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Analysis of Physico-Chemical Properties of Kaduna River Pollution and Their Effects on the Health of Residents of Kaduna Metropolis Nigeria

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Abstract
This study assesses the quality of Kaduna River water and its effects on health of the residents. The aim of the study was achieved through identification of the sources of pollutants in Kaduna River and determination of the spatial and seasonal variations of water quality of the River. Data were obtained from primary and documented sources. Water samples were collected from five sample points and 21 parameters were examined (temperature, pH, conductivity, colour, turbidity, TSS, TDS, DO, Ammonia, Nitrate, Nitrite, BOD, COD, Oil and grease, phosphate, copper, calcium, Magnesium, iron, Zn and faecal coliform) in situ through field determination of water quality and laboratory based analysis at Kaduna State Environmental Protection Authority laboratory. Water samples were systematically and carefully selected and collected to ensure that the samples were collected upstream, within and downstream of the land use types respectively. Hospital records were obtained for 10 years period in Kaduna Metropolis. The study used both descriptive and inferential statistics in the form of tables and frequencies and Paired sample T-test. Results show that the major sources of pollution in Kaduna River are agricultural run-off, industrial effluents and discharges, run-off from urban centre, surface run off, natural source and human activities. Also, the study indicated that the incidence of water related diseases in the area is on the increase. Inferential statistics results showed that the variety and level of pollution in Kaduna River is related to the size of population, and land use activities on the various parts of the Metropolis from where it receives run-off and pollutants. Therefore, it is recommended that prevention of pollution, treatment of polluted water, safe use of wastewater, restoration and protection of ecosystem, among others are desirable actions that will guarantee sustainable good quality use of Kaduna River by man.
Keywords: Physico-chemical; Properties; Health effects; Kaduna river; Water quality.

1. Introduction
A healthy environment is one in which the water quality supports and protects health. Ensuring adequate protection of surface water of Kaduna River will necessitate continuous monitoring of the water quality as population grows and industrialization increases. Poor water quality usually becomes a major constraint on development if not adequately considered within a given development programme. This is because water resource conditions are complementary to many other development inputs. But domestic use, agricultural production, industrial activities and other factors can alter the chemical, biological and physical characteristics of water in ways that can threaten ecosystem integrity and human health [1].

Rapid urban industrialization, socio-economic development, population growth and increase in industrial activities in Kaduna metropolis appear to cause both water pollution and water resources depletion of Kaduna River. River Kaduna serves as the main source of water for Kaduna metropolis, industrial use and irrigation agriculture that take place near the channel of the River. Considering the roles that rivers and streams play in water supply to the inhabitants of their immediate environments and the increasing human activities around them, the neeed for constant monitoring and assessment of the quality of such water bodies becomes highly imperative. Reversing the damage done to any water body is usually complicated and expensive [2].

River water quality study offers a measure of hope for identifying, planning and management of water resources. The spatial and seasonal variations in the pollution level of Kaduna River in relation to land use activities of the metropolis and the effects on health constituted the study problem. Pollutants are being discharged into surface water bodies that run through urban areas thereby leading to the deterioration of its quality. As a result of

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rapid population growth, increase in standard of living and industrial activities, every corner of the globe is however making increasing demands upon water resource in its surrounding thereby altering its quality [3]. In Nigeria, urban population growth and industrial demands on water have been on the increase, and water quality has experienced remarkable changes. Rapid population growth, industrialization and urban development with their attendant environmental problems have continued in Kaduna state and have created stress on the water quality of Kaduna River.

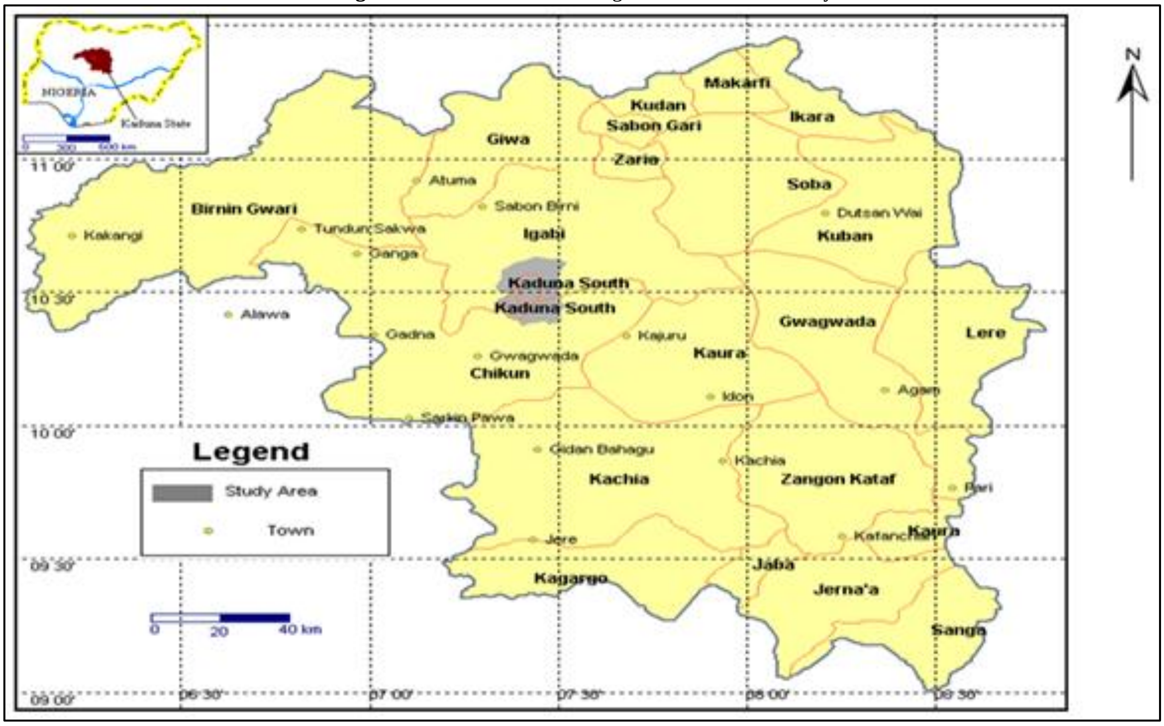
Amadi, *et al.* [4], examined the impact of water pollution on variables that determines health status of the household members. Most of the studies hypothesized that an improvement in water quality has a direct effect on diseases. Patronage of hospitals and other health care facilities in Nigeria is on the increase. Hospital records have confirmed high typhoid, cholera, dysentery, infectious hepatitis and guinea worm in urban settlements of Nigeria and other parts of the world [5].Water pollution has continued to generate unpleasant implications for health and economic development in Nigeria and developing World in general, the consequences of which include 4.6 million deaths from diarrheoa and a sizeable number of casualties from ascariasis (Esrey, Potash, Roberts and Shiff, 1991) hence the need for present study has become most imperative.

2. Study Area

Kaduna metropolis occupies a total area of 260 km^2 and is located at Latitudes $8^{0}58^{1}$N-$11^{0}30^{1}$N and Longitudes $6^{0}3^{1-}$E-$8^{0}48^{1}$E. It is located in the central area of what used to be called the Northern Region of Nigeria [2]. The British colonial officials led by Lord Frederick Lugard selected Kaduna as the regional headquarters of Northern Nigeria in 1912. Kaduna State derived its name from a Hausa plural word "Kadduna" meaning crocodiles [6]. This name was given to the town because of the presence of crocodiles in the river in the past that now divides the town into two, also called Kaduna River. The major concern of significance to pollution contributions in the river are a brewery company, a soft drink company, a flour mill company and a bottle production plant. The Kudenda industrial zone lies west of the western Bye-Pass-Bridge. It is the newest and fastest growing industrial area of Kaduna. There are four zones of development, each served by a major drain. For example, the Makera and Kakuri zones contain the textile mills, a brewery company, a fertilizer plant and an automobile assembly plant drained by the Rafin Dai.

During the colonial era, Kaduna grew both as a garrison town and an administrative centre. With the creation of states by the Federal Government in 1967, Kaduna ceased to be the capital of Northern Nigeria. It became the capital of Kaduna State and has emerged as a strategic centre for industries, defence, commerce and educational institutions. Kaduna State today ranks second only to Kano in Northern Nigeria in terms of population, industrial and commercial activities. As at 1991, Kaduna metropolis had a population of 337,639. At a growth rate of 3.5% per annum, it was expected to have a population of 600,000 or more by the year 2000 [7].

Figure-1. Kaduna State showing the location of the study area



Source: Kaduna State showing the location of the study area

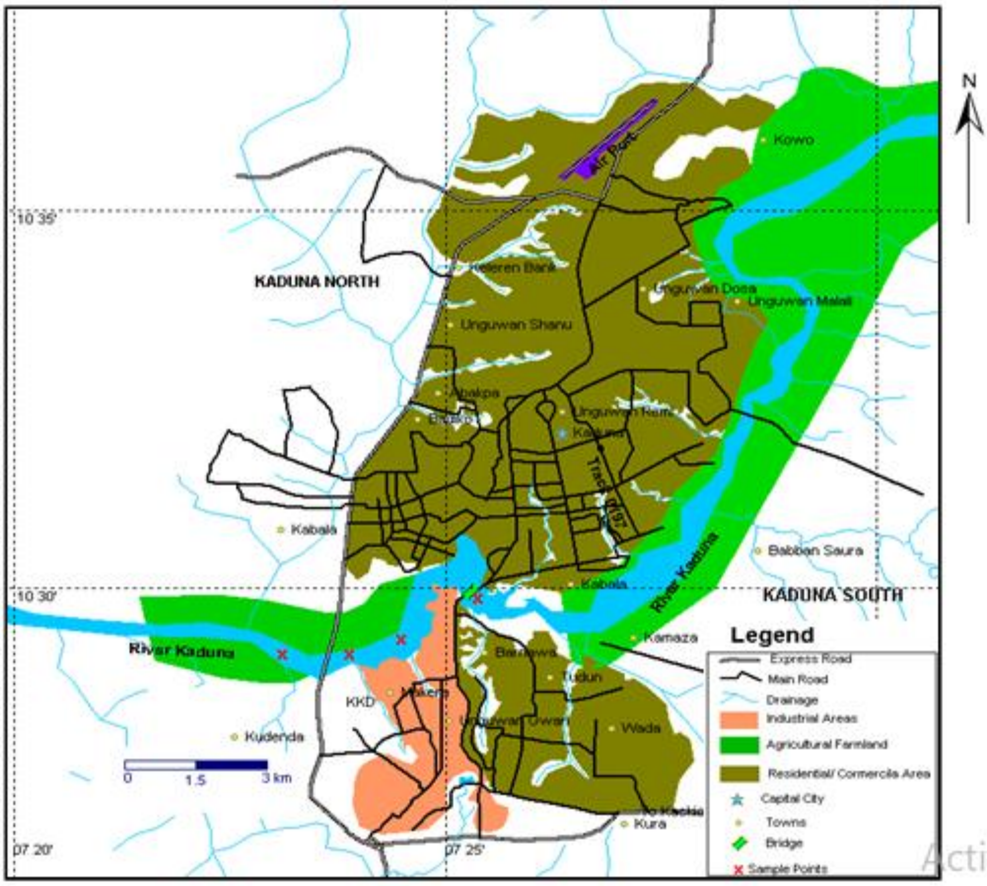
3. Materials and Methods

This study used both primary and secondary data. Data were obtained through direct field observation, collection and analysis of water samples. Secondary data for this study were published reports and Hospital records collected from Kaduna State Ministry of Health and Dr. Gwamna Awan General Hospital, Kakuri in Kaduna Metropolis. The study was carried out in dry and wet seasons respectively. The dry season study was carried out in February, 2015 to minimize confounding effects arising from surface runoff contamination of the water bodies during the rains. The rainy season study was carried out in September, 2019 being the peak period of rainfall in Kaduna metropolis. The study used descriptive statistics in the form of tables and frequencies. Inferential statistics employed was Paired sample T-test for the difference between physico-chemical properties of Kaduna River and the discharges from industrial and human activities.

Five sampling points with five samples each were purposively and carefully selected and collected to ensure that the samples were collected upstream of the land use type, within the land use type and downstream respectively. Water samples were collected between 5cm to 10 cm below the surface of the river and 2m from the bank of the river. As a result, the quantity and quality of water available for runoff and stream flow, as well as the physical, chemical and biological processes in the receiving water bodies may be affected. Channel flows were selected based on the land use types. The points where channels conveying water from the land use types and drain into the river were taken as reference samples to assess changes in water quality arising from land use type.

Water samples were randomly picked from each sample points. The sample points were Kawo (X1), Stadium (X2), Makera (X3), Bye-pass- Bridge (X4) and Kudenda (X5) as shown in figure 2. Collected water samples were preserved for laboratory based analyses of nutrients, heavy metals, total dissolved solids (DS) and suspended solids (SS), biological oxygen demand (BOD) and chemical oxygen demand (COD). Samples for heavy metals analyses were collected in acid rinsed glass and plastic bottles and stored at room temperature in KEPA laboratory. BOD samples were collected in BOD bottles and along with other samples stored by the use of ice-cooled, insulated plastic cooler boxes.

Figure-2. Kaduna metropolis, the study area



Source: Shenpam, 2016

4. Laboratory Analysis

Nutrients that were determined in the water samples included nitrate, nitrite, and total phosphate. In the laboratory, analyses were performed according to procedures for water and waste water by Yuncong and Kati [8] as follows:

COD: Chemical Oxygen Demand values were derived using the equation below:

$$\text{COD mg/l} = \frac{AB(A-B) \times N \times 800}{\text{m/samples}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where: A is volume FAS used for blank ml, B is volume FAS used for sample ml and, N is Normality of FAS.

BOD: To determine Biological Oxygen Demand (BOD), 100ml of each of the water samples was pippetted into 300ml BOD bottles. It was then filtered with enough dilution water. The DO was measured immediately as (D1). The bottle was then sealed and incubated at 20^0c for 5 days. The DO was again measured as (D2). Dilution waste was used as blank for rough checks. The formula below was used:

$$\text{BOD mg/l} = \frac{DI-D2}{P} \quad \ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

Where:

D1 is DO of dilluted sample immediately after preparation mg/l, D2 is DO of dilluted sample after 5 days incubation at 20^0c mg/l, and P is Decimal volumetric fraction of sample.

TS: To determine total solids, 100ml of the homogenized sample was measured into a pre-weighted evaporating dish. It was then evaporated to dryness on water bath. The dish was then solid-dried in oven at 105^oc, cool in a desicator and then weighted again. Total solids was then determined using the equation:

$$\text{Solid mg/l} = \frac{(A-B) \times 1000}{\text{Sample volume (ml)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where:

A is weight of dish (dried solid) mg/l, and B is weight of dish mg/l.

Heavy metals were analysed using 1.B. special – total reflection x-ray flouresceence (TRX F) method[8]. A standard solution of the elements analysed was prepared and then the sample volume of 5ml was evaporated on the silica ($S_1O_{2)}$ plate. The mass of the elements in the sample was calculated and a spectrum of the sample was taken into the TRxF system. Then the spectrum was analysed within 200 seconds. With a software package XAS (Xray Spectroscopy), the number of photons belonging to the different peaks and the corresponding background was determined [8].

These parameters were choosen because they determine the safety and quality of water for variety of uses. Analyses were performed at Kaduna State Environmental Protection Authority (KEPA) laboratory situated in Kaduna Metropolis behind Television Garage. Table 1 shows the Parameters analyzed and the FEPA (now Federal Ministry of Environment) permissible limit Standard.

Table-1. Parameters analyzed and permissible limits

S/N	Parameters	Unit	FEPA STD
A	Physical		
1	Temperature	$^O{}_{Celsius}$	Ambient
2	Ph	-	6.5-8.5
3	Conductivity	µs/cm	5.0
4	Colour	TCU	15.0 (colourless)
5	Turbidity	NTU mg/l	1.0
6	TSS (Total Suspended Solids)	Mg/l	30.0
7	TDS (Total Dissolved Solids)	Mg/l	500
8	Dissolved oxygen (DO)	Mg/l	7.5
B	CHEMICAL		
9	Ammonia	Mg/l	<1.0
10	Nitrate	Mg/l	10.0
11	Nitrite	Mg/l	1.0
12	BOD @ 20-25 ^{0}C	Mg/l	0.0
13	COD	Mg/l	40.0
14	Oil and Grease	Mg/l	0.05
15	Phosphate	Mg/l	5.0
C	HEAVY METALS		
16	Copper	Mg/l	0.1
17	Calcium	Mg/l	200
18	Magnesium	Mg/l	0.20
19	Iron	Mg/l	1.0
20	Zinc	Mg/l	5.0
21	Faecal coliform counts	Mg/l	0.00

Source: Federal Environmental Protection Agency (FEPA) now Federal Ministry of Environment, 2008.

5. Results and Discussion

Table-2. Paired Sample T test Table for the Difference between Physico-chemical properties of Kaduna River and the discharges from industrial and human activities

S/N	Parameters	Mean of Parameter	FME Standard	T cal	P value
Physical Parameters					
1	Temperature	24.1	25	2.07	0.07
2	PH	8.078	8.5	1.37	0.20
3	Conductivity	348.24	5	3.00	0.02*
4	Colour	254.29	15	4.63	0.00*
5	Turbidity	88.49	1	2.77	0.02*
6	TSS	56.5	30	1.52	0.16
7	TDS	94.1	500	15.70	0.00*
8	Dissolved Oxygen	6.3	7.5	1.23	0.25
Chemical Parameters					
9	Ammonia	1.692	1	0.97	0.36
10	Nitrate	6.9571	10	1.45	0.18
11	Nitrite	0.1869	1	8.73	0.00*
12	BOD	104.573	0	2.20	0.06
13	COD	279.9	40	1.83	0.10
14	Oil and Grease	0.4683	0.05	2.50	0.03*
15	Phosphate	4.016	5	1.04	0.32
Heavy Metals/Biological Parameter					
16	Copper	0.285	0.1	1.81	0.10
17	Calcium	2.4543	200	217.18	0.00*
18	Magnesium	2.4724	0.2	5.46	0.00*
19	Iron	1.741	1	1.99	0.08
20	Zinc	0.775	5	13.10	0.00*
21	Feacal Coliform	15.87	0	4.96	0.00*

Source: Field work, 2019, * = Significant at 0.05

From the analysis in Table 2, at significant level of 0.05, it shows that some parameters are significant in the water while some are not significant. For the physical parameters for example, results showed that conductivity (0.02), colour (0.00), turbidity (0.02) and T.D.S (0.00) were all significant because all these parameters are less than 0.05 significant. Other physical parameters were not significant in the river because their levels of significance were above 0.05. This tends to suggest that the river is polluted because the parameters that were significant in the river are important in assessment of water quality. High conductivity was observed in a study carried out by Duru, *et al.* [9] on study of human activities and water quality: A case study of Otamiri River, Owerri, in Imo state. Conductivity values increased significantly ($p<0.05$) along the sampled points. This goes to agree with the present study. High conductivity value observed in this study could be attributed to high level of dissolved solid (0.00) in the river. This also agreed with a study of Amadi, *et al.* [4] on Nworie River. The river like many other rivers in sub-saharan Africa is facing serious water pollution problems due to increased discharge of industrial, commercial and domestic effluents into the river system. The highest turbidity levels of 11.00 and 17.72 were recorded at different sampled sites. The water here was dark coloured and murky.

For chemical parameters, result for oil and grease (0.03) and nitrite (0.00) all showed significant level of less than 0.05. The presence of oil and grease on the surface water bodies in Nigeria is a sign of pollution which may have serious effect on the aquatic ecosystem of the nation. Oil and grease is toxic to aquatic organisms in general and also capable of reducing dissolved oxygen. Elevated levels of oil and grease have been reported by Osibanjo, *et al.* [10] at the downstream of rivers Ona and Alaro in Ibadan, South – Western Nigeria. The authors attributed these to urban run-off from auto-repair workshop and petroleum depot. The presence of oil and grease observed in Kaduna River may be attributed to Ahmadu Chanchanji auto repair workshop and petroleum depot located in Makera land use zone in Kaduna metropolis. This has affected the water quality of the Kaduna River negatively and agrees with the study of Oketola and Osinbajo [11] using industrial pollution load in rivers of Lagos State Nigeria.

Heavy metals studied for Kaduna River showed significant level. For example; calcium (0.00), magnesium (0.00) and zinc (0.00) all showed significant values. This agrees with the study reported by Ayenimo, *et al.* [12] in metal pollution of Warri River by industrial discharges. The river was monitored for heavy metals such as Fe, Cu, Ba, Pb, Cd, Cr, Ni and Co. Results showed elevated values of these metals at sampled point located near an industry. Industrial effluents when discharged directly into the rivers without prior treatment have capacity of increasing water quality parameter. Onipede and Bolaji [13], indicates that less than 10% of industries (point source of pollution) in Nigeria treat their effluents before being discharged into the rivers. This has led to high load of inorganic metals such as Pb, Cr and Fe in most water bodies [14, 15]. The resultant effect of this is on the receiving streams and rivers impacting on water quality impairment, reduction in fish abundance and effects on water-usage for recreation, industrial and domestic purposes. From the above Table, it shows that Kaduna River is polluted which shows that the physico-chemical properties of the river are significantly related to discharges from the industrial and human activities of the metropolis. The study also agreed with studies carried out by Vivan, *et al.* [16]; Essoka and Umaru

[17], and Eniola, *et al.* [18]. These studies reported that heavy metals present in most Nigerian rivers and found in concentrations well above acceptable and permissible levels include zinc among others.

Table-3. Trend of Water Related Diseases in Kaduna Metropolis (2003-2013)

Year	Typhoid	Cholera	Dysentery	Hepatitis	Malaria	Diarrhea
2003	817	32	15	19	10,906	50
2004	1,538	40	50	134	2,040	164
2005	3,097	22	34	37	3,575	380
2006	7,366	61	26	158	9,079	641
2007	529	40	200	94	4,668	2,407
2008	1000	30	152	105	20,315	6,371
2009	809	18	500	84	23,758	7,528
2010	608	13	460	11	11,086	3,146
2011	1,024	843	76	10	3,113	1,999
2012	60	165	550	782	30,855	5,788
2013	251	136	743	1,058	70,918	6,238

Sources: Kaduna State Ministry of Health and DR. Gwamna Awan General Hospital, Kakuri, Kaduna, 2014

As could be seen on Table 3, the trend of the prevalence of water related diseases in Kaduna metropolis in 2003 to 2013 showed that malaria was the most prevalent. This was because the number of malaria cases recorded (10,906) was higher than the other diseases. Typhoid fever was next with 817 cases, followed by diarrhea (50 cases), cholera (32 cases), hepatitis (19 cases) and dysentery (15 cases). This shows that malaria was the most highly recorded case, followed by typhoid fever. Malaria cases in 2004 dropped from 10,906 to 2,040 cases, but this could not be said about others. For instance, typhoid increased from 817 to 1,538. In the order of most recorded cases, diarrhea had the next case of 164 followed by hepatitis with 134 cases, dysentery (50 cases) and cholera (40 cases) respectively.

Contrastingly, malaria cases increased from 2,040 to 3,575. Similarly, typhoid with next highest case also increased from 1,538 in 2004 to 3,097. Diarrhea (380 cases) followed, and in that order by hepatitis (37 cases), dysentery (34 cases) and least cases was cholera (22 cases). In 2006, malaria cases continued its dominance and increasing rate with a sharp increase to 9,079. Malaria is followed in this order by typhoid (7,366 cases), diarrhea (641 cases), hepatitis (158 cases), cholera (61 cases) and dysentery (26 cases). There were drops in the number of cases of these diseases in 2007 except in dysentery which increased from 26 in 2006 to 200 in 2007. Despite this increase, the incidence of malaria was still more than that of other diseases (4,668 cases). Malaria is followed at a distance by diarrhea (2,407 cases), typhoid (529 cases), dysentery (200 cases), hepatitis (94 cases) and cholera (40 cases).

The reported cases of these diseases increased in 2008 except for dysentery and cholera which decreased. Specifically, the cases were still most in malaria (20,315 cases) followed by diarrhea (6,371), typhoid (1000), dysentery (152), hepatitis (105) and cholera (30). Malaria continued its increasing trend in 2009 by rising to 23,758 and it was followed by diarrhea (7,528), typhoid (809), dysentery (500), hepatitis (84) and cholera (18). Year 2010 recorded a drop in trend for all the cases. Specifically, malaria still dominated with 11,068 cases and was followed in that order by diarrhea (3,146), typhoid (608), dysentery (460), cholera (13) and hepatitis (11). In 2011, malaria continued its domination of the recorded cases of 3,113 and was followed at a distance by diarrhea (1,999), typhoid (1,024) and cholera (843), Meanwhile, 2012 recorded a drastic fall in the number of cases of typhoid from 1,024 in 2011 to only 60 cases in 2012. But cases of other diseases increased noticeably with malaria increasing from 3,113 cases in 2011 to 30,855 in 2012. On the other hand, the number of cases of malaria remained the highest and is followed by diarrhea (5,788), hepatitis (782), dysentery (550), cholera (165) and the least was typhoid (60 cases). Lastly, 2013 recorded a small decrease only in the cases of cholera from 165 cases in 2012 to 136 cases in 2013. The same could not be said about other diseases as they moved up greatly. Precisely, malaria increased from 30,855 in 2012 to 70,918 in 2013, while, typhoid and hepatitis increased to 251 and 1,058 from 60 and 782 in 2012 respectively. Malaria dominated the number of recorded cases in 2013 with 70,918 and was followed in that order by diarrhea (6,238), hepatitis (1,058), dysentery (743), typhoid (251) and lastly cholera (136).

In general, the trend of these diseases was such that it moved up quickly and at some times fell easily. Specifically, malaria had the highest movement because it started with 10,906 in 2003 and dropped to 2,040 in 2004 and continued in that trend until 2012 when it increased from 3,113 in 2011 to 30,855 and increased further to 70,918 in 2013. From the above, it tends to suggest that incidence of some water related and water born diseases are on the increase in the study area**.** For example, cases of malaria, diarrhea and hepatitis were on the increase in Kaduna metropolis most especially in the year 2013. This may be as a result of persistent crises of Boko- haram in the study area which rendered many people homeless exposing them to mosquito bites and sourcing water from sources that represent greater risk to health.

6. Conclusion

The sources of pollution in Kaduna River comprised of the agricultural runoff, industrial effluents and discharges , runoff from urban center, underground seepage and natural sources which can be grouped under the point source (PS) and non-point source (NPS) of pollution. The rapid growth of urban centers coupled with the development of unstructured infrastructural and social services have created an unpleasant environmental situation in many parts of Kaduna Metropolis which has effects on healthy living of residents. Human activity of the metropolis has effects on the quality of Kaduna River, which leads to its pollution. The study revealed direct link between urban environment degradation and human health in terms of water related and water born diseases such as malaria, diarrhea, dysentery, cholera and typhoid.

Recommendations

Given the complexity and magnitude of the challenges revealed by this study, an effective response to surface water pollution will involve concerted action by all stakeholders, including the public and private sectors and civil society.

In industry, solutions include reformulating products so that they produce less pollution and required fewer resources (including water) during their manufacture. In agriculture, reducing the use of toxic materials for pest control, nutrient application and overall water usage can reduce pollution. Examples of implementation of Good Agricultural Practices include crop rotation, cover cropping conservation agriculture, improved irrigation management and integrated pest management techniques. In human settlements, the most obvious solutions include increasing improved sanitation coverage, considerations of settlement design (such as the types of materials used for construction), the location of industry and the handling of storm water, as well as reducing wastewater production.

In cases where contaminants result from domestic, industrial or agricultural activities, wastewater must be treated before discharging. Treatment strategies for contaminated water range along a continuum from high-technology, energy-intensive approaches to low-technology, low-energy, biologically and ecologically focused approaches. Where good water distribution and treatment systems are already in place, constant effort is needed to maintain and expand their effective operation.

In peri-urban and rural areas, treated human wastewater can be a viable source of water for re-use. Ecological situation, for example, is a low-cost method of dealing with human waste promoted by many development agencies. It involves the separation of urine and faecal matter –sterile urine may be applied directly to plants while faecal matter is composted until it is safe for land application. This approach has been implemented in several countries and regions, including China, India, Burkina Faso, Kenya, Niger, Sweden and parts of Eastern Europe. By recycling water and using dry pre-stored human wastes, jobs are created for local populations as well as market opportunities for provision of indigenous fertilizers and soil conditioners for agriculture.

Safe re-use of wastewater, as a component of cleaner production application, can improve water and energy efficiency and consequently generate environmental benefits. For example, industry can re-use wastewater from certain processes in other applications that do not require high-quality water or apply appropriate technologies like treatment of polluted water to process wastewater for procedures requiring water of higher quality.

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