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Event Mean Concentrations of Urban Stormwater Runoff Quality from a Small Catchment in Nigeria

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In this study, the event mean concentrations (EMC) of stormwater runoff from a medium cost residential area of Mubi, in Adamawa State Nigeria, were examined. A total of 79 samples were analyzed for pH, turbidity, total suspended solid (TSS), total dissolved solid (TDS), copper (Cu), iron (Fe) and zinc (Zn). The ranges of event mean concentrations (EMC) were 57.17 – 1004.22 mg/L for TSS, 283.74 – 3152.76 mg/L for TDS, 0.0292 – 0.3042 mg/L for Cu, 0.3530 – 7.5970 mg/L for Fe and 0.0189 – 0.1799 mg/L for Zn. These gives site mean concentration of 360.27 mg/L, 1049.14 mg/L, 0.1443 mg/L, 2.8066 mg/L and 0.0633 mg/L for TSS, TDS, Cu, Fe and Zn respectively. EMC for all constituents show large inter-event variation. Correlation analysis showed that no strong correlation between rainfall characteristics and the EMC values. However, the EMC of TDS has significant influence on EMC of Cu and Fe in the storm water runoff. Also, EMC of TSS has significant influence on EMC of Zn. All pollutants, show the occurrence of the first flush, indicating higher mass load delivery during the early part of storm events.

Keywords: Event mean concentration; Storm runoff pollution

I. INTRODUCTION

Urban Stormwater runoff has been recognized as one of the major sources of nonpoint pollution, contributing to the degradation of the quality of receiving waters (Carmen 1997; Adams and Papa 2000; Yusop et al., 2005). The sources of urban pollution are diverse and associated with both natural and human activities. They can be broadly categorized into point source (PS) and non-point source (NPS). NPS refers to the pollutants that have no readily identified source and are transported into receiving water in diffuse manner, primarily during storms via surface runoff. NPS pollutant includes street dirt, accumulation and wash-off of atmosphere dust, fertilizer and pesticides from lawns, and direct discharge of pollutants into storm sewers (Novotny and Olem, 1994; Nazahiyah et al., 2007). The quality of urban runoff in terms of the amount and types of pollutants generated and transported will vary depending on land use. Urban runoff quality has been shown to have a high variability among different land uses such as residential, industrial, agriculture and recreational purpose.

Impervious areas, such as road surface,

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contribute a considerable amount of runoff even during less intense frequent storms events (Ball et al., 2000). A wide range of pollutants such as particulate, heavy metals and petroleum hydrocarbons with primarily originate from land transportation activities can accumulate on the road surfaces (Gan et al., 2007). During storms events, they are washed off and discharged into receiving water. The level of pollution caused by urban stormwater runoff into the receiving water bodies is largely unknown in developing countries. Event Mean Concentration (EMC) is a widely used method of estimating stormwater pollutant loads. It is defined as the total constituent mass discharged during an even, divided by the runoff volume (Adam and Papa, 2000) as in Equation (1)

$$\text{EMC} = \frac{M}{V} = \frac{\sum QiCi\,\Delta t}{\sum Qi\,\Delta t} \qquad (1)$$

where M is total mass of pollutant over the entire event duration (g), V is total volume of flow over the entire event duration (m^3), t is time (min), Q_i (t) is the time variable flow (m^3/min), Ci is the time variable concentration (mg/L) and Δt is the discrete time interval (min) measured during the runoff event.

This paper assessed the EMCs of stormwater runoff from a residential catchment in Mubi, Adamawa State. The influence of the rainfall characteristics on storm runoff quality and correlation among the quality constituents were also examined.

II. MATERIALS AND METHODS

A. Study Area

The study site is Adamawa State University (ADSU) Staff Residential Quarters, in Mubi, Adamawa State (Figure 1). The area is typical medium cost residential areas with a catchment area of 6.134 ha containing 24 single story houses. The catchment drains into an open concrete drainage which empty into the Vimtim River. Figure 1 shows the map of the study area while the physiographic characteristics of the catchment is given in Table 1.

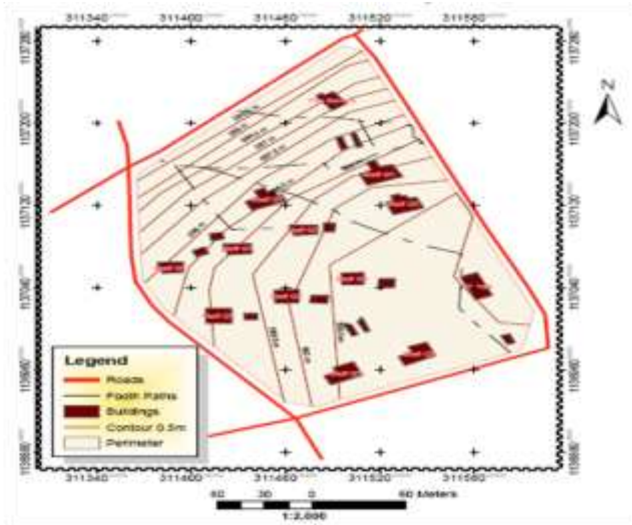

Figure 1: Map of the study area

Table 1: Physiographical characteristics of the catchment

Catchment characteristics	Unit	Value
Area	Ha	6.134
Slope	%	0.380 to 0.857
Total drainage length	M	1259
Culvert length	M	5.3
Culvert width	M	0.64
Culvert depth	M	0.54

B. Rainfall Data Collection and Runoff Measurement

Rainfall data for events that produced significant runoff from May to August, 2016 were collected from the Meteorological Unit of the Department of Geography ADSU. Stormwater runoff from the catchment is conveyed via a rectangular culvert outlet and the discharge was computed. The velocity of flow at the surface ($v_{surface}$) was measured using a float gauge method and the discharge (Q) was computed as the product of velocity and cross-sectional area of the outlet according to Equations 2 and 3

$$v_{mean} = kv_{surface} \quad (2)$$

$$Q = Av_{mean} \quad (3)$$

where k is a surface factor that is equal to 0.85 for rough surfaces (Gioi et al; 1990) and A is the cross sectional area of the flow which is obtained by multiplying the measured depth of flow (y) with the width of the channel (B).

C. Water Quality Analysis

Grab samples of the stormwater was collected using 750ml plastic bottle. Approximately 8 to 15 samples were collected during each storm event monitored. For every sample, the sampling time and water level were recorded. A total of eight storm events were monitored between May to August 2016, giving a total of 86 samples. The samples were taken to the Chemistry Laboratory of ADSU, Mubi and analyzed for total suspended solids (TSS) solid, total dissolved solid (TDS), copper (Cu), Iron (Fe) and Zinc (Zn). All samples were analysed in accordance with standard methods for the examination of water and wastewater (APHA, 2006).

III. RESULTS AND DISCUSSIONS

A. Rainfall and Generated Runoff

The rainfall and peak runoff data over the study period are summarized in Table 2. The rainfall depth varied from 8.5mm to 56.0mm and the corresponding runoff produced varies from 0.011 to 0.098m3/s. The corresponding rainfall durations and intensities are also presented in the table.

Table 2: Rainfall and Runoff Characteristics of the Catchment

Date	Rain fall Depth (mm)	Rainfall Dura-tion (min)	Rainfall Inten-sity (mm/hr)	Peak Runoff (m^3/s)
23-May-16	56.0	42	80.0	0.300
3-Jun-16	17.7	31	34.0	0.034
15-June-16	20.5	39	31.5	0.094
11-July-16	24	22	66.6	0.070
22-July-16	8.5	31	16.3	0.047
14-Aug.-16	40.5	39	62.3	0.021
23-Aug.-16	32.0	30	64.0	0.011
27-Aug.-16	11.5	27	25.6	0.013

It is obvious that, the peak runoff increases with increase in rainfall depth and intensity if antecedent moisture condition of the soil is kept constant. This is also true with this research though the correlation between depth, rainfall intensity and peak runoff is very weak with R2 values of 0.099 and 0.05 respectively.

B. Event Mean Concentration

The EMC values, calculated using Equation 1, show considerable variation between events as shown in Table 3. The site mean concentrations (SMC) which are the average EMCs of all storm events are 360.27 mg/L, 1409.14 mg/L, 0.1443 mg/L, 2.8066 mg/L, 0.0633 mg/L for TSS, TDS, Cu, Fe, and Zn respectively. The SMC ratio of TSS to TDS is about 1:3, indicating that accumulated solids were dissolved. The ranges of concentration for TSS and TDS were large, which indicate that the concentration varied during the storm episode. Street sweeping activities may reduce the accumulation of pollutant coming from the road surface in the study area.

Table 3: Events mean concentration (EMC) of various pollutants during seven storm events

Storm events	TSS mg/L	TDS mg/L	Cu mg/L	Fe mg/L	Zn mg/L
3-Jun-16	119.7	904.16	0.140	1.605	0.046
15-Jun-16	57.17	283.74	0.029	0.353	0.019
11-July-16	260.6	861.89	0.086	1.388	0.028
22-July-16	334.6	954.95	0.087	0.786	0.069
14-Aug.-16	419.4	1253.7	0.095	2.342	0.052
23-Aug-16	1004.	3152.8	0.304	5.575	0.180
27-Aug-16	326.2	2452.9	0.269	7.597	0.049
Mean	360.3	1,409.	0.144	2.807	0.063
Standard Deviation	311.1	1015	0.103	2.720	0.054

C. Rainfall Influence on EMC

Table 4 shows the correlation between rainfall characteristics [rainfall depth (mm), rainfall duration (min), rainfall intensity (mm/min)] and EMCs of the five pollutants. It could be observed that there was a significant relationship ($P<0.05$) between the EMCs of the various pollutants. However, the correlation between rainfall characteristics and the EMC was not significant.

IV. CONCLUSION

This study gives a better understanding of the pollutant transport from a typical residential catchment in Nigeria. Such information will be useful for the control and management of urban runoff pollution. It is concluded that the events mean concentration (EMCs) of TSS and TDS show large inter-event variation and the EMCs did not show significant correlation with storm characteristics.

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