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Heavy Metal Concentrations in Urban Stormwater Runoff and Receiving Stream.

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Abstract
Stormwater and receiving stream water samples were collected along Abeokuta- Ibadan road at four different locations and analysed for heavy metals: copper, zinc, lead, cadmium, chromium and other pollution indicating indices like DO, BOD5, COD, total dissolved solid, EC, pH, chloride, hardness, and alkalinity. The result of the analyses showed the mean concentration of heavy metals were: 0.66 mg/L (Pb), 0.83 mg/L (Zn), 1.93 mg/L (Cu), 0.51 mg/L (Cd) and 0.44 mg/L (Cr). Copper is the most prominent metal both in the stormwater and the receiving streams in the study area compared to others. Average physico-chemical properties of stormwater such as pH w as 9.15±0.49, temperature, 26.27±0.51, EC, 276.00±48.86 µScm-1, hardness, 93.25±48.0 and alkalinity, 2.78±1.04 for the stream. Dissolved Oxygen (DO) in the stormwater ranges from 2.88 to 3.97 mg/L. Mean TDS, COD and BOD5 were 128.7 mg/L, 156.25 mg/L, and 47.06 mg/L respectively. None of these values exceeded the limit considered as potential hazard according to international standards. However, in the nearest future the pollution level may likely increase drastically exceed the recognised standards due to increasing urban activities, hence, there is the need to safeguard the health of the urban ecosystem by reducing stormwater pollution from sources and the development of sustainable urban stormwater management using best management practices (BMPs).
Keywords: Highways; Pollution; Urbanisation; Stormwater; Stormwater Management.

1. Introduction

Cities all over the world exemplify some of the most pressing current challenges, ranging from population explosion, unemployment, crime, climate change, flooding and environmental degradation (Bates et al., 2008; Battersby and Le Page, 2011). The management of urban development and urban ecosystems remained a daunting challenge in effort to balance environmental and developmental needs. Rapid urbanization of major and emerging cities in a developing country like Nigeria has brought significant changes in the physical properties of land surfaces, such as the decreasing permeability and infiltration of the soil, and accelerated surface runoff in the cities. Cities generally have large paved areas and impervious surfaces such as roads and highways, which means that most of the water in a rain event moves quickly into main rivers. Impervious surfaces such as roads and highway serve as temporary sinks for various types of pollutants which are washed off during rainfall as stormwater runoff into the proximate environment (Roesner and Bledsoe, 2003; Alo *et al.*, 2007; Aryal et al., 2007; Scholes et al., 2007; Joshi and Balasubramanian, 2010; Connor, 2011). Urban stormwater is a non-point pollution source from various channels ranging from direct rainfall to over-flown catchments and drainages around it course of flow. Stormwater runoff has been identified as a leading cause of water quality impairment (Furumai et al., 2005; Semenza et al., 2012). Uncontrolled stormwater runoff, especially in developing countries have the potential to pollute water bodies, cause downstream flooding, accelerate channel erosion and impair aquatic habitat (Johnson *et al.*, 2003; Roesner and Bledsoe, 2003; Walsh *et al.,* 2005; Davis, 2006; Alo et al, 2007; Alo, 2008; Joshi and Balasubramanian, 2010; Dwight et al. 2011; Sabo et al., 2013). Another important aspect of stormwater's impact on our environment that needs to be further emphasized according to Connor (2011) is its connection to climate change.

Heavy metal pollution from non-point sources such as highway stormwater runoff is a major concern of environmental regulatory bodies and other stakeholders the world over as they contribute to the pollutant load of the receiving environment, in most cases the water bodies and farmlands (Davis et al., 2006; Alo et al., 2007; Kim et al., 2007; Czemiel Berndtsson, 2008; Oyelami et al., 2013). Although, water from most sources is not pure as it acquires contaminants from its surrounding and those arising from natural and mostly humans activities (Mendie, 2005), we need to maintain good health by keeping water safe and free of contamination/pollution of any type (Sabo et al., 2013). Heavy metals delivered by urban stormwater runoff from roads and highways are considered serious pollutants because of their toxicity, persistence and nondegradable conditions in the environment. They constitute threat to human beings and other forms of biological life (Yuan et al., 2004; Mohiuddin et al., 2010; Connor, 2011). Traffic-related pollutants have an adverse effect on human health, including acute and chronic cardiovascular and respiratory outcomes (Li and Liu, 2001; Garshick *et al.*, 2003; Yusop, et al., 2005; Alo *et al.,* 2007; Brook *et al.,* 2007; Alo, 2008). Studies have

shown that a wide range of toxic metals such (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni) and zinc (Zn) can be found in highway stormwater runoff with about 75% (by dry weight) of the pollutants derived directly or indirectly from vehicles, road surface degradation, atmospheric sources, road maintenance and other human activities (Dwight *et al*., 2002; Lenntech, 2004; Pitt *et al*., 2004; Kominkova and Nabelkova 2007; Alo, 2008; Mohiuddin *et al*., 2010). Apart from the heavy metals, hydrocarbons and bacteria of human origin such as faecal coliforms alongside pollution-indicator indices such as total solids, total suspended solids, dissolved oxygen (DO), biochemical oxygen demand (BOD) and chemical oxygen demand (COD) are found in substantial quantity in highway runoffs (Perdikaki and Mason, 1999; Backstrom *et al*., 2003; Marsalek, 2005).
Inspite of the high level of vehicular emission from the various vehicles plying the major roads in Nigeria, limited information exists concerning the level of pollutants especially heavy metals in urban stormwater runoff in major metropolis. With evidence of increasing precipitation due to global climate change and continued urban expansion, the impacts of urban stormwater runoff will be more apparent in years to come. Identifying and assessment of heavy metal pollutant in urban stormwater runoff would serve as the basis for determining the Best Management Practice (BMP) in effort to tackle problems of pollution and reduce the health risks of the people. This study aims to assess of the concentration of heavy metal in urban stormwater runoff and receiving streams along a portion of Abeokuta-Ibadan road in Ogun State, Nigeria. The specific objectives include i) to analyse the physico-chemical properties and heavy metals concentration of the stormwater samples and water from receiving streams. ii) To compare the heavy metal concentration from different locations with the international standards. The study was carried out between May 5th and 13th June 2012 at four different points where stormwater runoff were discharged into streams close to the road.

2. Materials and Methods

2.1. Study area

The study area is in the north-eastern part of the metropolis along the Abeokuta-Ibadan road. The area like other erstwhile rural communities on the outskirt of Abeokuta are experiencing rapid urban development as a result of the expansion of the metropolis forcing people to move into those areas. These areas have witnessed rapid and extensive urban and infrastructural developments in the past decades resulting in the creation of vast amount of impervious surfaces (i.e. areas covered with buildings, roads, parking areas, and sidewalks) where water cannot infiltrate into the ground. These developments have proceeded in an unprecedented fashion, altering the natural process of rainfall runoff and generating huge amount of surface runoff mostly laden with pollutants from anthropogenic activities. Human activities in this area include building construction, small-scale industries (such as block making, welding, car washing) abattoir, and automobile repair garages attracting huge volume of traffic along the corridor. The road under study is a major highway that links Abeokuta to Ibadan in Oyo state. Daily, huge volume of traffic (both vehicular and pedestrian) transverse the area constituting traffic logjam especially during the rush hour and contributing to the emission of heavy metals and particulate matters, which has deleterious effects on the surrounding urban ecosystem such as the streams and vegetation. The characteristic features of the study locations are summarised in the table 1.

2.2. Sample Collection and Preservation

The portion of the road selected for the study was about 7.5 km with four sampling points located at Moore Junction (MJ) at Asero, Odo Eran (OE), Eleweran (EW), and Kotopo (KP) respectively (Fig. 1). These points were chosen based on their proximity to the receiving streams. Each of these points has a stream close into which the stormwater runoff is discharged during rains. Effort was also that made the points chosen had a lower probability of pollution influence from other sources apart from other non-highway related activities such as industries and domestic waste. In most cases the stormwater runoff were channelled into the receiving streams via concrete drains constructed along the road. The coordinates of the point of stormwater collection are obtained using Garmin GPS (Table 2). The samples were collected using a two litre plastic keg, this is because plastic do not dissociate into water thereby reducing chemical interference in the analyses. The kegs for stormwater collection were set in the direction of flow of the water so that there was free flow of the stormwater into the containers.
The samples were collected at different points so as to be able to observe differences in the concentration of the heavy metals. In addition, water samples were collected from receiving streams close to point of stormwater collection (i.e. 100m before point of discharge, and 100m after point of discharge) and analysed for heavy metal pollution from the stormwater. In view of the unpredictable condition of rain even in tropical country like Nigeria, collections of sample were flexible and were done as soon as the rain subsided. Samples were collected between May 5th and 13th June 2012 mostly in the afternoon. The samples collected were stored in the refrigerator at 4°C to preserve its chemical properties prior to analyses.

2.3. Chemical Analyses

Temperature, total dissolved solid (TDS), electric conductivity and pH for each sample were determined in-situ using hand held digital analyser. All other analyses including heavy metals were carried out in the laboratory immediately after sampling. Dissolve oxygen (DO) and Biochemical Oxygen Demand (BOD5) were determined by the Azide modification method; hardness was determined by the EDTA titrimetric method, acidity and alkalinity by titrimetric to pH 8.3 phenolphthalein. Chemical oxygen demand (COD) was determined by open reflux method (Standard Analytical Procedure, 1999). Replicate samples were digested for metal analysis using wet digestion method, and the digested samples were analysed for selected metals using atomic absorption spectrometer (AAS Buck 200 model). All parameters were determined within their holding time with necessary preservatives added where applicable.

3. Results

The physico-chemical characteristics of the stormwater and receiving streams samples are shown in table 3 below. The mean pH of the stormwater was 9.24 ± 1.02 with a maximum of 9.85, which was slightly higher than the USEPA standard USEPA (1994), while that of the receiving stream is 9.15 ± 1.05. It should be noted that the United States Environmental Protection Agencies (USEPA) the standard for pH of stormwater is between 6 and 9. Increase in pH of stormwater might be due to detergents and soap-based products used in domestic activities such as washing of clothes and car washing along the roadside. Alkalinity measures the ability of water bodies to neutralize acids or buffering capacity of a water body thereby maintaining a fairly stable pH. However, the mean stormwater pH at Kotopo was 7.72 which lower than other locations. This probably due to the activities at the automobile garage nearby. The mean total dissolved solid (TDS) of the stormwater was high with mean value of 128.75 mg/l and this could be responsible for the higher values found in the streams they flow into. Electrical conductivity was also high with a value of 417µScm-1 at Odo-Eran, while the TDS was 206 mg/l. Electrical conductivity is directly proportional to TDS for all locations. The dissolved oxygen (DO) was low with mean value of 3.30±0.4 mg/L and the highest value of 3.97 mg/L at Kotopo. The mean BOD5 values obtained from the study for the stormwater runoff was 47.06, with the maximum value of 78.0mg/L at Eleweran and a minimum of 36.0 at Kotopo.

BOD_5 is the amount of oxygen used over a five-day period by microorganisms as they decompose the organic matter in water bodies at a temperature of 20° C (68° F). It is a measure of the pollution present in water, obtained by measuring the amount of oxygen absorbed from the water by the microorganisms present in it. BOD_5 for the receiving streams especially at points after the discharge of the stormwaters were also high compared to those points before stormwater discharge. On the other hand, the COD is the amount of oxygen required to oxidize the organic matter by use of dichromate in an acid solution and to convert it to carbon dioxide and water. The value of COD is always higher than that of BOD_5 mainly because many organic substances can be oxidized chemically but cannot oxidize biologically. The values obtained from the study of BOD_5 was higher than the standard of 8-25mg/L set by the UK (Institute of Highway and Transport, 2001) and the value falls within 14.7 – 272.2 in the US (FHWA, 1996).

The mean COD for the stormwater was 156.25mg/l which was however higher than the USEPA limit of 120 mg/L, an indication of high rate of chemical oxidation of organic substances at some of the sampling locations such as that of Eleweran (280.00 mg/L). Cl concentrations in the stormwater were: 24 mg/L for MJ, 16.5 mg/L for OE, 24.0 mg/L for EW, and 20.0 mg/L for KP. The pH for the receiving streams ranges between 8.46 and 9.47, with a mean of 9.15 ±2. (Table 4). The temperature is within the limit as there is no thermal (high heat) transfer from the stormwater to the receiving stream. The mean temperature was 26.27°C and the highest was 26.80°C. The mean value for DO level for the streams was 3.0±0.99mg/L, which was lower compared to the USEPA standard of 12.7mg/L. The chloride level ranged between 21.00 and 27.50, with a mean and standard deviation of 23.6 ±3.01, which was higher than the value of 4.7 reported for the study in Lagos by Alo et al. (2007). The result of metal analysis indicated that the most dominant metal in both the stormwater and receiving stream was copper followed by zinc the lowest was chromium. Table 5 below shows the concentration of metals in stormwater and receiving stream in the study area. Cu concentrations in the stormwater samples were relatively higher than the receiving streams in all the sampling points. The Cu concentrations at MJ were: 3.13 mg/L for stormwater, 1.10mg/L for point before discharge, and 2.30mg/L for point after discharge into the stream. Similarly, for the location at EW, the metal with the highest concentration in stormwater was copper (2.08 mg/L), while it was 0.65 mg/L for point before discharge and 0.85 mg/L for point after discharge. Copper is a very common substance that occurs naturally in the environment and spreads through natural phenomenon. Highway storm water runoff represents a significant source of dissolved copper to surface waters (Li, 2006; Nason et al., 2012). Copper is a nutrient known for its lack of mobility in soils, and in solution, copper hydrolyzes at about pH 7.5. At high pH > 7-8, precipitation phases are mostly $Cu_2(OH)\ 2CO_3$. Copper is used for electrical equipment (60%); construction such as roofing and plumbing (20%); industrial machinery such as heat exchangers (15%) and alloys (5%) (Lenntech, 2004).

4. Discussion

Most of the areas along the study area are dominated by rapid urban expansion, necessitating construction activities of varying scale; therefore, one can expect high amount of copper in the immediate environment. It is well-established that even low concentrations of dissolved copper can be toxic to many aquatic organisms (Nason *et al*., 2012). In this study, zinc was found to be next to copper in concentration in the samples collected. The level of zinc in the stormwater was 1.15, 0.77, 0.75 and 0.65 mg/L for MJ, OE, EW and KP respectively (Table 5). Zinc has being reported in urban runoff in other major studies (Davis *et al*., 2001; Karlen et *al*., 2001; Mangani *et al.,* 2005). Backstrom *et al.* (2003) reported Zn at concentration of 89.3 and 124 ppb respectively in road runoff collected in summer and winter at Svaneberg, Sweden. The study showed that traffic on the roads could be important source of zinc in urban runoff. Furthermore, Mangani, *et al* (2005) have observed ed that zinc was the most abundant of the heavy metal studied from the first flush analysis of runoff from a highway in central Italy, with variability in observed concentrations ascribed to site characteristics and rain fall pattern. Zinc is a widely used metal for producing die-castings, used extensively by the automotive, electrical, and hardware industries. Zinc oxide is also an important substance in the manufacture of paints, rubber products, cosmetics, pharmaceuticals, floor coverings, plastics, printing inks, soap, storage batteries, textiles, electrical equipment, and other products. In this study, cadmium was 0.52mg/L in the stormwater at EW, while the point before and after discharge the sampling locations were 0.47 and 0.49 mg/L respectively, which indicate no significant pollution after the discharge of the stormwater (Table 6). Cadmium is released as a by-product of zinc (and occasionally lead) refining. The highest lead concentration in stormwater was found at MJ (0.90mg/L), while it was 0.67 mg/L for point before discharge and 0.81 mg/L for point after discharge. Lead is reported to be emitted during its mining and smelting activities, from automobile exhausts (by combustion of petroleum fuels treated with tetraethyl lead antiknock) and from old leads paints (Lenntech, 2004). When lead is burned, lead salts (chlorine, bromines, and oxides) will originate which enters the environment through the exhaust of cars. While larger particles will drop to the ground immediately and are carried by the stormwater, the smaller particles will travel long distances through air and remain in the atmosphere.

This may have accounted for the low value of lead in the stormwater, with an average concentration of 0.65 ± 0.102 mg/L. Comparing the results of this study with the standard of the Federal Ministry of Environment for metals found stormwater discharge into surface water. Although zinc and lead metals were expected to be higher for typical pollutants associated with vehicular traffic, the result of this study found concentrations lower than standard. This might be due to large fractions of these metals dispersed into the atmosphere and latter settled on roadside soil. Most lead concentration found in the samples collected could be ascribed to human activities such as the application of leaded gasoline used by car engines. Davis *et al*. (2001) also analyzed runoff from roadways and reported that brake wear from automobiles are important sources of copper in urban runoff. The result from this study are consistent with the trend of similar studies around the world showing that varying human activities in the various part of the world have shown the type of pollutant they released into the environment (Li and Liu,2001; Oyelami et al., 2013). In a study conducted on the eight lanes dual carriage busy Ikorodu Road in Lagos State, Nigeria, the presence of heavy metal such as Zn, Cu, Pb and Cr were reported (Alo, 2008). Similarly, the levels of the toxic heavy metals observed for the stormwater runoff and soil samples were relatively high at busy spots such as Oshodi and Tin-Can areas of the expressway also in Lagos State. Peak concentrations of 69.1 mg/L Zn, 157.6 mg/L Pb and 18.1 mg/L Cu were obtained in the roadside soils, while the runoff quality was poor (Alo, 2008). The concentrations of metals determined in this study were lower than standard despite the quarry activities and heavy duty vehicles plying the roads every day This may be due to the sloppiness of the road that whenever there is rain, the rainfall flushes the deposited metals away quickly.

Generally, runoff from urban/high traffic sites and first-flush samples exhibited higher copper concentrations than other samples. It should be noted that the level of pollution depends on the nature of civil works on the highway, the duration of the Antecedent Dry Period (ADP) before the rainfall, size of the rainfall, volume of traffic per day of the study site and nature of land use of the adjoining area (Driscoll *et al*., 1990; Lee et al., 2002, 2004). According to Soller *et al.* (2005), in study conducted in San Jose, US, the concentration of heavy metals in first flush (i.e. samples collected within the first few minutes of the commencement of rainfall) is dependent on the antecedent dry period and the size of the rainfall with an observed range of 25-260 ppb, 40-70 ppb, and 0.7-18.5 ppb for Zn, Cu and Pb respectively. The first flush is regarded as a suitable marker towards identifying the upper limits of these pollutants (Lee et al., 2002, 2004; Soller and Stephenson, 2004; Soller *et al*., 2005; Mangani *et al*., 2005). Studies such as Perdikaki and Masson (1999); Backstrom *et al*. (2003); Soller and Stephenson (2004) and Mangani *et al.* (2005) substantiated the fact that heavy metals such as Pb and Zn could remain strongly bound to the particulates during long exposures to extreme pH conditions which may likely occur in receiving water and sediments.

5. Conclusion

Concentrations of selected heavy metals in stormwater runoff and receiving streams in this study were consistently lower than those from previous studies. The metals analysed in the samples were lead, zinc, copper, chromium and cadmium with concentration in the magnitude of 0.66 mg/L (Pb), 0.83 mg/L (Zn), 1.93 mg/L (Cu), 0.51 mg/L (Cd) and 0.44 mg/L (Cr). The study have shown that copper is the most prominent metal both in the stormwater and the receiving streams in the study area. COD of the stormwater ranged between 140.00 mg/L to 280.00 mg/L, while TDS was between 74.00 mg/L to 206.00 mg/L. Dissolved Oxygen (DO) in the stormwater ranges from 2.88 to 3.97 mg/L, while the DO of the receiving stream ranged between 2.08 and 4.36 mg/L. These values did not indicate any significant depletion of oxygen in the samples. Presently, none of these values obtained for the metals and other pollution indices, except for the COD that were up to USEPA standard (USEPA, 1983). However, in the nearest future coupled with trend of development in the study area, the pollution level may likely increase drastically exceeding the recognised standards set for all pollutants in urban stormwater. Current activities on the major road indicate a future increase in the imperviousness of the road and the area at large leading to increase in the overland flow and pollution from non-point pollution sources. The implications of the findings of this study to urban runoff management are inextricably linked to the heavy metals of concern for the receiving waters in the study area.

It should also be noted that the quantity and quality of pollutants washed from a roadway is primarily a function of the number of vehicles passing, their speed, the number of dry days preceding a given rainstorm and the quantity of rainfall. There is the need for urgent measures to control stormwater pollution in the areas to safeguard the health of the urban ecosystem, especially by adopting effective method to reduce stormwater pollution at sources. In fact, management of stormwater at the source is essential as the problem can be easily isolated or the treatment system adjusted. Several different kinds of control measures, or best management practices (BMPs), use sedimentation, infiltration, or biofiltration as the mechanism for removing pollutants. The development of sustainable stormwater management in city must be given priority and the urban environment can be protected from stormwater pollution through regular drain clearing, upkeep of vegetation on slopes and exposed surfaces, maintenance of flow, speed reduction devices in drains, removal of waste materials arising from road works, and avoiding the use of herbicides and other toxic or polluting substances along roadsides. Finally, geographic information system (GIS) can be used to produce excellent maps of urban infrastructures and utilities which can help planners pinpoint sources of significant stormwater discharges and pollution in order to take control measures. Geographic-based enforcement can also be adopted where the overall focus is on facilities in close proximity to impaired streams or recreational fishing areas.

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Table 1. Characteristics and attributes of the study area

Characteristics	Attributes	Mode of analyses
Average daily traffic	1,000	Estimation
Lanes	1+1	Field Observation
Road surface type	Asphalt coated	Field Observation
Rainfall for the period	490.36mm	Meteorological data
Topography	Undulating	Field Observation
Land use	Commercial and residential	Field Observation
Imperviousness	>90%	Field Observation
Maintenance regime	Occasional street sweeping	Field Observation
Runoff treatment	None	Field Observation

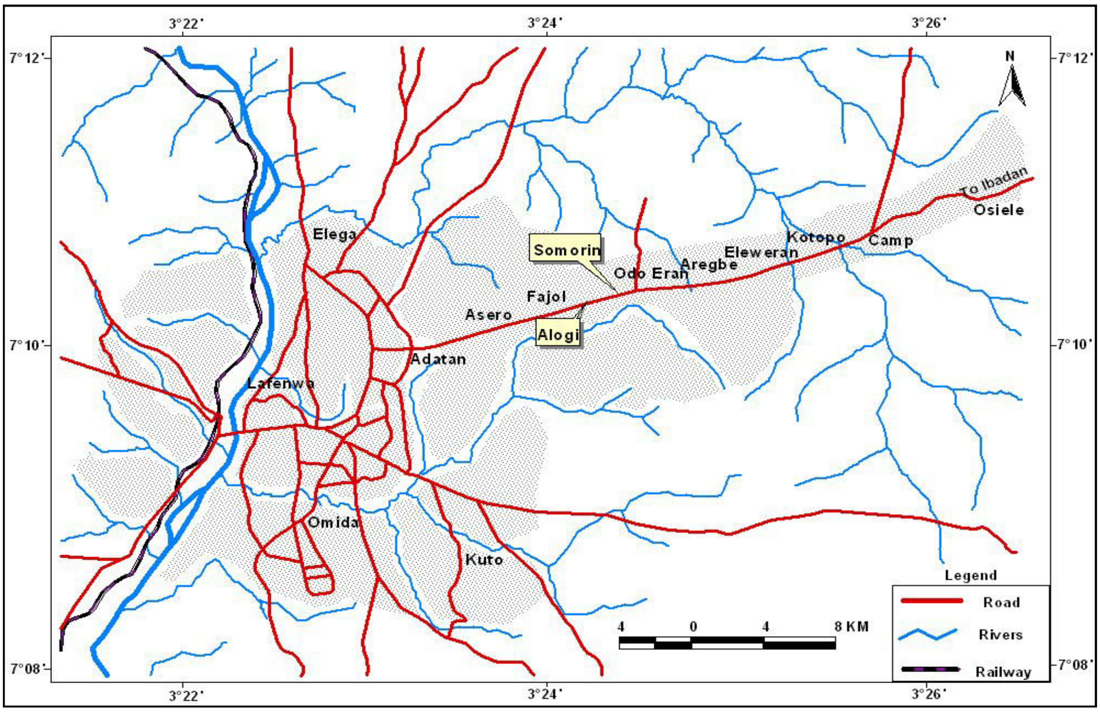

Figure 1. Map of the study area

★ **Sampling Points**

Table 2.Geographical coordinates of points of stormwater collections

Sample location	Position	Elevation in metres
Moore Junction	07.10 39 490N	
	03.23 27 74 0E	125
Odo-Eran	07.10 49 910N	
	03.24 53 650E	146
Eleweran	07.10 52 800N	
	03.25 18 840E	135
Kotopo	07.10 59 160N	
	03.26 03 55 0E	153

Moore Junction (MJ) at Asero, Odo Eran (OE), Eleweran (EW), and Kotopo (KP)

Table 3 Physico-Chemical Properties of Stormwater Samples

Parameter	MJ	S1	S2	OE	S1	S2	EW	S1	S2	KP	S1	S2
pH	9.85	8.95	9.14	9.83	9.12	9.53	9.54	9.02	9.47	7.72	8.23	8.46
Temp °C	26.3	26.0	26.8	26.9	26.5	26.5	26.0	26.2	25.6	26.0	26.6	26.2
EC µScm^{-1}	274	208	325	417	167	304	147	200	215	198	206	260
TDS mg/l	137	107	162	206	175	158	74	128	106	98	107	130
DO mg/l	2.88	2.80	3.08	2.98	3.10	2.08	3.37	3.06	2.48	3.97	2.48	4.36
BOD mg/l	39.04	94.5	70	65.2	64.2	86.4	78.0	39.2	40.9	36.0	65.2	70.6
COD mg/l	140	120	213	205	192	209.3	280	178.5	206	100	193.5	230.4
Chloride mg/l	24.0	27.1	23.5	16.5	25.2	23.8	24.0	24.8	23.6	20.0	25.2	24.8
Hardness	125	88.2	140	101	88	103	81	112	90.8	83	130	110
Alkalinity	1.80	2.56	1.92	2.85	2.62	2.13	1.80 1	.93	2.09	2.10	2.46	1.97

MJ (Moore Junction) Asero, OE (Odo Eran), EW (Eleweran) and KP (Kotopo), S1 = before discharge, S2 = After Discharge

Table 4. Descriptive statistics of the physico-chemical parameters for receiving streams

Parameters	Minimum	Maximum	Mean	Std. Deviation
pH	8.46	9.53	9.15	0.49
Temperature °C	25.60	26.80	26.30	0.51
EC µScm^{-1}	215.00	325.00	2.76	48.86
TDS mg/l	106.00	162.00	1.39	26.20
DO mg/l	2.08	4.36	3.00	0.99
BOD mg/l	39.42	94.5	66.35	19.34
COD mg/l	120	230.4	192.84	33.32
Chloride mg/l	21.00	27.50	23.63	3.01
Hardness	45.00	155.00	93.25	48.56
Alkalinity	1.90	4.25	2.79	1.04

Table 5 Metal analysis result for both stormwater and receiving stream (mg/L)

Sample Points	Sample	Lead (Pb)	Zinc (Zn)	Copper (Cu)	Cadmium (Cd)	Chromium (Cr)
MJ	Stormwater	0.90	1.15	3.13	0.56	0.49
	Stream (Before)	0.67	0.70	1.10	0.45	0.35
	(After)	0.81	0.95	2.30	0.49	0.75
OE	Stormwater	0.50	0.77	1.50	0.47	0.42
	Stream (Before)	0.55	0.65	0.75	0.52	0.30
	(After)	0.60	0.70	0.90	0.57	0.38
EW	Stormwater	0.67	0.75	2.08	0.52	0.38
	Stream (Before)	0.52	0.67	0.65	0.47	0.50
	(After)	0.62	0.75	0.85	0.49	0.39
KP	Stormwater	0.55	0.65	1.00	0.48	0.45
	Stream (Before)	0.60	0.67	1.25	0.58	0.4
	(After)	0.60	0.65	0.70	0.58	0.38

MJ (Moore Junction) Asero, OE (Odo Eran), EW (Eleweran) and KP (Kotopo)

Table 6 Descriptive statistics of the physico-chemical parameter and heavy metals for the stormwaters

Parameters		Minimum	Maximum	Mean	Std. Deviation
pH		7.72	9.85	9.07	0.65
Temperature	°C	26.00	26.90	26.30	0.38
EC	μScm^{-1}	147.00	417.00	243.42	76.40
TDS	mg/l	74.00	206.00	132.33	57.41
DO	mg/l	2.08	4.36	3.05	0.63
BOD	mg/l	36.00	94.5	62.44	19.63
COD	mg/l	100.00	280.00	188.98	49.31
Chloride	mg/l	16.50	27.10	23.54	2.76
Hardness		81.00	140.00	104.33	19.47
Alkalinity		1.80	2.85	2.19	0.35
Lead	mg/l	0.00	0.90	0.65	0.10
Zinc	mg/l	0.65	1.15	0.08	0.16
Copper	mg/l	0.65	3.13	0.90	1.16
Cadmium	mg/l	0.45	0.57	0.09	0.13
Chromium	mg/l	0.30	0.50	0.12	0.11