Effects of Discharge Effluents from Kaduna Refinery on River Rido, Kaduna, Nigeria

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Abstract

The study assessed the effects of effluents from Kaduna Refinery and Petrochemical Company on the quality of water from River Rido. A total of seventeen samples were taken for the study; comprising of five control samples at interval of 1km from each other before the point of discharge of effluents from the refinery, and twelve samples after the point of discharge at interval of 1km each every sampling month. The transient method was used to determine sampling points along the river. The water samples were taken at two different periods; raining and dry seasons. The parameters determined were temperature, pH, total suspended solids, total dissolved solids, turbidity, conductivity, alkalinity, dissolved oxygen, biochemical oxygen demand, sulphate, phosphate, nitrate and chloride. The metals determined in the water samples were As, Cd, Cu, Cr, Fe, Mn, Ni, Hg, Pb and Zn. The findings reveals that the concentrations obtained for physiochemical parameters were all higher than those obtained for the control samples in both dry and wet seasons. The results of the physicochemical parameters showed that all the concentration values obtained for these parameters in water were below the tolerable or permissible levels recommended by regulatory bodies except for turbidity that had values higher than the tolerable or permissible levels. The general irrigation water quality parameters values are within the standard guidelines recommended by FAO and therefore, the water from this source is fit for irrigation.

Keywords: Effluents, Heavy metals, Irrigation, Physicochemical, Water quality.

1. Introduction

The importance attached to water gave rise to most human civilizations developing along water courses which provided water for many purposes. In Africa, water has been an important resource determining human habitable sites and activities. Thus, the location of most African settlements was associated to locations where water presence was an advantage. Because there are numerous human activities requiring water, the available water resources seems not to meet the demand. This is an indication that water is in short supply and requiring proper utilization and management. As observed by Christopherson (2006) that though water is a renewable resource, the increasing demand by rapid population growth and human activities have further resulted in the decline in quality and quantity of water in streams, rivers, lakes, lagoons and underground aquifers.

Water is not evenly distributed universally both in space and time. This has resulted in water surplus and scarcity in the different regions of the world. That is why Enger and Smith (2006) are of the view that the increasing demand of water for different uses will require the utilization of all available water especially in climatic regions characterized by inconsistency in distribution. They also observed that different water uses will require different quality standards thus, water considered not fit for a particular use may be applied for other uses. Water trapped in surface reservoirs can easily be accessible, cheap to exploit and is replenished directly by rain drops from atmospheric precipitation. However, most of fresh water resources are contaminated through human activities

Increasing industrialization and exploding human population had increase the demand for water. Yet, a considerable pant of this limited quantity of water is polluted by human activities, sewage industrial wastes and a wide array of synthetic chemicals (Dara, 2004). Most human activities such as agriculture, domestic and industrial use pollute water resources. That is why every human use of water, whether for drinking, irrigation, and industrial processes or for recreation has some quality requirements in order to make it acceptable. This quality criterion can be described in terms of physical, chemical and biological properties of such water (WHO, 2008).

The increase in industrial activities has led to pollution of surface waters both from industrial, agricultural and domestic sources. This is because wastes entering these water bodies are both in solid and liquid forms, and mostly derived from Industrial, agricultural and domestic activities. Thus, water bodies which are the major receptacles of treated and untreated or partially treated industrial wastes have become highly polluted. The resultant effects of this on public health and the environment are usually great in magnitude (Reza et al, 2010). The increase in human population, urbanization, industrial and agricultural land use, has led to a tremendous increase in discharge of a wide diversity of pollutants to receiving water bodies. This has caused negative effects on the different components of the aquatic environment and on fisheries. As a result, there is concern globally that the management and utilization of natural resources need to be improved and that the amount of waste and pollution

generated by human activity need to be reduced on a large scale (Osibanjo et al, 2011).
With increase in industrial activities and the realization that industrialization is considered necessary for the advancement of any society, the ecological devastation and human disasters that have occurred over the years has revealed that industries contribute to degrade the environment and pollution of various magnitudes. This is more so that the waste and emissions generated by industries contain hazardous and toxic substances of different kinds which can be detrimental to human health (Vivian et al, 2012). Thus, the pollution effects of waste from industries should be of concern to all, because United Nations recently reported that close to 70% of untreated industrial wastes in developing countries is discharged into water where they contaminate existing water supplies. Thus, the discharge of industrial waste into water will often impact negatively on water resources and livelihoods.
The uncontrolled disposal of waste by refineries into water renders water unsafe for human use and poses a threat to human life. Hence, proper management of water resources is necessary to avoid water borne diseases and water caused health related problems. This is necessary, because industry is the direct user of water resources as well as the main sources of water pollution. Thus, drinking water contaminated with refinery effluents can cause health problems.

2. Implication of Problem Statement

There is an increasing concern about the contamination of natural water bodies by industrial effluents in developing and densely populated countries like Nigeria. This is because rivers are a major means of waste disposal and especially effluents from industries that area located close to a river. Thus, major sources of drinking water such as estuaries and water bodies in the country are often contaminated by the activities of the adjoining population and industrial establishments (Susan, 2016). These has often rendered the water unsuitable for use. Effluent discharge management practices in Nigeria are poor and when discharged it becomes a threat to cities where industries are located. Government realizing the danger posed by this threat established The National Environmental Standard and Regulatory Enforcement Agency (NESREA) to check these threats and environmental abuses. Unfortunately, the impact of the agency on pollution control especially in the cities is not much felt.
The environment is considered as man's important asset that must be protected for his life support. Regrettably, the situation is different where oil refinery and petrochemical plants operate. This is because emissions and effluent discharge in these areas poses serious threat to the ecosystem particularly water and soil, often with undesirable effects (Atubi, 2011). Thus, proper utilization of water requires that the quality of water should be determined to ensure that it meets the standard proposed for a specific or a general use (WHO, 2006). Studies conducted on water quality have indicated that hardly is water pure containing with no minerals or chemicals exists naturally in the environment (Ademorati, 1996). Incompatible human activities have introduced to water bodies both in surface and underground sources

substances at intensities above the threshold level considered safe for such sources culminating therefore in water quality problems (Susan, 2016).The poor quality of most water in recipient sources suggests that to use such water for any purpose will require an evaluation of the water so as to determine if the concentration of substances is within acceptable limit values considered safe.

Kaduna Refinery and Petrochemicals Company generate effluents of different grades in the process of carrying out refining activities. This waste is discharge into River Rido; which is an important source of water for Rido community. It is expected that the discharge of untreated wastes from the industry will affect the quality of water in the river. It is against the background of the damning consequences of KRPC operations on the quality of River Rido water, that this study was undertaken. Also, there is little known about the types and abundance of pollutants discharged by the company into River Rido hence, the purpose of this study.

Research findings in Nigeria reveals that most of the common freshwater sources are polluted which have resulted to outbreak of diseases and health related problems. Several studies (Atubi, 2011**;** Onojake et al, 2011; Salisu and Mustapha, 2013) on different aspects of water quality and pollution in different parts of Nigeria have revealed various levels of negative impacts of anthropogenic activities on the environment.

Studies conducted in Kaduna on water quality for example Susan, 2016 has reported that River Romi has become contaminated by the effluents discharged from the refinery and another study also reported that Industrial activities in Kaduna Refinery and Petrochemical Company have adverse effects on the environment. However, despite the fact that the refinery has a waste water treatment plant, the waste released into the river from the refinery contaminates the water in River Romi. Amadi, *et.al* **(**2013) reported pollution of soil and heavy metals at locations near the refinery. Aderogba (2011) asserted that the polluted wastewater from the company is discharged directly to the environment. Vivan, *et.al* (2014) study discovers soil contaminations with liquid gaseous and solid waste disposal from the refinery. Ahmad (2014) findings confirm the efficiency of effluent treatment by the management of the refinery. Though most of the studies in the study area have been conducted on the analysis of the different aspects of water quality while this research is on the assessment on how the effluents discharge from the refinery affects the water quality of the Rido River.

3. Material and Methods

3.1 The Study Area

The study area lies between latitudes 10° to 11 ° North and longitudes 7° to 8° east (Figure 1). The main reason for sitting the petroleum Refinery and Petrochemical industry in the study area, according to the Ministry of Petroleum Resource was to guard against emitting pollutants to the metropolis; as the tropical and continental winds run parallel to the region. The climate of the area lies within the tropical wet and dry climatic zone, characterized by variations in seasonal rainfall and climatic distribution. The seasonal climatic condition is as a result of oscillation of two air masses namely; the Maritime Tropical air mass and the Tropical Continental air mass with contrasting rainfall and temperature characteristics. The region experiences rain between May and September when the Maritime Tropical is prevalent and experiences dry season when Continental Tropical prevails, which is characterized by cold, dry and dusty wind. River Rido is one of the tributaries of River Rigasa, which drain into Kaduna river system, which is the largest river in study area. All streams and rivers within the study area experience flash floods during the rainy season. Runoffs begin soon after the start of rainfall. In valley undersides, the water table is closer to the surface and water logging occurs. Initially the provision of disposing refinery liquid waste into River Rido was one of the reasons why the refinery was located in Rido. The river flows throughout the year but its volume reduces during the dry season and increases in volume during the rainy season. The river at Rido receives effluent from the Kaduna Refinery and Petrochemical Company.

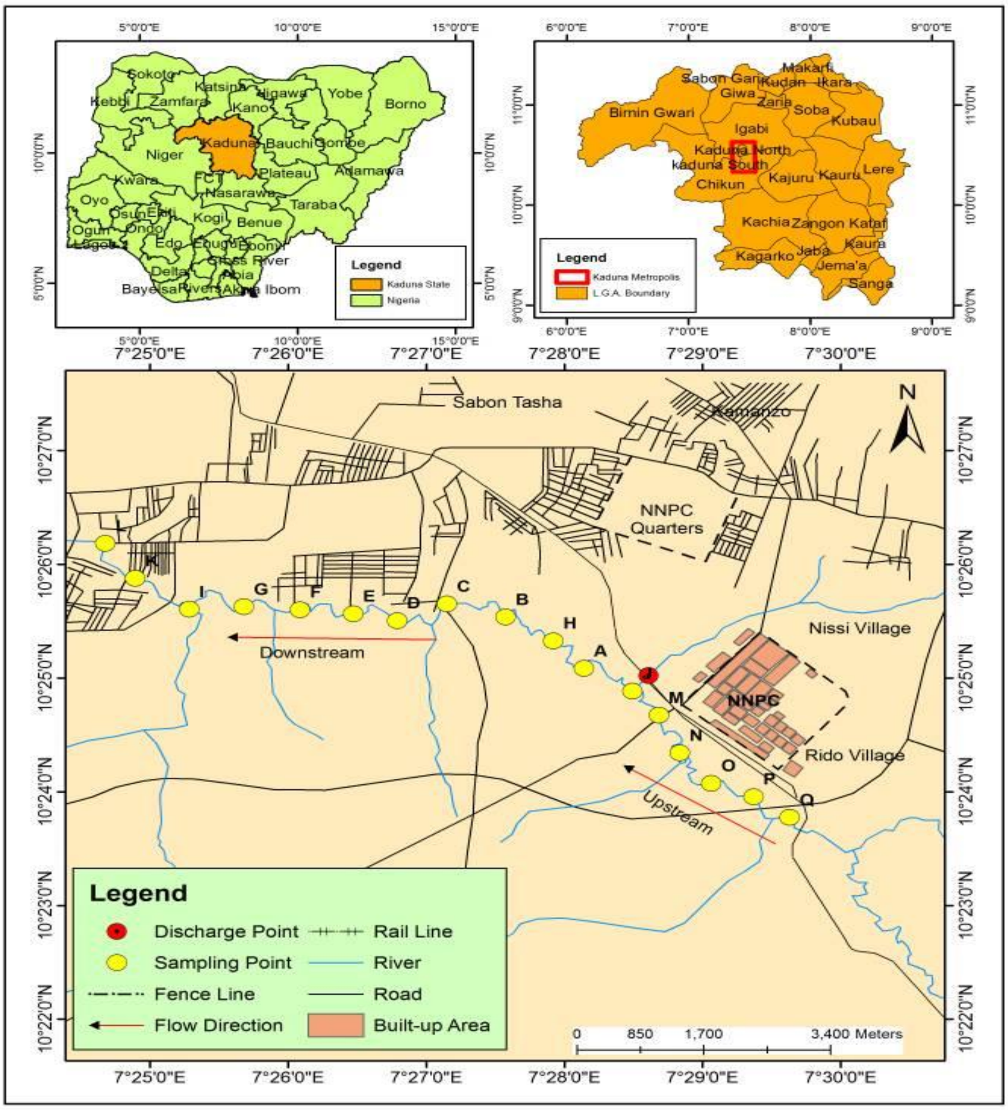

Figure 1: Kaduna state showing study area and sampling sites.

3.2. Research Methodology

The primary sources were derived from the laboratory analysis of water quality of the water samples collected by transect methods from River Rido. The process involved the collection of water samples along the river. The transient method was used to determine sampling points along the river. This was done to allow flexibility in fixing of the points in the river at which samples were taken. A total of seventeen samples were taken for the study; comprising of five control samples at interval of 1km from each other before the point of discharge of effluents from KPRC, and twelve samples after the point of discharge at interval of 1km each every sampling month. The water samples were taken at two different periods; raining and dry seasons. For the purpose of this study, high flow was defined as a condition when surface runoff was entering the river, and concentrations of suspended material in the water appeared to be higher than at low flow. High-flow samples were collected in the months of June, July and August (Raining season). Low-flow samples were collected in January, February and March (Dry season). The sampling points were determined by use of a 100 metre synthetic tape to fix distance for each sampling point. Collection of water samples along the river took take place in the morning between 8-10 am when the temperature was low because high temperature might alter the level of pollutants by enhancing chemical reaction. These samples were collected using Grab method which is effective enough for surface water investigation of inland hydrological systems.

The parameters evaluated in this study included properties associated to salinity from dissolved salts, sodicity caused by sodium ion and toxicity by trace elements. The Physicochemical Parameters Are Temperature, pH, total dissolved solid, total suspended solid, turbidity, conductivity (Electrical Conductivity, EC), dissolved oxygen, biochemical oxygen demand, sulphate, phosphate, nitrate and chloride ion. The heavy metals properties analyzed are: Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Mercury (Hg), Nickel (Ni) and Zinc (Zn).

Metal analysis was done by the digestion of water Samples. After which the clear digest was run through atomic absorption Spectrophotometer AAS (ICE 3000AA0213410.VI.30 System). About 250cm^3 of water sample was collected into an evaporating dish and 5.0cm^3 of concentrated HNO_3 was added. The sample was digested for about 60 minutes using digestion block in a fume cupboard until the solution reduces to 25 cm^3 with a characteristics color, indicating a complete digestion. The digest was allowed to cool and transferred to a 50 cm^3 acid washed volumetric flask and brought to 50 cm^3 mark with deionized water.

4. Results and Discussion

4.1. Physiochemical Parameters for water samples from River Rido

The result of the values of physicochemical parameters measured in this study in the water samples from River Rido during the dry season shows that the mean temperature value for the water samples during the dry season was 27.67 ˚C and the range was 26.90 – 28.20˚C. This implies that temperature of Rido River is tolerable and the mean temperature in this is however lower than the mean value of 25˚C. The result also shows that the mean pH value for the dry season was 6.84. The dry season mean value for total suspended solids (TSS) was 2.42mg/L and 83.75mg/L for total dissolved solids (TDS). Mean turbidity values recorded for samples of water from River Rido during the dry season was 14.56 NTU. The mean value of electrical conductivity for the samples of water in the dry season was 122.12 μS/cm. The mean alkalinity value for water samples from River Rido was 1.97 mg/L $CaCO_3$ in the dry season. The mean value of dissolved oxygen (DO) in water samples from the River Rido determined was 85.93 mg/L during the dry season.

In the dry season, the mean value for BOD obtained from River Rido water samples was 12.18 mg/L. The mean value of sulphate from River Rido water samples during the dry season was 36.35 mg/L. Dry season mean concentration of phosphate in this study was 1.19 mg/L. Nitrate mean concentration from River Rido during the dry season was 2.57 mg/L. The value of chloride in the water samples from River Rido in terms of the mean values during the dry and wet seasons was 5.15 mg/L. The dry season results of the physicochemical parameters in control water samples from River Rido, Kaduna shows that the physicochemical parameters assessed included the following: temperature, pH, TDS, TSS, turbidity, conductivity, alkalinity, DO, BOD and sulphate, phosphate, nitrate and chloride ion. The mean values were 27.50˚C, 7.20, 75.60 mg/L, 1.12 mg/l, 2.42 NTU, 83.28 µS/cm, 0.82 $CaCO_3$ mg/l, 62.20 mg/L, 5.28 mg/l, 12.87 mg/l, 0.24 mg/l, 0.63 mg/l and 2.12 mg/l respectively. These mean values from the control samples are lower than the dry season physicochemical parameters assessed in this study. This could be attributed to the refinery discharge in River Rido after the points taken as control sampling points

The Physiochemical Parameters for Water Samples from River Rido in the Wet Season reveals that the mean temperature value for the water samples during the wet season was 26.37 ˚C. This value is however; lower than the value of 30 ˚C obtained from analysis of physicochemical parameters of water and sediments collected from Rawal Dam Islamabad by Zubia *et al* (2015). It is also slightly lower than the mean values of 27.73˚C, 27.00˚C and 28.80˚C in different surface water samples during the wet season reported by Abgaire and Obi (2009). The mean pH value for the wet season was 6.62. In the wet season, the mean values for TSS was 3.93 mg/l while TDS was 133.29 mg/l. The mean turbidity values recorded for samples of water from River Rido during the wet season was 32.82 NTU. The mean value for conductivity of water samples from the River Rido during the wet season was 184.67 µS/cm. The mean alkalinity value in this study was 3.23 mg/L $CaCO_3$ during the wet season. The mean value of DO determined was 83.68 mg/L during the wet season. The higher values of DO reported in this work is an indication that there were no much organic matters to be broken down by anaerobic microbes as such would not drawn much of the dissolved oxygen.

The mean value of BOD obtained from River Rido water samples was 11.26 mg/L during the wet season. The mean value of sulphate from River Rido water samples during the wet season was 28.96 mg/L. The mean concentration of phosphate from River Rido water samples during the wet season was 2.68 mg/L. The mean concentration of nitrate in water samples from River Rido during the wet season was 2.13 mg/L. The mean value of chloride in the water samples from River Rido during the wet season was 3.91 mg/L.

The result of the physicochemical parameters in control water samples from River Rido during the wet season shows that the physicochemical parameters assessed included the following: temperature, pH, TDS, TSS, turbidity, conductivity, alkalinity, DO, BOD and sulphate, phosphate, nitrate and chloride ion. The result shows that mean values were 26.30˚C, 7.22, 71.92 mg/L, 2.09 mg/L, 3.20 NTU, 91.28 µS/cm, 0.84 $CaCO_3$ mg/L, 54.30 mg/L, 4.48 mg/L, 7.87 mg/L, 0.81 mg/L, 1.27 mg/L and 1.53 mg/L respectively. These mean values from the control samples are lower than the values for all the physicochemical parameters assessed for the study area in the raining season. The discharge from the refinery into River Rido after the points taken as control sampling points may be responsible for this.

4.2: Heavy Metal Contents in River Rido water

The results on the level of heavy metals in water samples from River Rido during the dry season together with the mean metal levels shows that arsenic concentration is 0.0337 mg/l for dry season. Cadmium mean concentration for dry season was 0.0094 mg/l. Copper mean concentration was 0.2789 mg/L during in dry season. The mean concentration for chromium in water samples from the River Rido was 0.0098 mg/L for the dry season. Dry season iron mean concentration was found to be 1.0282 mg/L during the dry season. The mean concentration of manganese in water samples from River Rido was 1.4024 mg/L during the dry season. Dry season manganese mean concentration for nickel was 0.0305 mg/L. Mercury (Hg) was not detected in this study but lead mean concentration was 0.0198 mg/l. Zinc mean concentration in this study was 0.3397 mg/L during the dry season.

For the level of Heavy Metal Contents in Control Water Samples from River Rido in the Dry Season shows that the mean concentration of As was 0.0061,Cd was 0.0017, Cu was 0.1030, Cr was 0.0019, Fe was 1.0334, Mn was 1.1592, Ni was 0.0019, Hg was 0.00, Pb was 0.0481 and Zn was 0.0978 mg/L. These values were found to be lower than the mean values for all the parameter in the water samples from the River Rido. And this could be attributed to the discharge of effluents from the Refinery into the River Rido.

The result on the level of Heavy Metal Contents in Water from River Rido in the Wet Season also contains information on the mean metal levels and the parameters determined in this study. Arsenic mean concentration was 0.0419 mg/L Cadmium mean concentration for wet season was 0.0107 mg/L. The level of copper in water samples from the River Rido in terms of the mean concentration was 0.6955 mg/l. Mean chromium concentration was 0.0817 mg/L during the wet season. The mean concentration of iron in water samples from River Rido was found to be 1.6684 mg/L during the wet season. Wet season mean concentration of manganese in water samples from the River Rido was 1.6803 mg/L. Nickel mean concentration in River Rido was 0.0427 mg/L in wet season. Mercury (Hg) was not detected in the water sample from The River Rido during the wet season while mean concentration of lead was 0.0225 mg/L. Wet season mean concentration of zinc is 0.4992 mg/L.

The Level of Heavy Metal Contents Control Water Samples from River Rido in the Wet Season shows the results of the metal concentrations from all the control sampling points during the wet season and it also shows the parameters determined in this study. The mean concentration of As was 0.0125, Cd was 0.0017, Cu was 0.4192, Cr was 0.0265, Fe was 1.0052, Mn was 1.1931, Ni was 0.0252, Hg was 0.00, Pb was 0.0038 and Zn was 0.5531 mg/L. These values were found to be lower when compared with the mean values for all the parameter. This may be due to the effects of the activities of the refinery into the river.

4.3: Seasonal variation in Physicochemical Properties and heavy metal content of water samples

1 Variation in the Physicochemical Parameters of Water

The result shows that the mean values for all the physicochemical parameters for both the dry and wet seasons are in ranges for all the parameters from the minimum values to the maximum values. The mean temperature value for the water samples during the dry season was 27.67 ˚C and that for the wet season was 26.37 ˚C. There was however, no much difference between the values for the two seasons. This is because the values are within the same range. The little difference between the values in dry and wet seasons could be attributable to the hot weather that prevails during the dry season.

In the dry season, mean pH value 6.84 while in the wet season it was 6.62. These values are within the same range. There was a little difference between the values for the two seasons and there were generally low. The implication of low values of pH is that could increase the concentrations of some dissolved metals in water and could eventually increase the toxicity levels of these metals. Suspended solids recorded a mean value of 2.42, 83.75 in the dry season while recorded 3.93, 133.29 mg/L during the wet season. This differences in values obtained between the seasons is because River Rido receives run- off water during the wet season from different points.

The mean turbidity values recorded for samples of water from River Rido during the dry and wet seasons were 14.56 NTU and 32.82 NTU respectively. The value of turbidity during the dry season was lower than in wet season. This is because River Rido normally receives part of the run off waters during the wet season hence, its higher turbidity during the period. The mean values for the samples from the dry and wet seasons were 122.12 and 184.67 µS/cm respectively. Most of the conductivity values from wet season samples are higher than the ones for the wet season. This could be traced to the run-offs that are discharged to the receiving water at different points during the wet season. Water samples from River Rido recorded mean alkalinity values of 1.97 for dry season and 1.51 mg/L $CaCO_3$ in wet seasons. High dry season values than for wet season could be due to reduced volume of water due to drying up of water during the dry season.

The mean values of DO determined were 85.93 mg/L and 83.68 mg/L during the dry season and wet season respectively. Most of the values obtained during the wet season were within the same range with those of the dry season even though there were always run-off waters from farmlands and other different places being discharged into the River Rido. The higher values of DO reported in this work is an indication there were no much organic matters to be broken down by anaerobic microbes as such would drawn much of the dissolved oxygen.

dry season. The mean values for BOD obtained for water samples from River Rido was 12.18 mg/L in the dry season and 11.26 mg/L for wet season. The slightly higher value of BOD during dry season compared to wet season could be because of reduced volume of water due to drying up and the quantity or amount of organic contaminants that would go with very high level of microbial activities with the eventual reduced levels of oxygen in water being on the increase. Sulphate mean value from River Rido water samples during the dry was 36.35 mg/L while the wet season recorded 28.96 mg/L. The high value for the dry season may be due to reduced volume of water due to drying up of water during the dry season.

The mean concentrations of phosphate from River Rido water samples for the dry season was 1.19 mg/L and it was 2.68 mg/L in the wet season. The high level of phosphate during the wet season can be due to run-off waters discharged into River Rido from farmland where fertilizers and pesticides that contains phosphate had been used (Ademoroti, 2006). The mean concentrations of nitrate in water samples from River Rido in the dry season was 2.57 mg/L while the wet season recorded 2.13 mg/L. There is a little difference between the results obtained during the dry season compared to that obtained during the wet season. The slightly higher dry season mean value than that of the wet season may be due to drying and concentration (Ademoroti, 2006).

The mean concentration of chloride in the water samples from River Rido in the dry was 5.15 mg/L .The chloride concentration dropped to 3.91 mg/L during the raining season. The drop in mean concentration during wet season might be attributed to the dilution with rain water thus, lowering the concentration of chloride in raining water of the river. The high values during the dry season might also be due to drying of water volume and concentrating of the chloride ion. The parameter with the highest variability in both dry season and wet seasons was conductivity which had coefficient of variation of 141.51 % and 120.99 % respectively and the least varied parameter was temperature which had 1.55% and 1.18% in dry and wet seasons respectively.

2 Variations in the Heavy Metal Contents of Water from River Rido

Table 1 shows the mean values for all the heavy metals determined for both the dry and wet seasons. The result reveals that the mean concentration of arsenic was 0.0337 mg/L in the dry season and 0.0419 mg/L for wet season. The level of the element during the wet season was higher than that of the dry seasons. Arsenic is associated with sulphide ores of tin, tungsten, silver, gold cobalt and nickel. It is also associated with sulphides of iron, copper and zinc. Therefore, the high level of arsenic during the wet season could be attributed to run-off water from different places that are always discharged into the water body particularly from places where there are evidence of the metals mentioned above.

Table 1: Summary of the Level of Heavy Metal Contents in Water from the River mg/L

Parameters		As	Cd	Cu	Cr	Fe	Mn	Ni	Hg	Pb	Zn
Dry Season	Max.	0.0826	0.0231	0.5946	0.0910	1.5134	1.6492	0.0600	N/A	0.1751	0.5649
	Min.	0.0112	0.0031	0.1056	0.0019	0.4183	1.1463	0.0190	N/A	0.0009	0.1056
	Mean value	0.0337	0.0094	0.2789	0.0098	1.0282	1.4024	0.0305	N/A	0.0198	0.3397
	SD	0.0387	0.0085	0.1421	0.0265	0.3370	0.1685	0.0179	N/A	0.0498	0.1366
	CV%	114.83	90.43	50.95	270.40	32.78	12.02	58.68	N/A	251.51	40.21
Wet Season	Max.	0.0976	0.0316	1.0466	0.2356	2.3356	2.3653	0.0755	N/A	0.1904	0.9135
	Min.	0.0127	0.0010	0.4093	0.0273	0.9163	1.2435	0.0297	N/A	0.0010	0.1238
	Mean value	0.0419	0.0107	0.6955	0.0817	1.6684	1.6803	0.0427	N/A	0.0225	0.4992
	SD	0.0480	0.0014	0.2017	0.0666	0.5245	0.3329	0.0197	N/A	0.0541	0.2381
	CV%	114.56	13.08	29.00	81.52	30.84	19.81	46.14	N/A	245.91	44.83

SD = Standard Deviation, CV% = Coefficient of Variation, N/A = Not Available

The mean concentration of cadmium for dry was 0.0094 mg/L and 0.0107 mg/L was recorded in the wet season. Cadmium level for wet season was higher than that obtained for the dry season, and this could be as a result of runoff water that flows into the River Rido during the wet season. Copper recorded a mean concentration of 0.2789 in water samples from the River Rido in the dry season while 0.6955 mg/L was recorded in wet season. The higher concentration during the wet season than in dry season could be due to run-off that sweeps all manner of pollutants into water bodies during wet season. Most of the sampling points showed that chromium was not detected during the dry season but were detected in most points of sampling during the wet season. This was however largely due to run-offs that go into the River Rido at different points during the wet period. In the dry season chromium recorded a mean concentration of 0.0098 mg/L and value for wet season was 0.0817 mg/L.

The mean concentrations of iron in water samples from River Rido were found to be 1.0282 mg/L in the dry season and 1.6684 mg/L for wet season. Due to run-off waters that are discharged into the river during the wet season the value of iron in most of the samples had higher values during the wet season than those obtained for the samples in dry season. Manganese is a mineral that naturally occurs in rocks and soil and may also be present due to underground pollution sources. Manganese is rarely found alone in a water supply. It is often found in iron-bearing waters but is more rare than iron. Chemically it can be considered a closely related to iron since it occurs in much the same forms as iron. The mean concentrations of manganese in water samples from the River Rido was 1.4024 mg/l for dry season and 1.6803 mg/l in wet season. Majority of water samples during wet season had concentrations of manganese in water higher than most of the samples of water obtained during the dry season due to run-off water that are discharged from different point into the River Rido during the season in question.

Nickel emissions could come from power plants, waste incinerators and metal industries. It could be emitted directly from industries through discharge on surface waters. The mean concentrations of nickel in water samples from the River Rido was 0.0305 mg/L for dry season and 0.0427 mg/L was recorded in wet season. Run-off waters that go into the river during the wet season may be responsible for higher nickel concentrations recorded in the season. Mercury is a chemical element which silvery room-temperature and due to its density being more than 5.0 g/dm^3 it is referred to as a heavy metal. This chemical element can be found in natural ores deposits and manufactured devices such as barometers, thermometers, dry-cell batteries, switches, fluorescent light bulbs, and other various electronics.

Mercury could find its way into water supplies thorough devices containing it which are discarded properly, as runoff from landfills & farm land, dumped by factories, or from natural deposits. Mercury was not detected in any of the water samples from the River Rido for both the dry and the wet seasons. The main sources of lead exposure include lead in paints, gasoline, water distribution systems, food and lead used in hobby activities. It is sometimes found free in nature, but usually obtained from the ores galene (PbS), anglesite ($PbSO_4$), cerussite ($PbCO_3$) and minium (Pb_3O_4). Mean concentration of lead is 0.0198 mg/L for dry season and 0.0225 mg/L for wet season. Flow of run-off into the river during the wet season may be responsible for higher mean lead concentration in the season.

Zinc recorded mean concentrations of 0.3397 mg/L in the dry season and the wet season recorded 0.4992 mg/L. Zinc from concentration found to be higher in many of the sampling points during the wet season than from all the sampling points during the dry season could be attributed to run-offs that flows from agricultural lands and other contaminated places into the River Rido during the wet season. The parameter with the highest variability during the dry season and wet season were chromium and lead which had coefficient of variation of 270.40 % and 245.91 % respectively and the least varied parameter were manganese in the dry season with coefficient of variation of 12.02% and cadmium in the wet season with coefficient of variation of 13.08%.

5. Conclusions

This study observed that River Rido has been contaminated by the effluents discharged from the refinery with concentrations higher than the values recommended by regulatory agencies as the tolerable or permissible limits for the specific metals. The turbidity level is higher than the recommended tolerable limits. Thus, with the result obtained, the effects may destabilize the balance of the ecosystem and water from the river cannot be relied upon for various human activities. If the water from this source is to be used for agriculture, domestic and industrial purposes then, there should be a routine check on its quality by appropriated agency of government so that the effluents are properly and adequately treated and tested fit before being discharged into water bodies. Finally, efforts should be made by the refinery to ensure that the effluent quality meets standards, since it is used for irrigating farms during the dry season, in order to avoid bioaccumulation of toxic pollutants in the agricultural products.

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