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Orignal Report

STORMWATER CHARACTERISTICS ON 3RD MAINLAND BRIDGE LAGOS, NIGERIA

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Abstract: Stormwater from highways contain pollutants from vehicular activity. Vehicle emissions include pollutants such as heavy metals, oil and grease and particulates which settle on the highway. To understand the magnitude and nature of stormwater, the quality of highway stormwater runoff from 5 points on 3rd Mainland bridge in Lagos, Nigeria was monitored on monthly basis for a period of three years for 22 different parameters. Samples were analyzed for stormwater events (SWEs) using standard procedures. Inter-parameter correlations of event mean concentrations (EMCs) were also carried out. Best Management Practices (BMPs) were investigated for concentration reduction in SWEs.

Keywords: Stromwater, environment, 3rd Mainland bridge, Nigeria

INTRODUCTION

Lagos state Nigeria has experienced tremendous environmental stresses over the years as provoked by intensive rainfall, flooding and erosion among others. In the intervening periods, flood has been a persistent problem both for the inhabitants particularly to the urban poor in the low-lying flood plains of the numerous creeks and lagoons of the state. Due to this geographical location, historical antecedents and political imbroglio, the menace has continued to ravage such areas of the state.

According to Taebi and Droste [1], concern for the quality of urban runoff originated when some engineers and researchers observed that urban surface runoff accounted for most of the negative effects, including acceleration in the erosion of river banks, devastation of river habitats,

faster eutrophication rates in lakes, and a decline in receiving water quality in rivers, lakes and other receiving waters downstream or within urban areas.

Although sources of specific pollutants may vary widely in urban areas, motor vehicles are recognized to be a major source of pollutants, contributing oils, greases, hydrocarbons, and toxic metals. Typically, loadings of urban pollutants are greatest from industrial and commercial areas, roads and freeways, and higher density residential areas. The more cars and trucks we have, and the more streets and parking lots we build to accommodate these vehicles, the greater the concentration of urban runoff pollutants and the more money we have to spend managing these pollutants [2].

Urban runoff is a large source of mass emissions to river, coastal oceans and it contains pollutants that pose a risk to human health, indigenous plants and animals. This risk increase has resulted in an increase in the number of sources and pollutant accumulation over longer periods of time prior to highly variable seasonal flows [3]. .

Best Management Practices (BMPs) are usually required to mitigate non-point source pollution. In an urban setting, BMPs are of two types: source and treatment controls. Source controls are preventive practices that keep pollutants from entering the runoff, such as covering storage areas, diverting runoff from pollutants sources, street sweepings and household hazards waste recycling programs. Treatment control BMPs refer to devices such as vegetated swales and buffers strips, infiltration ponds, detention basins, and catch basin inserts [4].

Urban runoff is unique, in that most of the sources are the result of nonpoint influences. Nonpoint sources of pollution include sediment from small construction sites, metals and other contaminants washed from streets and/or fertilizers or pesticides washing from lawns. The runoff becomes a point source because storm sewers, which are not connected to wastewater treatment plants, collect the runoff and convey it to surface waters.

MATERIALS AND METHODS

Study Area

The city of Lagos is the commercial nerve- center of Nigeria. Lagos is an African megacity which is located in southwestern Nigeria, on the West Coast of Africa, within latitudes 6° 23' N and 6°41' N and longitudes 2°42' E and 3°42' E. Lagos is also within the Atlantic coast in the Gulf of Guinea, west of the Niger River delta, located on longitude 3° 24' E and latitude 6° 27' N. The state is flanged from the north and east by Ogun State, in the west by the Republic of Benin and the south by the Atlantic Ocean/Gulf of Guinea. The total landmass of the State is about 3,345 square kilometers, which is just about 0.4% of the total land area of Nigeria. It is physically the smallest but the most highly populated state in the country. The climate is the wet equatorial type influenced by nearness to the equator and the Gulf of Guinea. The major climatic seasons are wet or rainy season, which begins in March or April, and ends in October and the dry season, which begins in November and ends in March or April.

The Third Mainland Bridge (3rd Mainland Bridge) is the longest of the three bridges onnecting Lagos Island to the mainland, the other two being the Eko and Carter bridges. It is the longest bridge in Nigeria. It is regarded as the second most busy and most used bridge in Nigeria after the Ogun river bridge on the Lagos – Ibadan express way. The bridge starts from Oworonsoki which is linked to the Apapa-Oshodi express way and Lagos-Ibadan express way, and ends at the Adeniji Adele Interchange on Lagos Island. It measures about 11.8km in length as shown in fig. 1.

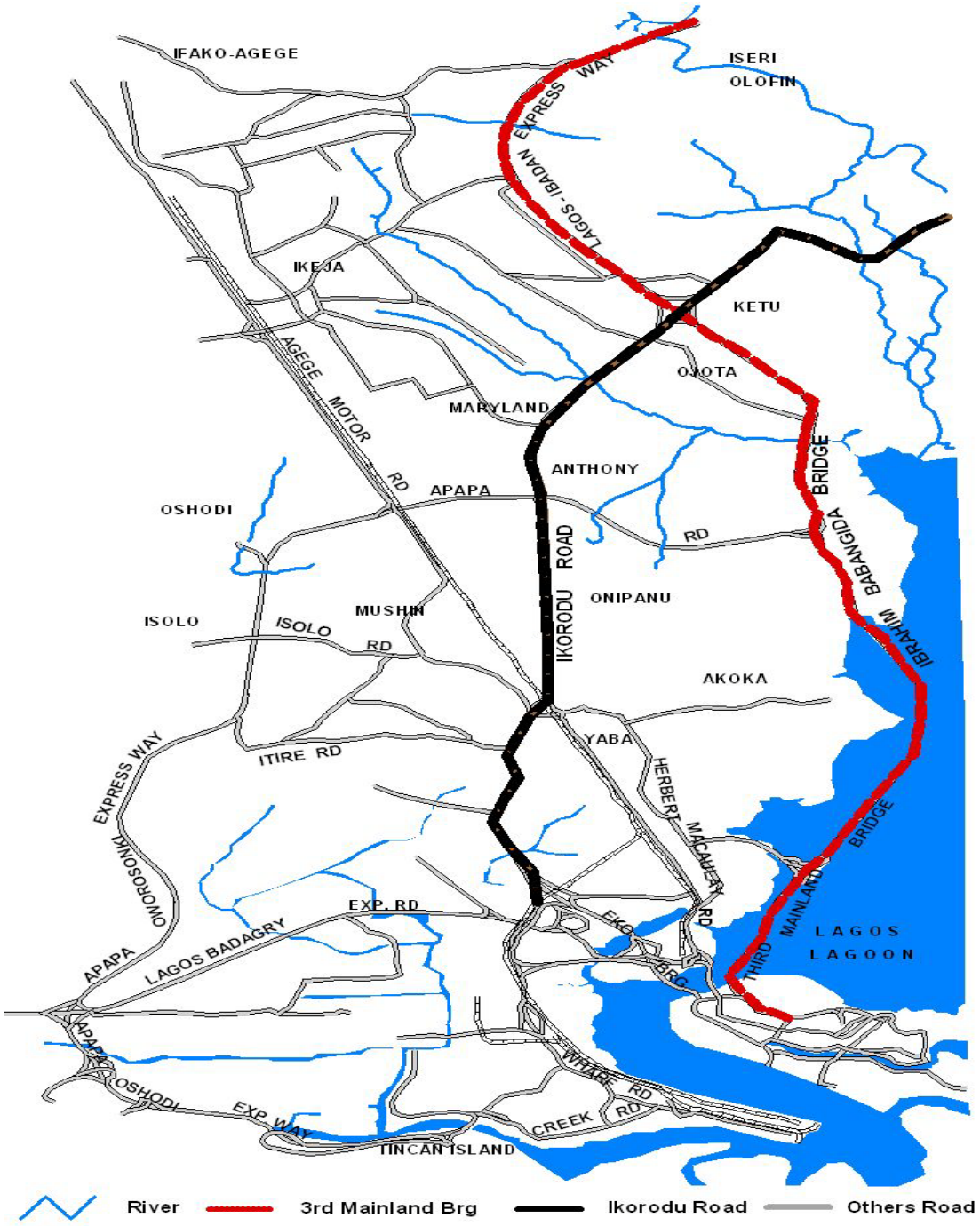

Fig. 1: Study area - 3rd Mainland Bridge

Sampling

Prior to sample collection, preliminary precaution and conditions were established. Several factors and preferences were taken into account in order to ensure that the selected sites were true representative of the state. The factors include: site assessment, evaluation of highway slope, soil type, and estimation of traffic volume, assessment of land use characteristics and land use of the area. Assessment of rainfall, daily traffic density, drainage type and land use were obtained by site inspection and assistance from Lagos State Ministry of Physical planning. Standard and approved methods of analysis are employed for all parameters. In particular

American Public Health Association (APHA), American Water Works Association (AWWA) and Water Environment Federation (WEF) standard methods for the examination of water and wastewater employed for water analysis.

Data Analysis

Statistical methods applied to the data generated in this study were (i) descriptive statistics to obtain arithmetic mean, standard deviation, mean, mode, range, sum variance, maximum and minimum values, and (ii) Pearson's correlation to establish the strength of relationships for relevant parameters and events variations. The statistical software package used in computation was SPSS 16 for Windows ® 2007. The Event Mean Concentrations (EMC's) for each constituent were derived from the average value of the constituent for each of the runoff events monitored and for which a sufficient volume of runoff was generated to complete the chemical analyses.

RESULTS AND DISCUSSION

Conventional parameters

The Event Concentrations (EvC) for the conventional parameters (pH, temperature, conductivity, turbidity, acidity, alkalinity and total hardness) are as following:

EvC values for pH were found to be between, 6.96 and 7.16 for 0 Km, 6.90 and 7.26 for 3 Km, 6.93 and 7.06 for 6 Km, 6.86 and 7.10 for 9 Km, 6.86 and 7.10 for 12 Km. Temperature EvC values were found to be between 26.76 and 27.50 for 0 Km, 26.6 and 27.43 for 3 Km, 26.66 and 26.93 for 6 Km, 26.73 and 27.93 for 9 Km, 26.66 and 27.30 12 Km. Conductivity EvC values were found to be between 11.50 and 13.06 for 0 Km, 11.93 and 14.53 for 3 KM, 11.66 and 13.50 for 6 Km, 12.06 and 16.2 for 9 Km, 14.70 and 14.70 for 12 Km. Turbidity EvC values were found to be between 69.70 and 92.00 for 0 Km, 68.60 and 87.86 for 3 Km, 73.73 and 88.06 for 6 Km, 68.00 and 84.93 for 9 Km, 68.50 and 86.83 for12 Km. Acidity ($CaCO_3$) (mg/l) EvC values were found to be between 34.96 and 45.23 for 0 Km, 33.90 and 44.06 for 3 Km, 34.80 and 41.83 for 6 Km, 35.66 and 42.66 for 9 Km, 35.60 and 42.16 for 12 Km. Alkalinity ($CaCO_3$) (mg/l) EvC values were found to be between 4.46 and 7.86 for 0 Km, 6.00 and 7.10 for 3 Km, 4.40 and 5.36 for 6 Km, 3.83 and 4.73 for 9 Km, 3.80 and 18.06 for 12 Km. Hardness ($CaCO_3$) (mg/l) EvC values were found to be between 69.26 and 73.56 for 0 Km, 69.13 and 72.90 for 3 Km, 69.30 and 73.26 for 6 Km, 69.43 and 73.86 for 9 Km, 68.66 and 72.60 for 12 Km.

Aggregate parameters

The aggregate parameters namely, total coliform, fecal coliform, total solids (TS), total suspended solids (TSS), total dissolved solids (TDS), oil and grease (O&G), dissolved oxygen (DO), biochemical oxygen demand (BOD) and chemical oxygen demand (COD), have Event Concentration as following:

Total Coliform (TC) (mg/l) EvC values were found to be between 43.9 and 82.46 for 0 Km, 82.46 and 67.46 for 3 Km, 66.70 and 85.76 for 6 Km, 63.83 and 83.53 for 9 Km, 87.13 and 64.16 for 12 Km. FC (mg/l) EvC values were found to be between 5.46 and 7.86 for 0 Km, 6.36 and 8.20 for 3 Km, 7.03 and 11.06 for 6 Km, 7.10 and 8.40 for 9 Km, 23.36 and 10.40 for 12 Km. Total Solids (TS) (mg/l) EvC values were found to be between 377.76 and 653.86 for 0 Km, 380.00 and 642.26 for 3 Km, 360.1 and 646.23 for 6 Km, 3665.35 and 643.00 for 9 Km, 380.61 and 650.97 for 12 Km. TSS (mg/l) EvC values were found to be between 54.56 and 69.70 for 0 Km, 44.96 and 55.7 for 3 Km, 42.4 and 56.33 for 6 Km, 49.3 and 61.83 for 9 Km, 42.90 and 63.30 for 12 Km. Total Dissolved Solids (TDS) (mg/l) EvC values were found to be between 316.53 and 587.36 for

0 Km, 335.03 and 586.56 for 3 Km, 314.10 and 495.93 for 6 Km, 313.10 and 496.36 for 9 Km, 33.46 and 587.66 for 12 Km. Oil and Grease (O&G) (mg/l) EvC values were found to be between 5.90 and 7.93 for 0 Km, 6.33 and 9.23 for 3 Km, 6.56 and 8.90 for 6 Km, 7.33 and 8.63 for 9 Km, 6.13 and 8.53 for 12 Km. Dissolved Oxygen (DO) EvC values were found to be between 17.50 and 19.66 for 0 Km, 18.60 and 20.93 for 3 Km, 18.03 and 21.60 for 6 Km, 19.83 and 24.13 for 9 Km, 18.60 and 25.26 for 12 Km. BOD (mg/l) EvC values were found to be between 62.93 and 84.46 for 0 Km, 70.96 and 80.60 for 3 Km, 69.00 and 78.56 for 6 Km, 71.56 and 89.93 for 9 Km, 70.66 and 87.80 for 12 Km. COD (mg/l) EvC values were found to be between 198.00 and 273.16 for 0 Km, 220.40 and 269.60 for 3 Km, 226.20 and 257.06 for 6 Km, 215.48 and 274.10 for 9 Km, 208.20 and 260.30 for 12 Km.

Metal parameters

The Event concentrations of heavy metals (Cd, Cr, Cu, Zn, Pb and Fe) in the stormwater are as following:

Cadmium (Cd) EvC values were found to be between 0.26 and 0.42 for 0 Km, 0.25 and 0.30 for 3 Km, 0.26 and 0.36 for 6 Km, 0.28 and 036 for 9 Km, 0.26 and 0.38 for 12 Km. Chromium (Cr) EvC values were found to be between 13.46 and 21.13 for 0 Km, 15.46 and 18.4 for 3 Km, 16.76 and 19.93 for 6 Km, 16.56 and 19.03 for 9 Km, 18.00 and 22.03 for 12 Km. Copper (Cu) EvC values were found to be between 41.73 and 67.96 for 0 Km, 25.50 and 47.06 for 3 Km, 18.66 and 44.80 for 6 Km, 26.16 and 35.63 for 9 Km, 15.20 and 60.36 for 12 Km 12. Zinc (Zn) EvC values were found to be between 23.06 and 41.33 for 0 Km, 74.83 and 55.60 for 3 Km, 62.86 and 67.76 for 6 Km, 55.83 and 65.16 for 9 Km, 56.00 and 73.03 for 12 Km. Lead (Pb) EvC values were found to be between 51.56 and 57.93 for 0 Km, 58.40 and 66.40 for 3 Km, 60.43 and 65.06 for 6 Km, 59.80 and 63.03 for 9 Km, 59.56 and 63.76 for 12 Km. Iron (Fe) EvC values were found to be between 350.53 and 379.66 for 0 Km, 353.80 and 381.16 for 3 Km, 356.13 and 424.86 for 6 Km, 369.36 and 422.60 for 9 Km, 375.93 and 405.7 for 12 Km.

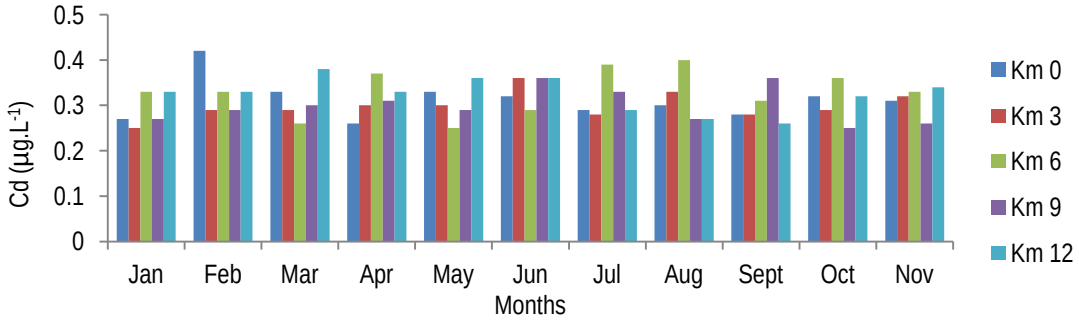

Fig. 1: Monthly concentration of Cd (µg.L^{-1}) on 3rd Mainland Bridge, Lagos

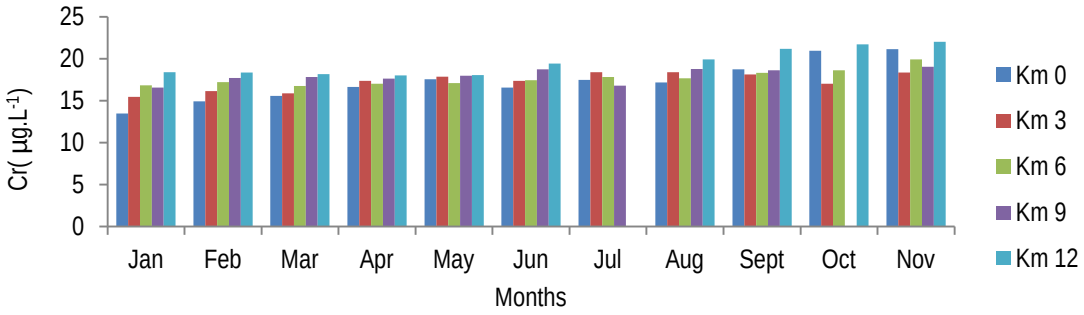

Fig. 2: Monthly concentration of Cr (µg.L^{-1}) on 3rd Mainland Bridge, Lagos

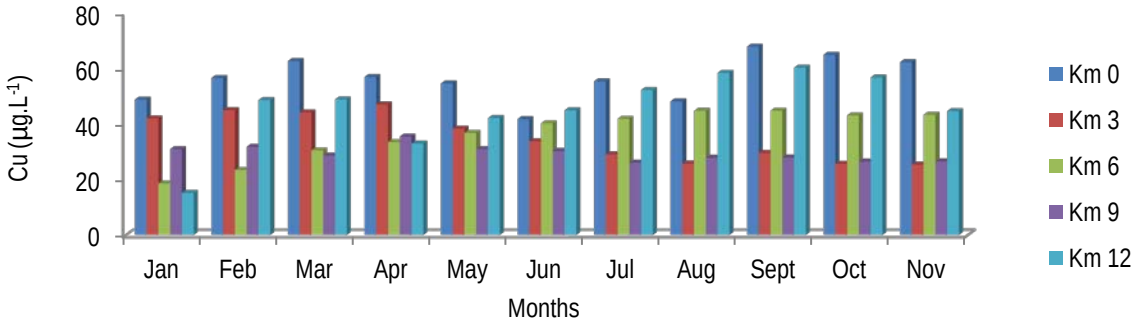

Fig. 3: Monthly concentration of Cu (µg.L^{-1}) on 3rd Mainland Bridge, Lagos

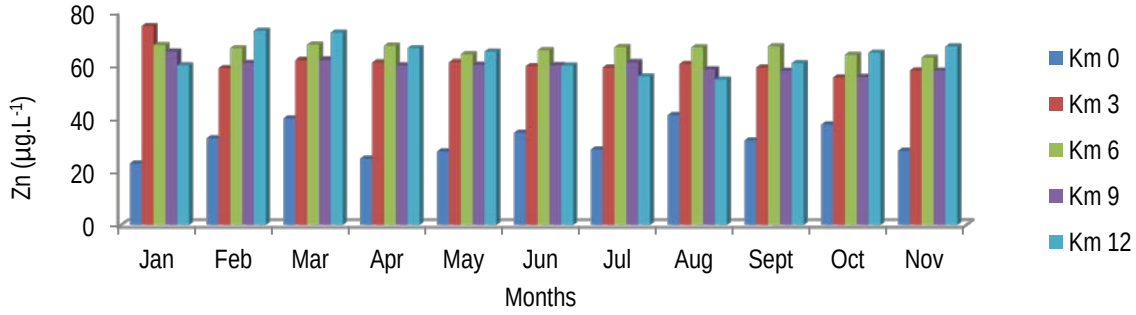

Fig. 4: Monthly concentration of Zn (µg.L^{-1}) on 3rd Mainland Bridge, Lagos

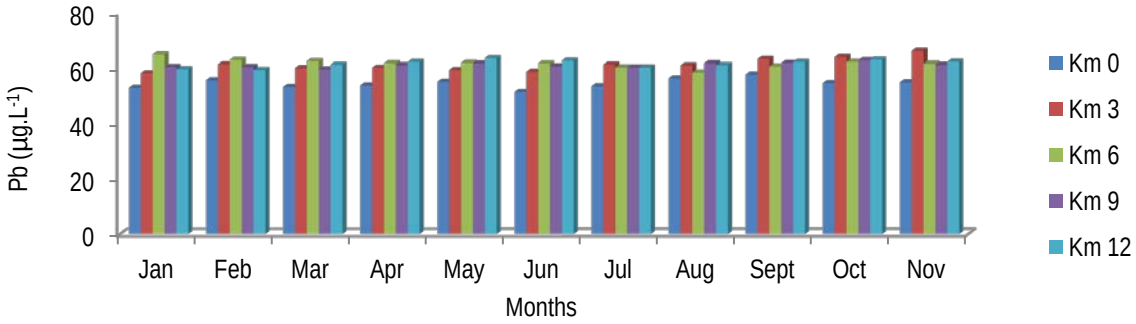

Fig. 5: Monthly concentration of Pb (µg.L^{-1}) on 3rd Mainland Bridge, Lagos

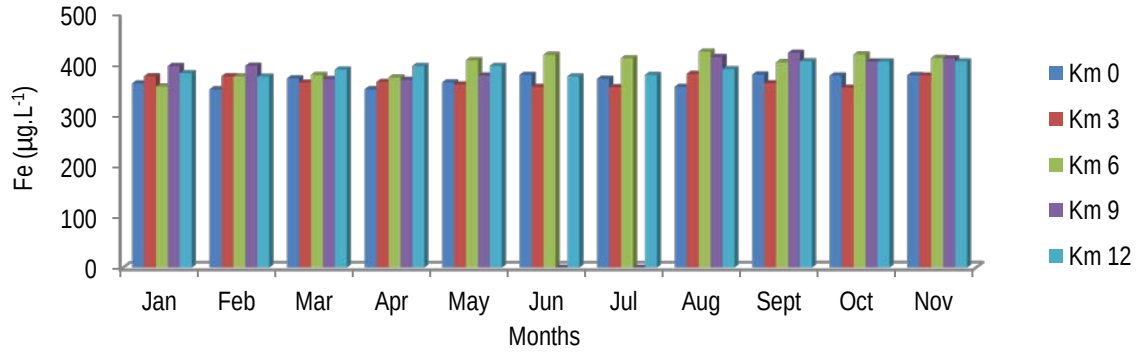

Fig. 6: Monthly concentration of Fe (µg.L^{-1}) on 3rd Mainland Bridge, Lagos

Summary Result

The summary result for the stormwater data obtained by pooling all the monthly data for each event is presented in Table1 while the inter parameter correlation coefficients (r) are given in Table 2. Conventional parameters for 3rd Mainland Bridge were found to be 7.10±0.15 for pH, 27.00±0.5 for temperature, 13.30±1.72 for conductivity, 78.20±7.09 for turbidity, 70.50±2.5 for Hardness $CaCO_3$, 6-60±0.35 for Alkalinity $CaCO_3$ and 39.60±4.14 for Acidity $CaCO_3$. Aggregate parameters for 3rd Mainland Bridge were found to be 72.30±8.9 for TC, 7.5±4.2 for FC, 480.10±27.34 for TS, 57.60±4.06for TSS, 421.1±28.66±for TDS, 7.50±0.87 for O&G, 19.80 ±2.77 for DO, 76.40 ±8.00 for BOD and 250.0±20.00 for COD. Metal parameters for 3rd Mainland Bridge were found to be 0.31±0.08 for Cd, 17.60±2.16 for Cr, 40.20±13.60 for Cu, 61.20±14.40 for Zn, 60.20±4.3 for Pb and 378.60±21.1 for Fe.

Close observation from Table 2, indicates that the useful ($p \leq 0.10$) relationships were identified as follows: The mean values for conventional parameters obtained for 3rd Mainland Bridge, Lagos were TSS versus conductivity, r = 0.579; BOD versus pH, r = 0.688; acidity versus pH, r = 0.554; Pb versus FC, r = 0.800; Cr versus FC, r = 0.790; alkalinity versus FC, r =0.822; oil and grease versus FC, r =0.624; oil and grease versus TS, r =0.624; TDS versus TS, r = 0.995;Zn versus BOD, r = 0.569; Fe versus Pb, r =0.657; Fe versus Cr, r = 0.556; Fe versus alkalinity, r= 0.902; Pb versus alkalinity, r = 0.723; Cr versus Cu, r = 0.530. The actual level of significance for each pair is given in Table 2.

Table 1: Pooled data for each stormwater event obtained from the 5 sites on 3rd Mainland Bridge, Lagos

S/No	Constituent	Unit	N	Mean	Median	Mode	SD	Range	Min.	Max
1	pH	-	165	7.10	7.00	7.10	0.15	0.80	6.80	7.60
2	Temperature	0C	165	27.16	27.00	27.00	0.50	2.00	26.40	28.40
3	Conductivity	µs/cm	165	13.28	13.00	13.30	1.72	7.10	10.40	17.50
4	Turbidity	NTU	165	77.88	77.20	86.90	7.09	33.10	62.50	95.60
5	TC	mgL^{-1}	165	73.82	72.30	68.90	8.9	83.00	6.50	89.50
6	FC	mgL^{-1}	165	8.99	7.50	6.80	4.20	23.80	4.50	28.30
7	TS	mgL^{-1}	165	484.59	480.10	478.60	27.34	161.40	417.50	578.90
8	TSS	mgL^{-1}	165	57.16	57.60	59.60	4.06	26.70	42.60	69.30
9	TDS	mgL^{-1}	165	426.85	421.10	421.00	28.66	168.20	357.50	525.70
10	O&G	mgL^{-1}	165	7.60	7.50	7.50	0.87	4.40	5.40	9.80
11	DO	mgL^{-1}	165	20.20	19.80	17.20	2.70	16.70	14.50	31.20
12	BOD	mgL^{-1}	165	77.30	76.40	71.20	8.00	52.60	47.20	99.80
13	COD	mgL^{-1}	165	250.40	246.30	260.50	20.00	106.30	196.20	302.50
14	Acidity $CaCO_3$	mgL^{-1}	165	39.58	39.60	40.10	4.14	20.50	27.80	48.30
15	Alkalinity $CaCO_3$	mgL^{-1}	165	6.59	6.60	6.60	0.35	1.50	5.70	7.20
16	Hardness $CaCO_3$	mgL^{-1}	165	71.24	70.50	72.60	2.50	11.30	64.50	75.80
17	Cd	μgL^{-1}	165	0.32	0.31	0.39	0.08	0.36	0.20	0.56
18	Cr	μgL^{-1}	165	17.99	17.60	17.30	2.16	14.00	12.30	26.30
19	Cu	μgL^{-1}	165	39.86	39.70	41.30	4.33	44.90	3.70	48.60
20	Zn	μgL^{-1}	165	61.20	56.60	61.20	14.40	63.00	15.20	78.20
21	Pb	μgL^{-1}	165	60.16	60.00	60.00	4.39	23.50	45.80	69.30
22	Fe	μgL^{-1}	165	384:00	378:00	378.60	21.1	82.20	345.60	427.80

Table 2: Useful inter-parameter correlations for stormwater events at 3rd Mainland Bridge study sites

S/N	Correlating Variables	Correlation Coefficient	p-Level
1.	Total suspended solids versus conductivity	0.579	0.062
2.	Total suspended soilds versus oil and grease	0.624	0.042
3.	Total suspended soilds versus total dissolved solids	0.995	0.000
4.	Fecal coliform versus Pb	0.800	0.003
5.	Fecal coliform versus Cr	0.790	0.004
6.	Fecal coliform versus alkalinity	0.822	0.002
7.	Fecal coliform versus oil & grease	0.624	0.040
8.	Fe versus Pb	0.657	0.028
9.	Fe versus Cr	0.556	0.076
10.	Fe versus alkalinity	0.902	0.000
11.	Pb versus alkalinity	0.723	0.012
12.	Cr verus Cu	0.530	0.093
13.	Zn versus BOD	0.569	0.068
14.	pH versus BOD	0.688	0.019
15.	pH versus acidity	0.554	0.077

Stormwater quality monitoring is an important aspect of water resources management because the pollution load of stormwater is virtually emptied into the receiving surface or groundwater. The stormwater quality, in this study was assessed based on the guidelines of the United States Water quality index (WQI) and Interim national water quality standards (INWOS) of Malaysia reported by [5].

The results obtained in this study, showed that the stormwater in 3rd Mainland Bridge in Lagos State, at the period of study, were characterized with pollutant concentrations that varied for the different study locations. For all the parameters, the level of significant difference in the mean of the Event Mean Concentrations (EMCs) relative to the median of the EMCs was attributed to the large variation in concentrations, with maximum EMCs that can be extremely high. The same phenomenon was observed in a comparable research project in Luxembourg [6].

The stormwater in the Lagos road networks may not likely harm aquatic lives in terms of pH values because, fishes for instance, live the best in waters with a pH between 6.5 and 8.4. Fish are affected if pH becomes too acidic (falls below 4.8) or too alkaline (goes above 9.2). The WQI-INWQS rating scale, designated a pH between 6.5 and 8.4 as highly acceptable, between 6 and 9 as acceptable, between 4.8 and 6.5 as acidic, below 4.8 and above 9.2 as inadequate. Based on this rating, the stormwater from the three study areas in this work were highly acceptable. In other words, have no effect on aquatic lives generally.

Another good quality parameter reported in this study is the temperature. A common cause of thermal pollution is the use of water as a coolant by power plants and industrial manufacturers before discharge. Elevated water temperatures decreases oxygen levels (which can kill fish) and

affects ecosystem composition, such as invasion by new thermophilic species. Urban runoff may also elevate temperature in surface water. Temperature, from this study, did not fluctuate significantly on monthly bases and the mean values were acceptable. Stormwater temperature can also affect aquatic habitats found in the receiving body, having the potential to affect the ability of water to hold oxygen as well as the ability of organisms to resist certain pollutants. For instance, increased water temperature increases the solubility of heavy metal pollutants [7].

In comparison of the aforementioned parameters with stormwater quality reported in other studies, results from this study revealed that the stormwater quality in Lagos has higher pollution load than the quality of stormwater in Stamford, Singapore, reported by [8 , 9]. The range given for the Singapore stormwater ranged from 6.3 to 7.1 for pH, 56 to 109 NTU for turbidity, 45 to 59 µS/cm for electrical conductivity, 10 to 40 mgL^{-1} for total alkalinity, 48 to 141 mgL^{-1} for TSS, 30 to 40 mgL^{-1} for TDS, 0 to 1.93 mgL^{-1} for oil and grease, 23 to 52 mgL^{-1} for COD, 0 to 0.03 mgL^{-1} for Zn, Cu, Fe, and Pb. Heavy metals such as Cr and Cd were not detected by Cheong (1991). Nonetheless, Barett *et al.*[10] reported 167.4 mgL^{-1} for Zn, 26.8 mgL^{-1} for Cu, 117.8 mgL^{-1} for TSS and 64 mgL^{-1} for COD in similar studies.

The report of Boogaard *et al.*[11] gave stormwater quality obtained in the Netherlands as 20 mgL^{-1} for TSS, 40 mgL^{-1} for BOD, 12 mgL^{-1} for Pb, 95 mgL^{-1} for Zn and 10 mgL^{-1} for Cu. Generally, except in a few cases, results from this study, when compared with the stormwater quality reported for outside of Nigeria showed that the Lagos stormwater was characterized by increased pollution load.

CONCLUSION

Storm runoff quality has been monitored on 3rd Mainland Bridge in Lagos, Nigeria for a period of three years. The pH, temperature, dissolved oxygen, conductivity, total suspended solids, oil and grease stormwater quality were within the acceptable limit. The turbidity of the storm waters were also within the threshold but very close to the upper limit. Stormwater were moderately hard. The stormwaters were essentially polluted by gross organic matter load (index by elevated BOD and COD) and heavy metals.

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