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Computation of Total Sediment load in River Osun, South-western Nigeria

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ABSTRACT
Modeling of sediment transport can be used to solve environmental and water quality problems. Sediment transport rate hinge upon hydraulic flow, upstream sediment supply and bed composition. River Osun is a river in southwestern of Nigerian that is ascribe in local mythology to have a woman turn into flowing water after a traumatic event. There is paucity of information on sediment transport dynamics of the riverHydrological and geometrical data were measured for 12 months at four sampling stations across River Osun. Stage and discharge rating equation was developed, the developed rating equation was used to predict discharge Schoklitsch's (1950) equation and equation developed by USACE (1995) and Ongley (1996) were used to estimate unmeasured and measured load, respectively. However, comparison was made between Meyer Peter's (1951) equation, Schoklitsch's (1950) equation, Nielsen's (1992) equation and Einstein's (1950) equation results.The slope, discharge, flow area and Suspended Sediment Concentration (SSC) ranged between (0.0032-0.0046), (0.53-17.48)m^3/s, (3.83-47.46)m^2 and (10-175)mg/l, respectively. The average median grain size was 2.4mm. The seasonal suspended and bed load across River Osun were 206.43x10^3kg/annum and 2,538.77x10^3 kg/annum, respectively. The total sediment load on River Osun was 9,512.72x10^3 seasonal kg/annum. The coefficient of regression of 78% was obtained between the simulated and measured discharge values. Considering the quantity of sediment load computed on River Osun, preventive measure should be taken by the appropriate authority to reduce the sedimentation in River Osun.

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I. INTRODUCTION

The major engineering challenges in earlier time were to control the tendencies for unforeseen channel migration, erosion and catastrophic flooding. The need to control these environmental problems makes sediment transport study an important area among morphological studies (Adegbola and Olaniyan, 2012). The major mechanisms of sediment transport are water, wind and gravity. Shape size and quantity of bed load resist flow of water and thus capable of altering flow depth.Sediment transport rates are depend bed composition, flow hydraulics and upstream sediment supply. The deposition of the particle on the bed or when the particle is eroded can cause change in composition of the channel bed, which in turn changes flow hydraulics and fractional transport rates (Olaniyan, 2014; Otun and Adeogun, 2010).

Suspended Solid and Sediment (SSAS) yield has great impact on water quality and its resources. The source of SSAS can be natural and artificial. The natural form of SSAS includes wind erosion, upland erosion (detachment by rainfall and nil erosion), storm water runoff, and bank erosion, while the artificial forms of SSAS are wastewater discharge, tillage, mining, construction, etc. pesticides, radioactive material and nutrients that have capacity to mar can form part of sediment load. Past studies have shown that total suspended sedimentconcentrations are positively relatedto total phosphorus and nitrate concentrations (Kalin andHantush, 2003).Quality of all forms of water body is very important for sustenance of human and aquatic lives.

Sediment can be deposited in coastal wetland to provide valuable nutrient for soil in order to boost agricultural product.The study of Natural River and the interface of man in natural bodies is quite difficult. However, increasing and shifting populations place more demands on the natural sources of fresh water. Although the basic principles for these studies are well established, a total analytical solution is not known but for the most basic cases (Yang, 2002).

Sediment transport can be deposited in coaster wetland to provide valuable nutrient for soil in order to boost agricultural product. It's impossible to measure sediment transport rate directly thus empirical formulae were developed.Many researchers have developed empirical formula or correlation for estimating sediment transport rate. These empirical formula are applicable under the range of data and flow condition which they are derived and calibrated. Any sediment transport equation used outside the range of its applicability requires calibration. Therefore, it is imperative to have a thorough understanding of the limitations of these sediment transport equations foe selection of appropriate empirical formula in solving problem at hand (Adeogun, Igboro and Ibrahim, 2011; Adegbola and Olaniyan, 2012).

Suspended load is the material in suspension of a flowing water that flows in turbulence manner at the same rate with flowing water while Suspended load is the material that is held at the bottom of a river which flows at lower rate to that of water (Olaniyan, 2014).

II. METHODOLOGY

Study area

River Osun is the largest river in Osun State, the major tributaries of this river include Erinle River, Oba River and Omi Osun River. It was gauged where the tributaries were impounded for reservoir. The origin of River Osun is at Ekiti State ($8^0 20'$N $5^0 16'$E) while its mouth is at Lekki lagoon (6.563210^0N 4.062032^0E). It flows through Central Yoruba land in Southwestern Nigeria into the Lagos lagoon and the Atlantic Gulf of Guinea. It is a river that's ascribed in local mythology to have a woman who turned into flowing water after suffering a severe trauma. The four sampling stations that was used in this study were selected between Osogbo and Orolu local government area as shown in Figure 1.

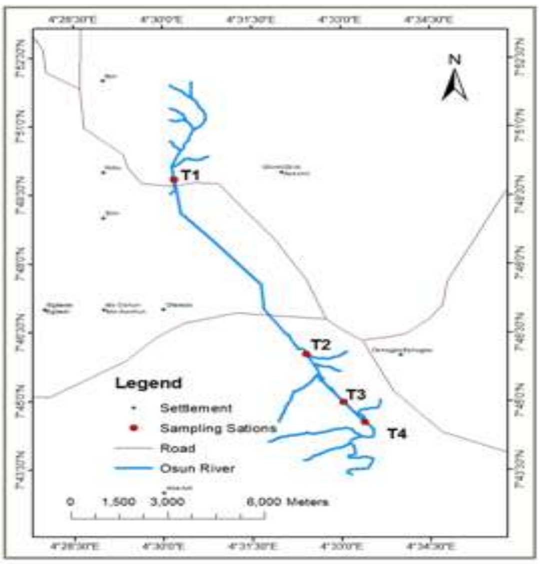

Figure 1: Map of the study Area

Study Approach

Both suspended load and bed load are major components of total sediment load. However, total sediment load was divided into unmeasured and measured load. The approach used in this study considered measured load to be addition of suspended sediment load and unaccounted suspended sediment load. Unaccounted suspended sediment load was determined using particle size limit of 0.34mm in line with (Adeogun et.al., 2011) and (Olaniyan and Adegbola 2012).

Field Measurement

Integrated sampler was used to collect water sample at the surface, middle and bed of the river. The water samples were filtered and weighted to determine the Suspended Sediment Concentration (SSC). A flow meter (model 32986-00) was used to measure the velocity at each cross section of the river. A calibrated rope was immersed in the water at every 1m from the river end, until the concrete cube weight end touches the bed of the river. The depth measurements from the stream were measured and recorded

Laboratory Analysis

Grain Size analysis was performed to determine the percentage of different grain sizes contained in the bed load. River Osun bed material were distributed into sub groups using U.S standard sieve grain size (millimeter) in order to separate unaccounted suspended sediment load from the bed local using limit particle size 0.35mm. Therefore the following grain size distribution were adopted in this study, grain size diameter (D) of gravely particle (i.e. D>4.00), D of fine and coarse particle (4.00>2.00), D of medium sand particles (2.00>0.40), D of particles that are mixture of medium and fine sand (0.40>0.200) and D of particle that are wholly fine sand silt/clay inclusive (0.20>D). Bed material samples that were taken from four sampling stations in River Osun and oven dried at 105ºC. The material were weighed, put into in a set of US standard sieve and were vigorously shaken electroninically for 15 minutes. Bed materials retained on each sieve were weighed and recorded. Grain size distribution curves were plotted to determine D_{50} as shown in Figure 1.

Suspended Sediment Concentration was measured to determine the quantity of measured sediment load across the river. Analytical weighing balance was used to measure 0.4μm filter paper and recorded as initial weight of filter paper. Respective water samples of 100ml were filtered after been thoroughly agitated. The wet filter paper was oven dried at 105ºC.. The dried filter paper was measured again and recorded as final weight of filter paper.The difference between final and initial weight of filter paper in mg/l gives quantity suspended sediment concentration across River Osun.

Computation of Bed Load

Schoklitch's(1950) equation was used to compute bed load of River Osun. The formula is given as:

$$m_s = 2500(\sin\theta)^{3/2}(q - q_c) \quad (1)$$

Where:

$$q_c = 0.26(s-1)^{5/3} d_{50}^{3/2} (\sin\theta)^{-7/6} \quad (2)$$

ms = mass sediment rate per unit width
q = volumetric water discharge (m^3/s)
s = relative density
sinθ = bed slope

Computation of Suspended Load

Equation 3 was established by United State Army Corps of Engineers (1995) and Ongley in (1996) for estimating suspended sediment load in kg/day. This was used in this study to compute Suspended Load

$$Qs = k.c.q \quad (3)$$

Where:
Qs: suspended sediment discharge (kg/day)
c = suspended sediment concentration (mg/l)
q = water discharge (m^3/s)

III. RESULTS AND DISCUSSION

The grain size analysis of the bed material across River Osun was used to determine median grain size (D_{50}) and limit particle size in accordance with (Adeogun et al, 2011) and (Adegbola and Olaniyan, 2012). The percentage of bed material particles above 5mm was 50% while the percentage of bed material particle distribution between 2-5 mm was 22.49% as shown in Table 1.The lowest percentages of the grain size distribution are the particles below 0.20mm with 1.29%. The average grain size distribution curve of bed material across River Osun is presented in Figure 1. The median grain size was estimated as 2.4mm

Table 1: Grain Size Distribution of Bed Material in River Osun

Grain size (mm)	Average grain size(mm)	Percentage of Distribution (%)
D> 5.00		53.97
5.00> D > 2.00	3	22.49
2.00> D > 0.60	1.5	18.76
0.6> D > 0.20	0.34	3.02
0.20> D		1.9

D_{50} = 2.4mm

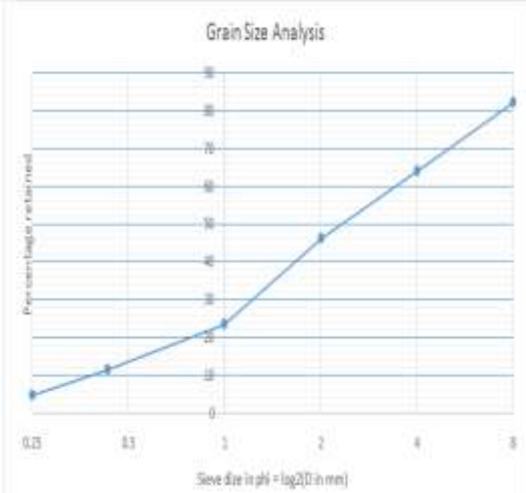

Figure 1: Average Grain Size Distribution Curve of Bed Material across River Osun

Table 2: Seasonal Sediment Load (Kg/annum) Transport in River Osun

Month (kg/month)	Measured Sediment Load (kg/month)*10^3	Unmeasured Sediment Load (kg/month)*10^3	Total Load (kg/month)*10^3
January, 2016	176.67	53.14	229.81
February, 2016	106.74	38.36	145.100
March, 2016	274.21	65.32	339.53
April, 2016	311.01	98.50	409.51
May, 2016	458.24	148.78	607.02
June, 2016	550.26	190.00	740.25
July, 2015	421.43	130.90	552.33
August, 2015	833.67	349.92	1183.59
September, 2015	1001.13	406.94	1408.08

Bed load is the dominant load of unmeasured load. 95.22% of unmeasured load represent bed load across River Osun using limit particle size of 0.34mm. The bed load across river Osun can be classified between gravely particle and coarse sand particle with median grain size of 2.4mm. The gravely particle and coarse sand particle of the bed load is one of the factors that is responsible for the high unmeasured load.

The monthly unmeasured load across river Osun ranges ranged 38.36 – 471.74 x 10^3 kg/month. The monthly average of unmeasured load across River Osun is 206.43 x 10^3 (kg/month) while the lowest unmeasured load is 38.36x10^3 kg/month. The seasonal unmeasured load across the river is 2477.17x10^3 (kg/annum).The seasonal bed load across the river is 95.22% of the measured load which gives 2358.77x10^3(kg/year).

IV. CONCLUSION AND RECOMMENDATIONS

The following conclusions were drawn from the study:

(i) The total annual sediment load in River Osun is 9,512.72 * 10^3 (kg/year)
(ii) The bed load material of River Osun has mean particle size of 2.4mm.
(iii) Meyer Peter and Nelson's equations overestimated the unmeasured load on Osun River as a result of lower percentage of slope used in their derivation.

Recommendations

The following recommendations were made from the outcome of this study

i. Considering the quantity of sediment load computed on River Osun, preventive measure should be taken by the appropriate authority to reduce the sedimentation in River Osun.
ii. Routine maintenance of waterways in Nigeria in other to provide easy access of researchers in taking field measurement for morphological studies.

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