Land Use-Land Cover Effects on Surface Flowing Water Quality: A Statistical Approach

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ABSTRACT: The drainage basin surrounding River Kaduna within the middle stretch is known to have numerous land uses and land covers. Several researchers have investigated the water quality of the river with respect to season and surrounding geology. However, none or little on the water quality of the river have been investigated with respect to land use and land cover (LULC). Hence, this paper examined the water quality of the middle stretch of the river in relation to the different land uses and land covers present using statistical techniques. This was achieved by monthly analyzing 10 physicochemical parameters from water samples collected in 15 sampling stations for a period of 12 calendar months using standard methods. The physicochemical parameters considered are; turbidity, total dissolved solids, pH, chloride ion and electrical conductivity. Others include dissolved oxygen, 5-days biochemical oxygen demand, chemical oxygen demand, total nitrogen and total phosphorus. The different LULC of the watershed obtained via ArcGIS 10.5 were agricultural, vegetation, built-up, industrial, water body and bare surface. Spearman's correlation analysis between laboratory results and the different LULCs determined via SPSS version 20 revealed that Built-up, industrial, and agricultural land uses contributes significantly to the impairment of River Kaduna water quality as the correlation coefficients between these LULCs and water quality deterioration ranged from 0.0281 to 0.6901. Nevertheless, there was a significant negative correlation (-0.1482 to -0.5490) between vegetation (forest coverage) and water quality deterioration, suggesting that forest cover can mitigate the deterioration of water quality to a certain degree.

KEYWORDS: Runoff water, Correlation Coefficient, LULC, Water quality, Sampling frequency.

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I. INTRODUCTION

Surface water quality has been identified by numerous researchers to be influenced by several factors such as season, geology of surrounding, land use-land cover, etc (Iyanu, 2011). The bulk of agricultural activities in Nigeria is situated in the Northern part of Nigeria (Dada *et al.*, 2011). However, Afua *et al.* (2015) reported that this region of the country is semi-arid hence, most farmers depends on groundwater pumping for irrigation of crops. Notwithstanding, River Kaduna in North-Western Nigeria flows all through the year (Dada, 2011). For this reason, farmers in communities that lie within the stretch of this river abstract water from it to irrigate crops.

The presence of different land uses and land covers most especially within the watershed of the middle stretch of the river have made the water quality questionable. This is because several researchers such as Niemi *et al.* (2010), Calder (2011) as well as Paul and Meyer (2011) have earlier identified Land Use and Land Cover (LULC) as major factors determining the quality of surface and ground water. This assertion was reaffirmed by Sickman *et al.* (2014) and Easton *et al.* (2014) who stated that rivers in watersheds with substantial agricultural and urban land use experience increased inputs and varying compositions of organic matter and excessive concentrations of phosphorus and other nutrients from fertilizer application and watershed releases.

The population of Kaduna metropolis has shown a rapid increase as follows: 10,653 in 1931; 44,540 in 1952; 149,910 in 1963; 173,000 (estimated) in 1965; 853,000 (estimated) in 1985; 1,111,282 in 1991 and 1,570,331 in 2006 (NPC, 2010). This rapid increase in population resulted to rapid urbanization which consequently led to the transformation of River Kaduna floodplain especially within the Kaduna city metropolis into developed areas as most of the agricultural land has been converted to built-up and industrial areas (Yusuf *et al.,* 2008). Hence, it is important to ascertain the water quality of the river (within Kaduna city metropolis) with respect to the various LULCs so as to understand the level of deterioration or improvement of water quality rendered by the different LULCs. This will help relevant regulatory agencies such as the Kaduna State Environmental Protection Authority (KEPA) to checkmate the activities carried out in LULCs identified to be impairing the water quality of the river since the river also serve the purpose of fishing, bathing and laundry activities.

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II. MATERIALS AND METHOD

Materials: Dissolved oxygen and pH were examined in-situ using portable DO meter (DO STARTER300D, ±1%) made by OHAUS Corporation, USA and a pocket sized pH meter (pHep®,±0.1) made by HANNA LTD, England respectively. Total dissolved solids and electrical conductivity were also determined in-situ via a pocket-sized dissolved solids and conductivity meter (TDS & EC hold, ±2%) made by Griffin Company, USA. However, Total nitrogen, total phosphorous and turbidity were analyzed ex-situ by means of kjeldahl auto distillation machine (Kjeltec 8200™ made by FOSS, Sweden), phosphorous meter (Colorimeter 257 made by Sherwood, USA) and HACH 2100N turbidimeter (made by HANNA, LTD, England) respectively. Glassware (BOD bottles, conical flasks, measuring cylinders, pipettes and burets) made by Kimax Company, England were used for titration during the determination of biochemical oxygen demand, chemical oxygen demand and chloride ion using standard methods. In addition, a handheld Global Position System (GPS) navigator (Etrex 20x) made by Garmin, USA was used in determining the geographical locations of the sampled points.

Sampling Frequency and Duration: The sampling was done monthly for a period of one year between June 2016 and May 2017 thus, covering two metrological seasons. This sampling frequency and duration is in line with Udiba *et al.* (2014), Esengul *et al.* (2014), Vujovic *et al.* (2012) and Carlos *et al.* (2007). The grab sampling technique was employed in each sampling location from the most upstream site first, and continued up to the most downstream site. Sampling in this manner assumes that before sampling downstream location, the water quality already sampled upstream must have flowed to that point. The collected samples were stored in a cooler containing ice and delivered on the same day to the laboratory where they were refrigerated until analysis using APHA (2012).

Drainage Basin and Land Use Maps: Watershed map was generated with the aim of identifying areas of land that drains rain water into the River Kaduna. This was done using Shuttle Radar Topography Mission (SRTM) data obtained from Global Land Cover Facility (online portal). In order to provide an undulating view of the terrain morphology, a Digital Terrain Model (DTM) was generated. In addition, a Triangulated Irregular-terrain Network (TIN) and a hill shed map types of model were also generated. All these analyses were carried out through the use of surface analysis tools in ArcGIS 10.5. The developed watershed map of the study area is shown in Figure 1.

Landsat Enhanced Thematic Mapper Plus (ETM+) imagery of 23rd August, 2016 with 30 m resolution was sourced from Global Land Cover Facility (online portal). This was used to generate the land use land cover map of the study area (Figure 2) using maximum likelihood classification method based on its high accuracy.

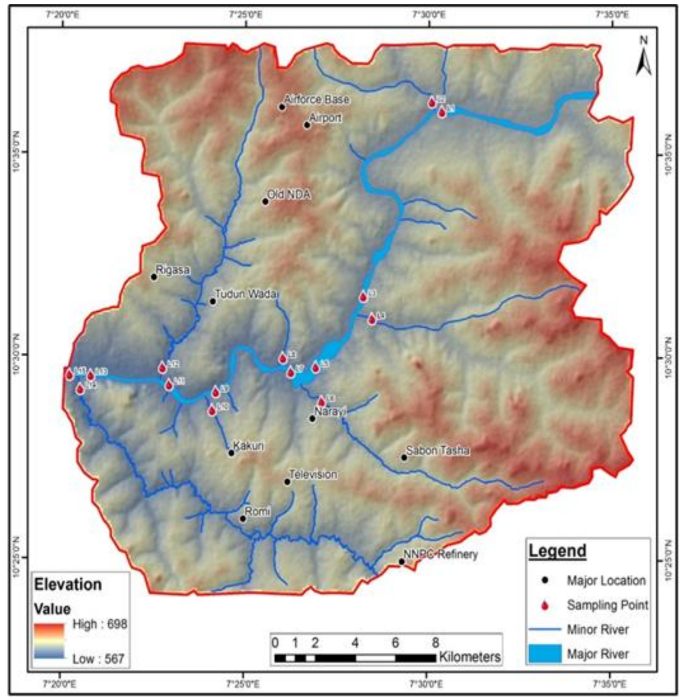

Figure 1: Watershed map of study area.

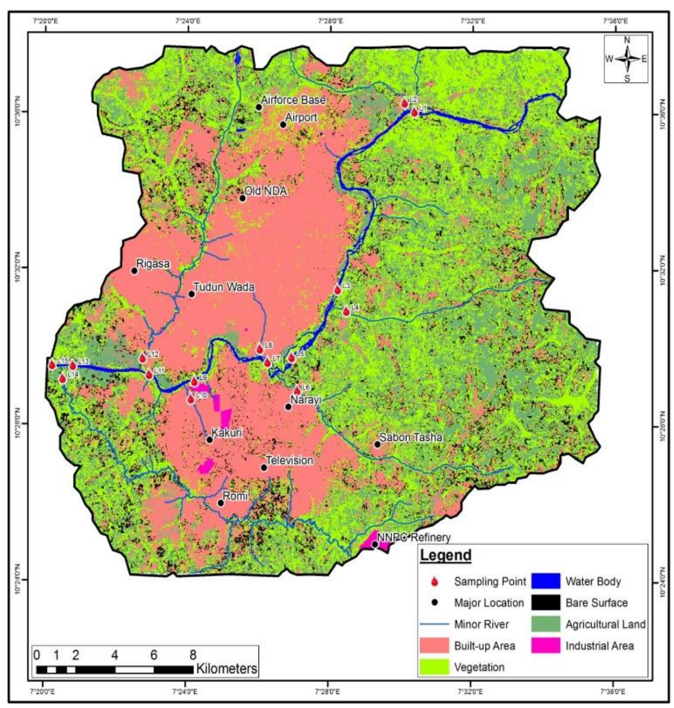

Figure 2: Land use land cover map of study area.

The images were classified into different land use themes as could be seen in Table 1. The whole watershed is 571.04 km^2 of which; built-up area is **1**97.97 km^2 (34.67%), vegetation is 178.46 km^2 (31.25%), agricultural area is 151.69 km^2 (26.56%), bare surface is 33.80 km^2 (5.92%), water body is 6.57 km^2 (1.15%) and industrial area is 2.25 km^2 (0.45%). However, the sub-basin distribution of the various land use land cover is shown in Table 2.

Table 1: Land use land cover classification scheme.

Land Use –Land Cover Type	Description
Agriculture	All cultivated lands.
Vegetation	All vegetated lands that are not yet cultivated such as grassland, shrubs, forest and other natural vegetation.
Built-up	Areas used for both urban and rural residential lands.
Industrial	Areas used for industrial purposes.
Water Body	All water surfaces such as rivers, streams and ponds.
Bare surface	Rocky lands without vegetation.

Table 2: land use distribution at sub-basin scale.

Sampling Site	Site Name	Geographical Location	Built-up area (%)	Vegetation (%)	Water body (%)	Bare surface (%)	Agricultural area (%)	Industrial area (%)
L1	*Malali	10°36'3.09"N 7°30'21.91"E	8.11	38.04	1.48	3.85	48.52	0.00
L2	+Kwarau	10°36'16.96"N 7°30'5.43"E	12.12	56.34	0.79	3.03	27.72	0.00
L3	*NNPC	10°31'29.23"N 7°28'14.04"E	48.93	22.58	1.16	7.85	19.36	0.12
L4	+Kuyi	10°30'56.02"N 7°28'28.84"E	24.05	32.93	0.54	14.22	28.26	0.00
L5	*Barnawa	10°29'44.46"N 7°26'56.86"E	26.74	33.58	0.46	10.41	28.81	0.00
L6	+Kutimbi	10°28'53.12"N 7°27'6.71"E	37.61	28.65	1.10	8.08	24.56	0.00
L7	*Living Faith	10°29'36.82"N 7°26'16.25"E	52.13	24.20	1.29	1.61	20.77	0.00
L8	+Kigo	10°29'57.44"N 7°26'3.32"E	68.04	14.73	3.98	0.61	12.64	0.00
L9	*Down Quarters	10°29'6.80"N 7°24'13.53"E	50.13	24.83	0.19	1.50	21.32	2.03
L10	+Breweries	10°28'40.07"N 7°24'7.42"E	61.37	16.50	1.50	3.03	14.19	3.41
L11	*Ungwa Mu'azu	10°29'17.15"N 7°22'56.89"E	40.89	25.49	1.40	10.35	21.87	0.00
L12	+Rigassa	10°29'42.63"N 7°22'45.92"E	50.76	23.50	0.65	4.91	20.18	0.00
L13	*Maigigiya	10°29'30.84"N 7°20'48.66"E	10.69	44.74	0.55	5.23	38.79	0.00
L14	+Romi	10°29'10.65"N 7°20'31.50"E	24.11	32.82	1.82	11.82	28.24	0.00
L15	*Railway Bridge	10°29'31.67"N 7°20'13.77"E	4.37	49.82	0.34	2.30	43.17	1.19

* = Sampling locations along River Kaduna,
\+ = Sampling locations along tributaries, 30 m away from confluence point.

Statistical Analysis: In order to understand the effect of land use and seasonality on the water quality of the catchment area, the seasons were categorized as Dry and Rainy with the months distributed as follows:

Dry Season – November, December, January, February, March and April.

Rainy season – May, June, July, August, September and October.

Spearman's rank correlation coefficients between the water quality parameters and the different land uses at each spatial scale in the dry and rainy seasons were calculated (Yin *et al.*, 2014). The effects of the different land uses (i.e built-up, vegetation, water body, bare surface, agriculture and industrial) on the water quality were explained based on the values of the correlation coefficients determined. Negative correlation coefficients signify inverse proportional relationship between land use and water quality parameter while positive correlation coefficients connotes direct proportional relationship. Since correlation coefficient (ρ) lies between –1.0 and +1.0 i.e $-1 \leq \rho \leq 1$, the strength of the correlation or relationship were explained as follows as recommended by Gupta (2011);

$\rho = -1$ (Perfect negative correlation)
$-1 < \rho \leq -0.5$ (Strong negative correlation)
$-0.5 < \rho < 0$ (Weak negative correlation)
$\rho = 0$ (No correlation)
$0 < \rho < 0.5$ (Weak positive correlation)
$0.5 \leq \rho < 1$ (Strong positive correlation)
$\rho = 1$ (Perfect positive correlation)

III. RESULTS AND DISCUSSION

The mean seasonal values for all the analyzed water quality parameters are presented in Tables 3 and 4. However, the effects of the various land uses and land covers (LULCs) on the analyzed water quality parameters are shown in Table 5.

Turbidity: The positive correlation between turbidity and built-up land use during the dry season as could be seen in Table 5 might be as a result of the domestic use of the river water for bathing and washing of cloths at the riverside. This is because water scarcity during dry season due to absence of rainfall and dried hand dug wells made many persons to limit the use of water obtain from boreholes for cooking and drinking only. Hence, bathing and laundry activities were done at the river side by most people who lived close to the river thus, rendering the water turbid. Also, during the dry season, despite the absence of surface runoff from built-up areas to rivers, domestic effluents still find their ways into the surrounding rivers through drainages, which also contribute to turbidity. On the other hand during the rainy season, surface runoff emanated from built-up areas carried sludge, oil, grease, sand, etc into the receiving streams and rivers which gave rise to turbidity.

Table 3: Water quality results during dry season (mean values).

Sampling Site	Turb (NTU)	TDS (mg/l)	pH	Cl^- (mg/l)	EC (µS/cm)	DO (mg/l)	BOD_5 (mg/l)	COD (mg/l)	TN (mg/l)	TP (mg/l)
L1	18.365	99	7.5	22.89	148	6.19	0.63	43.02	1.60	0.234
L2	5.990	119	7.3	33.95	177	4.89	0.77	44.56	1.33	0.194
L3	2.927	99	7.5	22.89	148	6.19	1.93	60.97	1.23	0.179
L4	6.223	107	7.1	27.93	160	4.50	1.47	49.88	1.34	0.195
L5	6.454	100	7.5	23.58	150	4.96	1.79	51.05	1.34	0.196
L6	4.696	514	6.8	257.33	769	3.30	2.36	56.80	1.31	0.186
L7	3.363	99	7.5	23.52	149	4.20	2.18	65.05	1.23	0.180
L8	1.258	552	7.0	279.08	827	3.19	2.52	74.08	1.70	0.216
L9	3.552	98	7.3	22.64	147	3.90	2.40	63.91	1.24	0.181
L10	1.572	579	9.2	296.11	869	2.76	2.16	71.09	1.60	0.233
L11	3.729	100	7.6	23.51	149	3.66	2.15	58.66	1.25	0.182
L12	3.174	511	7.1	256.89	766	3.60	2.53	64.45	1.45	0.212
L13	11.724	100	7.6	23.45	149	4.15	0.75	46.01	1.46	0.213
L14	6.217	122	7.7	36.69	183	4.43	1.53	50.89	1.33	0.195
L15	14.537	100	7.6	23.45	149	4.16	0.31	42.50	1.52	0.222
USEPA Limit	≤ 5.0	≤ 500	6.5 – 8.5	≤ 250	≤ 750	≥ 5.0	≤ 2.0	≤ 20.0	≤ 1.0	≤ 0.1

Turb = Turbidity, NTU = Naphelometric Turbidity Unit, TDS = Total Dissolved Solids, mg/l = Milligram per liter, Cl^- = Chloride ion, EC = Electrical Conductivity, µS/cm = micro Mohs per centimeter, DO = Dissolved Oxygen, BOD_5 = 5-Day Biochemical Oxygen Demand, COD = Chemical Oxygen Demand, TN = Total Nitrogen, TP = Total Phosphorus, USEPA = United States Environmental Protection Authority, < = less than, ≥ = greater than or equal to, ≤ = less than or equal to.

Table 4: Water quality results during rainy season (mean values).

Sampling Site	Turb (NTU)	TDS (mg/l)	pH	Cl^- (mg/l)	EC (µS/cm)	DO (mg/l)	BOD_5 (mg/l)	COD (mg/l)	TN (mg/l)	TP (mg/l)
L1	62.911	70	7.0	7.04	105	7.78	0.51	35.57	0.98	0.142
L2	59.068	82	7.0	13.21	122	6.35	0.59	36.87	0.81	0.118
L3	120.896	71	7.1	7.24	106	7.74	1.55	50.44	0.75	0.109
L4	66.661	76	6.7	10.51	114	6.10	1.08	41.27	0.81	0.119
L5	64.768	70	7.1	6.85	105	6.68	1.33	42.38	0.82	0.120
L6	76.484	383	6.4	184.26	574	4.36	1.94	46.99	0.71	0.110
L7	88.077	81	7.0	13.03	121	6.55	1.80	53.81	0.75	0.109
L8	151.383	418	6.3	203.45	626	4.31	1.98	61.46	0.93	0.123
L9	88.062	75	6.9	9.55	112	6.59	1.78	52.87	0.76	0.111
L10	134.691	501	8.7	252.07	752	3.97	2.27	58.81	0.87	0.127
L11	86.440	85	6.9	15.52	128	6.42	1.59	48.58	0.76	0.112
L12	89.599	467	6.4	232.29	700	4.29	1.97	53.37	0.79	0.116
L13	60.468	75	6.9	9.69	112	7.03	0.45	38.10	0.89	0.130
L14	68.198	89	7.4	17.84	133	6.33	1.07	42.32	0.81	0.118
L15	44.308	76	7.0	10.16	114	7.01	0.18	35.34	0.93	0.135
USEPA Limit	≤ 5.0	≤ 500	6.5 – 8.5	≤ 250	≤ 750	≥ 5.0	≤ 2.0	≤ 20.0	≤ 1.0	≤ 0.1

Turb = Turbidity, NTU = Naphelometric Turbidity Unit, TDS = Total Dissolved Solids, mg/l = Milligram per liter, Cl^- = Chloride ion, EC = Electrical Conductivity, µS/cm = micro Mohs per centimeter, DO = Dissolved Oxygen, BOD_5 = 5-Day Biochemical Oxygen Demand, COD = Chemical Oxygen Demand, TN = Total Nitrogen, TP = Total Phosphorus, USEPA = United States Environmental Protection Authority, < = less than, ≥ = greater than or equal to, ≤ = less than or equal to.

The positive correlation between turbidity and agricultural land use during the dry season (Table 5) might be due to the return flow of excess irrigation water into the streams and river. This is because during the dry season, a lot of farming activities were carried on the banks of the river, which were irrigated daily with water from the river mostly through water pumping machines. The excess or overflow water from this practice flows back into the river together with soil particles, grasses, ashes and other turbidity contributing materials. However, during the rainy season, turbidity from agricultural land use could be attributed to runoff from the agricultural fields. This is because soil particles in agricultural fields are easily detached and transported by runoff since the soil has been mechanically manipulated (ploughed and harrowed). In other word, runoff from agricultural fields carried a lot of debris into the receiving water bodies which made the water highly turbid.

Table 5: Spearman's correlation coefficients between water quality parameters and land uses.

	Turb	TDS	pH	Cl^-	EC	DO	BOD_5	COD	TN	TP
Dry Season										
Built-up	0.5026*	0.5446*	−0.2196*	0.4381**	0.4914*	−0.5982**	0.5397**	0.3722**	0.5944**	0.2672**
Vegetation	−0.5490*	−0.2125**			−0.1246**	0.2644**	−0.3102**	0.2805**	0.0146*	0.0113*
Water body	0.0116**	0.1068**	.0035*	0.1157*	0.1113*	0.0125*			0.1041*	
Bare surface							−0.0211*		−0.1635*	
Agriculture	0.5091*	0.4637*	−0.1732*	0.2969**	0.3803**	−0.3815*	0.2773**	0.3523**	0.7287**	0.4339**
Industrial	0.1227**	0.0973*	0.3286**	0.1694**	0.1334**	−0.3107*	0.2681**	0.2732**	0.2619**	0.1860*
Rainy Season										
Built-up	0.6130*	0.6828*	−0.2839*	0.3601**	0.4215*	−0.5679*	0.5016**	0.3091**	0.6513**	0.2885**
Vegetation	0.2426**	0.3004*	−0.1482*	0.0501*	0.1902*	−0.1821*	0.1170*	0.2037**	0.2811**	0.1414*
Water body				0.0883*						
Bare surface	0.0103*						0.0137*	0.0169*		
Agriculture	0.7035*	0.5063*	−0.2268*	0.2507*	0.2678*	−0.4714*	0.2948**	0.4112**	0.6901**	0.4910**
Industrial	0.0281*		0.1693**	0.1288*	0.1062*	−0.2696*	0.2014**	0.2885**	0.2023**	0.1205*

Turb = Turbidity, TDS = Total Dissolved Solids, Cl^- = Chloride, DO = Dissolved Oxygen, BOD_5 = 5-days Biochemical Oxygen Demand, COD = Chemical Oxygen Demand, TN = Total Nitrogen, TP = Total Phosphorous. Only significance levels (*<0.05 and **<0.01) are shown.

The negative correlation between turbidity and vegetation during the dry season might be caused by the absence of runoff during dry season. Also, people who lived in vegetation land cover which is more of forests and bushes were not much since only few Fulani herdsmen with their families reside in such areas (Dada *et al.*, 2011). Hence, human activities that could have caused turbidity such as domestic effluents from drainages and laundry at the river sides during dry season were minimal. However, during the rainy season, the positive correlation between vegetation land cover and turbidity could be linked to the effect of runoff. Nevertheless, the tendency for runoff to detached and transport soil particles in vegetation land cover is not much as the soil particles are not loosed since it has not been ploughed and harrowed. Furthermore, plants roots and grasses obstruct the free flow of runoff from vegetation lands thus, retaining some of the transported turbid causing particles from entering receiving water bodies. In addition, tree canopies (leaves) and branches intercept rainfall before reaching ground surface thus, reducing the energy for detaching soil particles. Hence, even though there is runoff during rainy season, the turbidity level of the runoff from vegetation lands is not as much as those from built-up and agricultural lands. This could be the reason why there was weak positive correlation between turbidity and vegetation land during the rainy season.

The positive correlation between industrial land use and turbidity might be as a result of the strong colour of effluents discharged by textile industries which contain a lot of dyes. However, the weakness of the correlation could be connected to the small percentage of industrial land use in the overall watershed (0.45%).

Total Dissolved Solids (TDS): The land uses and land covers that had realistic effect on the TDS content of the studied area (River Kaduna) were built-up, vegetation, water body, agricultural and industrial lands. Just like in the case of Turbidity, built-up and agricultural lands varies directly with TDS content in both seasons while vegetation land had direct and inverse relationship with TDS during dry and rainy seasons respectively. However, water body and industrial lands were positively correlated with TDS during dry season but without a significant correlation (at $p < 0.01$ or $p < 0.05$) during the rainy season.

The positive correlation coefficients shown during the rainy season could be attributed to runoff. That is, the larger the area occupied by these land uses and land covers, the more TDS in the runoff been drain into the receiving river. However, during the dry season, the positive correlation between built-up and TDS might be caused by municipal effluent discharges containing dissolved solids such as kitchen and laundry effluents. The negative correlation between vegetation land and TDS during dry season signifies the reduction (improvement) of TDS with increase in vegetation land cover within the drainage basin during dry season. The positive correlation between agricultural land and TDS could be associated with runoff (rainy season) and return flow of excess irrigation water (dry season) which carried several solid particles into the river. Water-body also showed positive correlation with TDS during dry season, signifying that during dry season, TDS in the river deteriorated with increase in surface area occupied by water. This is because during dry season, there is high abstraction of water from the river to meet water needs as well as high evaporation rate of water molecule from the river surface due to solar heating and low humidity. This resulted to a decrease in the depth of the river. Shallow depth and large surface area of water increase evaporation rate of surface water thus, increasing TDS content. The use of common salt (NaCl) and glauber salt in industrial processes (especially textile industries) directly increased the TDS level in the effluent which reflected as positive correlation noted between industrial land and TDS.

pH: The effects on pH by the different land uses and land covers within the watershed revealed that Built-up and agricultural lands were negatively correlated with pH during both seasons while vegetation land cover had negative correlation only during the rainy season. This implies that as the proportion of these land uses increase within the watershed, the pH of the draining river reduces thus, causing the water to be acidic. On the contrary, positive correlations were noted between industrial land use and pH during both seasons. This suggests that the larger the percentage of industrial land within the watershed, the higher the pH or alkalinity of the river. Notwithstanding, Table 5 indicates that all the correlation coefficients (negative or positive) between pH and the various land uses were very weak irrespective of the seasons as at the period this research was conducted.

Built-up areas are occupied by humans hence, the discharge of untreated sewage containing acidifying pollutant such as nitrogen compounds (ammonia, nitrite and nitrate) from human excreta are usually much. In other words, the released of these acidifying effluents into the river through point and non-point sources might be the reason behind the lowering of pH (acidic) with increase in built-up land that reflected as negative correlation.

Acidification of vegetation (forest) runoff could be caused by many factors. Forest canopies intercept or captured more atmospheric pollutants (e.g. sulphur dioxide and nitrogen dioxide) than shorter types of vegetation. This increased capture, also known as scavenging effect, arises due to the turbulent air mixing above and within the forest canopy and it is a function of the stand structures. The effect therefore becomes more important as trees grow and the height of the stand increases (Ogbozige *et al.,* 2018). The pollutants deposited in this way include nitric acid vapour (HNO_3), hydrochloric acid vapour (HCl) and ammonia NH_3. These various forms of acidic pollutants captured by forest canopies might have acidified the rainfall within the vegetation land cover which finally drains into the river through runoff. In addition, forest soils are characterized by having acid surface litter, fermentation and humus layers, due to the enrichment of the soil with organic matters such as fallen leaves and dead woods. Hence, the drop in pH with increase in vegetation (forest) might as well be initiated by the release of organic acids from these layers via precipitation that drains into the river.

The excessive application of organic and inorganic fertilizers in the agricultural lands might be the reason for the negative correlation between agricultural land use and pH. This is because fertilizers in the form of urea or ammonia nitrate are potentially acidifying due to nitrification of ammonia and leaching of nitrate. Furthermore, planting of nitrogen-fixing species such as cowpea, groundnut and soya beans at the river banks can promote nitrate leaching from soils to river. This leachate might have contributed to the river water acidification. In addition, cultivation disturbs and mixes the soil, potentially improving soil aeration and warming the soil. This can enhance the oxidation of soil organic matters and the release of organic acid and stored sulphate. The washout of these chemicals into the river by irrigation water and runoff might have also contributed to the acidic pH of the surface waters within the agricultural watershed.

The positive correlation between pH and industrial land suggest that the industries within the drainage basin discharged more of alkaline effluents. This could be linked to the effluents been discharged by the numerous textile companies in the hot spot industrial zone (Kakuri). This is because the pH of textile effluents are generally high because of the use of many alkaline substances in textile processing.

Chloride Ion (Cl^-): All the land uses and land covers showed positive correlations with chloride ion (Cl^-) as already shown in Table 5. This implies that the larger the expansion of these land uses and land covers, the higher the concentration of chloride ion (Cl^-) in the draining river or stream.

The presence of chloride ions in built-up watershed might be caused by point and non-point discharges of domestic and municipal effluents. This is because chloride ion occurs naturally in foodstuffs at levels normally less than 0.36 mg/g with an average intake of 100 mg/day when salt-free diet is consumed (Apte *et al.,* 2011). However, the addition of salt during processing, cooking, or eating can markedly increase the chloride level in food, resulting in an average dietary intake of 6 g/day, which may rise to 12 g/day in some cases. Hence, human excreta generated per person per day contain about 6 g of chloride (Ruth and Mathew, 2016; George *et al.,* 2004). In other words, effluent discharges from kitchen, leachate from failed septic tanks as well as the practice of defecating at the riverside by humans and livestock might be the reason for the increase in chloride ions with respect to the proportion of built -up area (positive correlation). In addition, landfill leachates could be another source of chloride ion in built-up watershed since food scrap, pet waste and condemned batteries are usually found in landfills.

The positive correlation (though weak) between vegetation land cover and chloride ion during rainy season was because, vegetation covers (grassland, shrubs, forest) were commonly used by herdsmen for grazing livestock. Hence, runoff from vegetation watershed carries excretes of herdsmen and grazing livestock into draining streams thus imparting chloride.

Rock-water interactions such as mineral dissolution and desorption usually increase the concentration of chloride ions. Therefore, the rise in chloride ions with increase in water body surface (positive correlation) could be attributed to the presence of numerous rocks in River Kaduna which might have leached out chloride ions in the course of weathering and getting in contact with the flowing water.

Irrigation and rising of groundwater tables is one of the main cause of Cl^- in agricultural watersheds, especially in the arid and semi-arid regions of the world where crop production consumes large quantities of water. This is because crops absorb only a fraction of the salt in irrigation water, thus making soil water to be more saline or salty which usually leached out through interflow and end up in the river. Also, the practice of excessive use of inorganic fertilizers to improve soil fertility by farmers might be another reason for the presence of Cl^- in the agricultural watershed.

Chloride ions in industrial watershed could be attributed to untreated effluent discharges from industries manufacturing pesticides, fertilizers, animal feed, detergents, pulp mills as well as a large number of small scale processing units in textile industries. In majority of these industries, the main source of chlorides in the effluent is the use of Lime ($Ca(OH)_2$) or Sodium Hydroxide (NaOH) for the neutralization of acidic effluents. This is because, at different instances, hydrochloric acid (HCl), or sodium Hydroxide (NaOH) can be a major part of the industrial processes, where they are used for the initial de-coating of oil film on the raw material thus contributing to the chlorides in wastewater.

Electrical Conductivity (EC): The impacts of land use and land cover on the electrical conductivity as shown in Table 5 informed that the various land uses had positive correlations with EC during both seasons with the exception of vegetation cover during the dry season. Electrical conductivity in built-up watershed might be initiated by discharges of both point and non-point sources of domestic and municipal effluents. The presence of dissolved solids such as sodium chloride (common salt) and mono sodium glutamate (magi) in kitchen effluents could have imparted EC since these substances contain sodium ions (Na^+). Runoff from lawns and gardens containing agrochemicals like fertilizer as well as leachate from failed septic tanks and landfills could also be other sources of EC in built-up watershed since they contain ions like potassium (K^+), nitrate (NO_3^{2-}), phosphate (PO_4^{3-}) and chloride (Cl^-). Furthermore, the presence of sodium carbonate (Na_2CO_3) and sodium sulphate (Na_2SO_4) in detergents could contribute EC in surface water that receives laundry effluents since these compounds contains sodium ion (Na^+).

Some of the sources of EC in surface water such as kitchen effluents, fertilizers, leachates from failed septic tanks and landfills as earlier mention are not usually found within shrubs and forested areas (vegetation cover). Also, EC has been identified to be a function of dissolved solids and one of the means by which dissolve solids gets into surface water is through surface runoff (Wright *et al.*, 2016; Garg, 2010; EPA, 2001). However, surface runoff is not experienced during dry season due to the absence of precipitation. Hence, the negative correlation (inverse relationship) between vegetation cover and EC during dry season might be as a result of the low or absence of domestic and municipal effluent loading, as well as the minimal or nonexistence of surface runoff during dry season. Conversely, vegetation covers (grasslands, shrubs and forests) usually served as grazing areas for livestock thus, causing vegetation covers to contain livestock excretes. The transportation of this livestock excretes together with other dissolved solids within the vegetation cover by runoff to the nearby waterways could be the reason for the positive correlation between vegetation cover and EC during the rainy season.

The rise in conductivity with respect to water body surface during the dry season suggests that, the numerous rocks in River Kaduna might have released ions such as chloride into the water as a result of weathering.

Fertilizer application (NPK) in farmlands within the studied area was very common. Runoff during the rainy season as well as return of excess irrigation water during the dry season might have carried nitrate ion (NO_3^{2-}), phosphate ion (PO_4^{3-}) and potassium ions (K^+) in the fertilizers to the draining water body which consequently increase the EC content. This effect was well noted as there were numerous plots of farmlands at closed range to the waterways (farms along the riverbanks). In other words, the rise in EC content of the river with respect to increase in agricultural land (positive correlation) was as a result of the excessive use of inorganic fertilizers by farmers.

The reason behind the positive correlation between EC and industrial land use could be due to the use of various salts by textile industries especially during the dyeing process. This might have increased the chloride ions in the effluent which consequently raise the EC of the draining river.

Dissolved Oxygen (DO): The level of impacts on the oxygen content of the river by the various land use practices disclosed that, Built-up, agricultural and industrial watersheds were negatively correlated with dissolved oxygen during both seasons. Nevertheless, vegetation watershed had a positive correlation with DO during the dry seasons and negative correlation during the rainy season.

Built-up (urban) areas are usually populated with humans and one of the associated effects is the tendency of polluting surface and ground water. This is because effluent discharges (point and non-point sources) from septic tanks, abattoirs, hospitals, laundries, kitchens, institutions and landfill leachates are mostly observed in built-up areas. This suggests that surface waters within a built-up drainage basin will contain more organic pollutant as built-up area expands (urbanization). However, organic pollutants in surface water usually deplete it DO content since bacteria consume or utilized the available oxygen to oxidize these organics. This might be the reason for the strong negative correlation between built-up drainage basin and dissolved oxygen content shown in Table 5.

Unlike urban or built-up areas, people hardly reside with their families in forested areas (vegetation covers) due to the fear of the presence of wild animals (Etusoaga and Randy, 2015). Though, few Fulani herdsmen with their livestock and families reside temporarily in the forested areas nevertheless, the activities of these people (Herdsmen) are more of grazing and watering of livestock. Hence, the absence of storm runoff during the dry season as well as lack of municipal effluent discharges enables forested watershed not to contribute much organic matters into the draining river. This might be the reason for the positive correlation between vegetation cover and DO during the dry season. On the contrary, during the rainy season, forest runoff carries excretes of; herdsmen, farmers, animals (livestock and wildlife) as well as decayed woods and leaves into the River Kaduna which reduced it DO content. In other words, during the rainy season, larger vegetation covers (grasslands, shrubs, forests) had the tendency of eroding more organic pollutants to surface waters than smaller vegetal areas. This explains the reason for the negative correlation between vegetation cover and dissolved oxygen during the rainy season.

The negative correlation between agricultural land and dissolved oxygen could be attributed to several factors. The excessive use of compost manure and animal dungs by farmers in enriching the soil might have increase the organic contamination of the draining river, following the washing of these organics by runoff or return irrigation water. Also, the practice of farmers spraying pesticides including herbicides and insecticides on weeds and insects might have added substantial quantities of decaying weeds and insects (organics) to the river when eroded by runoff or return irrigation water. In addition, the rotting residues of plant left behind on the field after harvest could have also increased the organic load of the river via runoff and return irrigation water.

The negative correlation between industrial watershed and dissolved oxygen suggest that the industrial effluents contain biodegradable organics. Biodegradable organics such as alcohol, starch, aldehydes and esters are usually associated with industrial effluents. The continuous utilization of the available oxygen in the effluents by bacteria in other to oxidized or stabilized these organics resulted to the depletion in DO which is reflect as negative correlation.

5-Day Biochemical Oxygen Demand (BOD_5): Built-up, Agricultural and Industrial land uses were positively correlated with BOD_5 during both seasons while vegetation cover had a negative and positive correlation with BOD_5 during dry and rainy season respectively. However, the correlation between bare surfaces and BOD_5 is insignificant (approximately zero) in both seasons.

Effluents from households, institutions, hospitals and abattoirs are usually found in built-up (urban) areas. The discharge of these effluents from both point and non-point sources might have caused the observed strong positive correlation between BOD_5 and built-up land use during both seasons.

The reduction in BOD_5 of the water with increase in vegetation cover (negative correlation) during dry season was due to the absence of surface runoff during the dry season. In addition, vegetation covers which are usually forested lands lack municipal effluents that could be discharged via drainages or pipes to receiving water body. On the other hand, the positive correlation (though weak) noted during the rainy season could be accredited to transportation of fallen and decayed leaves as well as animal excretes by surface runoff.

The increase in BOD_5 of the water with increase in the proportion of agricultural land use within the watershed (positive correlation) could be linked to the practice of using organic manures to enrich the soil by farmers. Runoff caused by precipitation during the rainy season as well as return flow of excess irrigation water during the dry season carried these organic matters to the draining river thus, reducing the DO content of the river and increasing its BOD_5.

The direct variation (positive correlation) between BOD_5 and industrial land use could be associated to the kind of effluents discharged by the industries. Majority of the industries within the watershed are textile industries (located at Kakuri). Biao *et al.* (2016) also recorded high BOD of industrial effluents and attributed it to organic pollutants which originated from compounds of dye stuffs, acids, sizing materials, enzymes, tallow etc.

Chemical Oxygen Demand (COD): Most residents living close to the river within the built-up areas usually do their laundry activities at the riverbanks. Certain detergent compounds like Alkyl Benzene Sulfonate (ABS) did not biodegrade as a result of its benzene ring. The use of detergents containing such compounds together with domestic and municipal effluents might have contributed to the positive correlation observed between COD and built-up (urban) areas during both seasons.

The negative correlation between COD and vegetation cover during the dry season could be allied to the same factors responsible for BOD as earlier explained. Conversely, the positive correlation noted during the rainy season in vegetation covers could be attributed to surface runoff carrying both biodegradable and non-biodegradable substances. The biodegradables could be fallen and decayed leaves as well as animal excrete while the non-biodegradables in vegetation cover include constituents of woody plants such as tannic and lignin acids, cellulose, and phenol.

Sengupta (2007) reported that textile effluents are often contaminated with non-biodegradable organics termed as refractory materials of which, the presence results in high COD value of the effluents. In other words, the positive correlation between COD and industrial land use suggests that the industrial effluents contain refractory materials such as detergents.

Total Nitrogen (TN): Apart from bare surface land use which showed a negative correlation during the dry season, other land uses and land covers had a direct relationship (positive correlation) with total nitrogen during both seasons. However, the positive correlation between total nitrogen and vegetation during dry season was very weak, approximately zero (0.0146).

Built-up areas are usually more populated with humans than the other land uses and land covers considered in this work. Nitrogen compounds such as ammonia (NH_3), nitrite (NO_2^-) and nitrate (NO_3^-) are constituents of human and animal excretes. Hence, the discharge of untreated sewage (point and nonpoint sources) such as excretes from humans, animals, poultry as well as leachates from poorly functioning septic systems into River Kaduna might have contributed to the positive correlation between TN and Built-up watershed. Also, nitrogen is a constituent of protein hence, the discharge of untreated abattoir effluents which is common in the built-up areas could have as well increase the TN content of the river. In addition, activities such as swimming, bathing and fish cleaning which is mostly common in built-up areas can contribute nitrogen to streams through body contact (Nyenje *et al.,* 2016; Yang *et al.,* 2014).

The herdsmen mostly grazed their animals in the vegetation cover (grassland, shrubs and forests) hence, animal excretes were much in grazing areas. Runoff from these grazing areas transported ammonia, nitrite and nitrate from the livestock dungs to nearby waterways. This explains the reason for increase in TN with vegetation cover (positive correlation) during the rainy season. Furthermore, death plants or animals (usually found in vegetation cover) are broken down to simpler forms by bacterial decomposition. Proteins for instance are converted to amino acids and further reduced to ammonia (NH_3) and if oxygen is present, the ammonia is oxidized to nitrite (NO_2^-) and then to nitrate (NO_3^-). Hence, the transportation of these forms of nitrogen (NH_3, NO_2^-, NO_3^-) by runoff into the nearby waterways could also be a reason for the positive correlation observed between TN and vegetation watershed. In addition, interflow of nitrogen contaminated water into the nearby water ways as a result of the processes explained above could cause the positive correlation noticed.

The rise in the concentration of nitrogen in line with water surface might be triggered by algal bloom. This is because blue-green algae which is the primary component of algal blooms, have the tendency of introducing nitrogen to surface water by biologically converting gaseous or atmospheric nitrogen to usable forms. Besides, nitrogen occurs naturally at low concentrations in surface waters as a result of decaying plants and other organic matters.

The negative correlation between nitrogen and bare surface during the dry season could be linked to the absence of surface runoff. Also, bare surface land is characterized as rocky land and land without plants (ETM+ in ArcGIS 10.5). This implies that there was no possibility of infiltrated water containing decayed organic materials such as dead plants and animals which would have interflowed into the nearby waterway (River Kaduna).

The increase in nitrogen content of the river alongside agricultural watershed (positive correlation) could be connected to the overuse of inorganic and organic fertilizer by famers to enrich the soil. Inorganic fertilizers such as NPK and organic manures like animal droppings are usually transported by runoff and return irrigation water to nearby streams. In addition, infiltrated water from the agricultural fields carried these materials down the soil as interflow and leached into nearby streams after meeting an impervious stratum. Furthermore, the nitrogen-fixing legumes within the watershed might have produced nitrate that leaked out of the root system into the soil and thereafter, infiltrated and interflowed into the nearby shallow water table been River Kaduna.

The direct variation between nitrogen and industrial land use (positive correlation) suggests that the industrial effluents discharged into River Kaduna contain nitrogen compounds.

Total Phosphorous (TP): All the various land uses and land covers apart from water body and bare surface had positive correlation with the concentration of total phosphorous (TP). This signifies that the presence of TP in the river is contributed by these various land uses and land covers. However, the degree or level of impacts of these land uses in contributing to the presence of TP in the river is reflected in the size of the correlation coefficients.

The presence of phosphorous in built-up watershed could be attributed to the fact that municipal wastewaters are major sources of phosphorus in surface water. This is because condensed phosphates are used extensively as builders in detergents while organic phosphates are constituents of body waste and food residues. Also, failed septic tanks in built-up areas could leach out phosphate into the nearby waterways.

Phosphate being a constituent of animal waste might have been incorporated into the soil in grazing areas which are mostly vegetation cover, and then conveyed by runoff and irrigation water as well as interflow into the receiving waterway (River Kaduna). This could be the reason for the positive correlation between total phosphorus and vegetation watershed.

Phosphate is also a major component of both organic and inorganic fertilizers which are usually used by farmers in improving or supplementing the natural fertility of soil. In other words, the presence of phosphorous in the agricultural watersheds which reflects as a positive correlation could be attributed to the extensive use of inorganic fertilizers (mostly NPK) and organic fertilizers (especially cow dungs) by farmers in improving the soil fertility.

The presence of phosphorous in industrial watershed could be linked to the practice of industries using phosphate compounds in boiler-water conditioning (Harley and Lawson, 2015; Utaro and Deravey, 2015; Peavy, 1998).

Actually, the presence of phosphorus in water do not represent a direct threat to humans and other organisms nevertheless, they do represent a serious indirect threat to surface water quality. This is because phosphorus is the limiting nutrient in surface waters hence, when the concentration is increased, rapid growth of aquatic plants such as algae usually result with severe consequences. This information suggests that the anthropogenic activities within the watershed that could trigger the increase of phosphorus should be thoroughly checked in order to avoid eutrophication of the river. One of the ways forward for this problem is by banning the practice of farming along the river banks.

IV. CONCLUSION

On the basis of empirical studies accomplished, it could be concluded that; Built-up, industrial, and agricultural land uses contributes significantly to the impairment of River Kaduna water quality. On the other hand, a significant positive correlation exist between vegetation (forest coverage) and water quality improvement, suggesting that forest cover can mitigate the deterioration of water quality to a certain degree. Hence; more vegetal cover within the watershed should be encouraged as it has the ability to lessen the deterioration of water quality.

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