	92.25	39.42	111.56	99.45		

NSDWQ – Nigerian Standard for Drinking Water Quality
NS – Not Stated
A – Control Site (point)
Source: Laboratory Result, (2017)

Table 4: Result of Physiochemical Analysis of Water Samples for the Rainy Season

S/N	Parameter	Unit	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Site I	Site J	Site K	Mean	NSDWQ
1.	Turbidity	NTU	42.0	90.0	141.0	102.0	135.0	95.0	150.0	140.0	92.0	125.0	170.0	116.54	5.0
2.	Colour	ρt/Co	18.0	75.0	84.0	108.0	90.0	76.0	100.0	56.0	108.0	34.0	78.0	75.18	15.0
3.	Suspended Solids	Mg/l	20.0	35.0	98.0	154.0	92.0	40.0	130.0	70.0	35.0	58.0	80.0	73.81	NS
4.	Electrical Conductivity	µs/cm	600.0	178.0	260.0	498.0	80.0	272.0	250.0	420.0	590.0	135.0	200.0	316.63	1000.0
5.	Total Dissolved Solid	Mg/l	30.0	68.0	80.0	390.0	190.0	210.0	200.0	180.0	170.0	150.0	90.0	159.81	500.0
6.	Temperature	^{O}c	29.1	29.0	28.5	29.5	29.5	28.0	27.0	28.2	29.0	28.0	26.2	28.36	Ambient
7.	Water Ph	-	7.0	7.8	6.2	7.8	5.8	6.5	7.2	7.0	7.4	7.0	6.8	6.95	6.5-8.5
8.	Total Hardness	Mg/l	30.2	70.5	90.5	170.0	130.0	70.0	128.6	93.0	88.0	150.0	173.0	108.52	150
9.	Total Alkalinity	Mg/l	18.0	78.0	70.0	138.0	50.0	93.0	80.5	152.0	30.0	90.0	100.5	81.81	NS
10.	Nitrite	Mg/l	0.001	0.005	0.003	0.082	0.001	0.004	0.008	0.030	0.100	0.006	0.08	0.03	0.20
11.	Phosphate	Mg/l	1.28	1.55	1.35	2.95	2.10	0.95	1.90	2.65	2.15	2.97	2.75	2.05	NS
12.	Manganese	Mg/l	0.0	0.4	0.1	1.5	0.2	0.0	0.3	0.0	0.1	0.1	0.3	0.27	0.20
13.	Copper	Mg/l	0.0	0.0	0.10	0.3	0.2	0.1	0.2	0.1	0.02	0.0	0.1	0.10	1.0
14.	Iron	Mg/l	0.1	0.3	0.3	1.55	1.2	1.0	0.45	0.2	0.1	0.1	1.0	0.57	0.30
15.	Cyanide	Mg/l	0.0	0.10	0.15	0.25	0.10	0.0	0.2	0.01	0.10	0.01	0.1	0.09	0.01
16.	Nitrate	Mg/l	0.70	2.0	1.9	12.5	9.5	3.0	4.8	4.8	6.0	2.5	8.5	5.10	50.0
17.	Phosphorus	Mg/l	0.10	0.62	0.80	4.85	0.7	4.00	2.50	0.60	0.80	1.0	1.95	1.62	NS
18.	E-Coli	cfu/100ml	10.0	14.0	19.0	69.0	40.0	20.0	24.0	30.0	22.0	55.0	25.0	29.81	0
19.	Total Coliform	cfu/100ml	1195	1560	1800	1270	1150	1905	1105	1120	125	1250	1095	1234.09	10
	Site Mean		105.34	116.33	141.15	155.80	105.59	148.66	116.45	121.29	68.72	109.93	108.38		

NSDWQ – National Standard for Drinking Water Quality
NS – Non-Stated Value
Site A – Control Site
Source: Laboratory Result, (2017).