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Dissolved Sediment Delivery by the Samaru Stream into Kubanni Reservoir of Ahmadu Bello University Zaria, Nigeria

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Abstract
This study analyzes the dissolved sediment delivery by Samaru stream, a tributary of Kubanni reservoir. The stream was monitored for 7 months, from 1st of April to 10th of October, 2014 which mainly marks the flow period of the year. The study analyzed the dissolved sediment concentration (DSC), discharge (Q), relationship between dissolved sediment discharge (DSD) and discharge (Q) and the estimate of the dissolved sediment yield for the year. The velocity and cross sectional area (AV) method was employed for the discharge measurement of the stream which gave a mean value of 0.2528 m^3/s, and an annual total discharge value of 4,850,232 m^3/yr. The lowest discharge of 0.057 m^3/s was recorded in April and the highest discharge of 4.133 m^3/s was recorded in August. DSC obtained varies from a minimum value of 20 mg/L to a maximum value of 120 mg/L with a mean value of 58.87 mg/L, and total sum of 4180 mg/L. DSD using the rating curve varied from a minimum value of 1.14 mg/s to a maximum value of 325.44 mg/s, and a total value of 3162 mg/s. DSD and Q were related and it gave a strong relationship because both values of r (0.866) and r^2 (0.749) are high. A total value of 174,000 kg/yr was estimated as the dissolved sediment yield of the stream with a Channel Sediment Yield (CSY) of 174 tons/yr. The amount is high and can be attributed to the anthropogenic activities upstream. It is therefore recommended that the Ahmadu Bello University should intensify on their efforts in creating awareness among the academic and neighboring Samaru community on conservative methods of reducing the rate of pollution of the reservoir.
Keywords: Dissolved Sediment, Discharge, Samaru Stream, Kubanni Reservoir, Ahmadu Bello University.

1. INTRODUCTION

Water is an essential resource for human development, and a key contributor to both health and diseases for humans (Zhao Y. et al., 2012; Akpofure, R. R. 2013). It contains a covalent bond, a liquid at standard temperature and pressure, but often co-exists on Earth in solid state as ice, and gaseous state as water vapor or steam (Pollack, 2011).

There have been several series of International Policy forums to address the issue of water safety and availability. One of such conferences is the International Conference on Primary Health Care, held in Alama-Ata, Kazakhstan in 1978, and world water conference in mar del Plata, Argentina in 1977, which launched the Millennium Development Goals (MDGs) adopted by the General Assembly of the United Nations (UN) in 2000 and the recent post-2015 development of the Sustainable Development Goals (SDGs).

A report by the Global Water Security (GWS, 2012) says that water scarcity is driven in part by poor water infrastructure which forces populations to rely on unsafe sources of drinking water, increasing the risk of waterborne diseases such as cholera, dysentery, and typhoid fever. They also argued that water scarcity-related diseases will disproportionately sicken poorer populations in developing countries, leading to decreased economic productivity, missed educational opportunities, and high health care costs. Some researchers have gone as far as to correlate safe water and a country`s GDP per capita (Rosling, 2003) which reflects well with the sub-saharan Africa, often hit by shortages of safe water and poor sanitation thereby affecting economic growth.

Also, in 2006 the United Nations Human Development Report says that on an average, a child dies from a water-related disease every 15 seconds, indicating that unsafe drinking water and poor sanitation are leading causes of death in the developing world for children under age 5.

The cholera outbreak in Haiti in 2010 from contaminated drinking water supplies it's a typical incidence. As of 30 September 2011, more than 455,000 Haitians had been treated for cholera, 242,000 were hospitalized, and 6,400 died (GWS, 2012).

In Nigeria, it was estimated that more than half of the population have no access to clean and safe drinking water, and many women and children walk hours a day to fetch water. According to the joint monitoting programme of the WHO and UNICEF reveals that 53% of household in Nigeria are without adequate clean water (Daily Trust, 2008).Although, the water sector budgetery allocation by the federal governments between 1999 to 2007 is over 357.86 billion naira to provide safe drinking water, yet there appears to be no solution in sight (Environment and Health, 2010). Millions of Nigerians depend on dirty and polluted water for domestic use. Hundreds, die every year from water borne diseases and heavy metals contamination (Garba and Egbe, 2007; Abdulmuminu A. et al., 2015).

It is in view of the importance of water to man that dams are constructed across rivers to retain water for various purposes which includes hydro electricity generation, irrigation, purification and cooling of nuclear reactors etc. The Ahmadu Bello University (ABU) dam was constructed in 1974 with a storage capacity of 2.6 x 10^6 m^3, depth of about 8.5m, a catchment area of 57 km^2, and a lake surface area of 83.4 ha and supply capacity of 13.64 million litres per day to cater for about 50,000 people (Committee on Water Resources and Supply, 2004). However, the utilization of the dam is being threatened by pollution and siltation.

Siltation occurs as a result of deposition of weathered and eroded sediments transported largely, in the case of the study area by fluvial processes into water bodies leading to decrease in depth or bank of the water and also effecting the environment through upsetting the dynamic balance in the biota and ecology of water body; disrupting the aquatic chemistry or natural buffer balance (cationic, anionic etc) of a water body; and lastly, the form and structure of a water channel (i.e. channel morphology) is changed as a result of sediment deposition (Steven and Daniel, 1997). Out of the three sediment types; suspended, dissolved and bed-load, dissolved sediment is one of the most difficult to assess because it contain materials that are usually not seen by the naked eye embedded chemically in the water or solution and are carried into a water body (Trimble, 2008).

Works on the siltation of the ABU dam with specific interest on suspended sediment load includes; Iguisi (1997), Yusuf (2006; 2009), Yusuf and Igbinigie (2010), and Yusuf (2012) and the results shows a decrease in depth of the dam over the years.

A recent study on the dissolved load of Samaru stream was conducted by Yusuf and Igbinigie (2010) where they examined the relationship amongst Q, suspended sediment discharge (SSD) and Q of Samaru stream, in which the DSD was derived from the DSC. The results indicates a relationship between DSC and Q. Recommendations were made among which is the proper monitoring of the anthropogenic activities around the basin for its preservation and protection.

The aim of this study therefore, is to assess DSD by Samaru stream into the ABUreservoir, to be achieved by determining the DSC and Q of Samaru stream, and estimating the dissolved sediment yield of the stream. Based on the objectives of the study, the hypothesis to be tested is that there is no significant relationship between DSD and Q.

2. THE STUDY AREA

The study area is Samaru in Zaria, Kaduna State, Nigeria. The study site is a minor tributary of the Kubanni River located within the Kubanni drainage basin, lying about $11^0$08'32"- $11^0$09'38"N and $7^0$38'36"- $7^0$38'48"E. The Kubanni River has its source from the Kampagi Hill, in Shika, near Zaria. It flows in southeast direction through Ahmadu Bello University. The Kubanni River which forms one of the main drainage systems in Zaria carries water almost throughout the year.

A map showing the study area is presented in Fig.1.

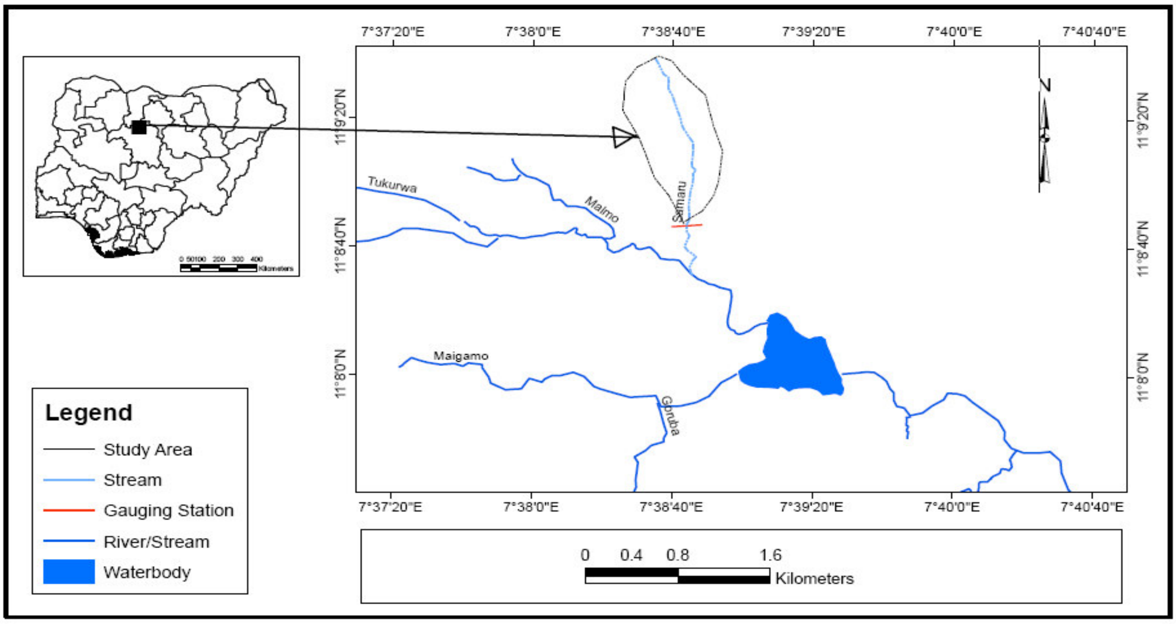

Fig.1: Location of the Study Area on the Kubanni River Basin.
Source: Zaria SHEET 102 South-West.

The Kubanni river basin belongs to the tropical continental climate corresponding to Koppen`s wet and dry climate zone (Oladipo, 1985). The developed crystalline metamorphic rocks of the basement complex overlain by wind and drifts sediments (Wright and McCurry, 1970) while the soil is highly leached ferrugenous tropical soils, developed on weathered regolith overlain by thin deposit of windblown silt from sahara desert. Furthermore, the natural vegetation of the study area is northern guinea savannah characterized by scanty deciduous trees, herbs, shrubs and grasses(Oluwu, 1986), the landforms falls within the Galma basin situated on an extensive peneplain developed on crystalline basement rock(Du Preez, 1952), the land use pattern prior to year 2000, was agriculture, grazing and fishing which is the dominant activity in the basin catchment before they were stopped in an attempt to reduce the rate of siltation of the ABU dam (Iguisi, 1997; Yusuf, 2006). Trees plantation have since taken over the basin and lastly the drainage characteristic of Samaru stream linking the Malmo stream is a 1st order basin with a stream length of 1.05 km, a basin area of 2.28 km^2, drainage density of 0.4605 m/km^2 and a relative relief of 30.48m which finally empties into the Kubanni river (Iguisi, 1997; Yusuf and Igbinigie, 2010).

3. METHODOLOGY

In order to achieve the aim of the study, data on dissolved sediment concentration and stream discharge were collected from the gauging station indicated in Fig.1 during the study period from April, 2014 to October, 2014 covering 7 months and marking the flow period of the study area.

Stream Discharge: There are a number of ways in which stream or river discharge can be measured. The velocity-area technique was adopted (Yusuf, 2006). Measurement were observed after rainfall events and twice daily; 7am in the morning and 6pm in the evening everyday and the average taken which represent instantaneous and regular interval monitoring (Ogunkoya, 2000).

3.1 Dissolved Sediment Concentration (DSC)

The USDH 48 sediment sampler was used to collect samples at the gauging stations after rainfalls events and during discharge measurement taking. The samples were then stored in a clean plastic bottles, labeled and taken to the laboratory for analyses (Matthes *et al*., 1991).

3.1.1 Estimation of Dissolved Sediment Yield (DSY)

As dissolved sediment measurements are rarely continuous, temporal extrapolation is often required to enable a reasonable estimate of dissolved sediment yield to be made. It involved all data on DSC and DSD; a product of DSC and discharge to stream discharge on the basis of a limited number of sediment measurements (Yusuf, 2006).

A precise form of rating curve as proposed by Bauer and Tille (1969) was used to regress stream discharge on the dissolved sediment discharge, by using their log exponents (log) as shown below:

Log DSD = log a + b log Q ……………………………………………………………..1

Where DSD = Dissolved Sediment discharge in mg/s; Q = Stream Discharge in m^3/s

a + b = Constants representing the intercept and slope of the rating plot respectively.

The DSD in mg/s, a product of discharge and concentration would be then converted to kg/day thus:

$$DSD = \frac{Q * DSC}{1000} * 60 * 60 * 24 \quad \ldots\ldots 2$$

Where DSD = Dissolved Sediment Discharge in kg/day; Q = Stream Discharge in m^3/s; DSC = Dissolved Sediment Concentration in mg/L.

Therefore, a continuous record of DSD provided an estimate of the DSY throughout the year (Bauer and Tille, 1969; Ferguson, 1987).

3.2 Statistical Analyses

Result of the samples analysed in the lab was interpretated using both descriptive and inferential statistical test. The inferential statistical test used is the regression analysis as represented by the rating equation. All analyses were carried out by the use of the Microsoft Excel and SPSS statistical package. The confidence level used in accepting or rejecting the hypotheses is 95% corresponding to an alpha value of 0.05.

4. RESULTS AND DISCUSSION

4.1 Discharge (Q)

Stream discharge measurement and observation of Samaru stream started on the 1 April, 2014 and ended on the 31 October, 2014 covering a period of 7 months and total of 214 days. Data on daily mean stream discharge in m^3/s and the summary statistic was obtained for 214 days which gave a total discharge value of 54.107 m^3/s, with the lowest value of 0.01m^3/s recorded in October and the highest value of 4.133 m^3/s recorded in August with a mean value of 0.2528 m^3/s.Converting the daily mean discharge values from m^3/s to m^3/day and then $m^3/month$ as seen in the regime Table 1 gave a total stream discharge value of 4,805,232 m^3/yr for the year 2014 with October having the lowest percentage discharge of 1% and August with the highest percentage discharge of 38%.

Table 1: Discharge Regime Table (m^3/month)

NO:	MONTHS	DISCHARGE (m^3/months)	FRACTION OF TOTAL DISCHARGE	PERCENT OF TOTAL DISCHARGE (%)
1	Jan	--	--	--
2	Feb	--	--	--
3	March	--	--	--
4	April	374025.6	0.08	8
5	May	515289.6	0.11	11
6	June	500688	0.10	10
7	July	710380.8	0.15	15
8	Aug	1822272.4	0.38	38
9	Sept	820627.2	0.17	17
10	Oct	61948.8	0.01	1
11	Nov	--	--	--
12	Dec	--	--	--
TOTAL		**4,805,232.2**	**1**	**100**

The annual total discharge of 4,805,232 m^3/yr obtained using the AV method is higher in relation to the total annual discharge of 1,204,200 m^3/yr obtained by Yusuf (2006) in a study of the Samaru stream using both the weir and AV. The difference can be attributed to the difference in the position of the gauging station with increasing volume of water passing down the stream.

4.2 Dissolved Sediment Concentration (DSC)

Data collected on DSC began on 7 April, 2014 and ended on 10 October, 2014. The summary statistics is presented in Table 2. The result obtained from the summary statistics shows that the range is 100 mg/L and the mean value is 58.87 mg/L, with minimum and maximum values of 20 mg/L and

120 mg/L respectively. These minimum and maximum DSC values were spread across the year with April marking the commencement of the rainfall season having more of 120 mg/L DSC values while October has values of 20 mg/L.

The variation in distribution of the dissolved sediment values can be explained to the fact that before the commencement of rainfall in April, more mineral compounds or constituents as dissolved materials are being concentrated in the soil surfaces and as the rain commences in April, the mineral matters concentrates are being washed down into the stream as dissolved sediments loads. Another observation is that the rate of dilution of minerals increases as rainfall progresses.

Table 2: Summary Statistics of Dissolved Sediment Concentration (mg/L)

STATISTICS		VALUE
N	VALID	71
	MISSING	143
Mean		58.8732
Std. Error of Mean		3.47193
Std. Deviation		292550
Variance		855.855
Range		100.00
Minimum		20.00
Maximum		120.00
Sum		**4180.00**

Dissolved Sediment Discharge (DSD) - Discharge (Q) Relation: A log-log relationship of a rating curve relating the daily mean instantaneous discharge values to DSD is shown in Fig. 2 and a rating equation derived from the relationship, using their log exponents, as shown in Table 6 is of the form:

Log DSD=$10^{2.068}Q^{57.576}$ (i.e DSD = 52.845 $Q^{57.576}$)……………………………………………….3

While the regression equation is of the form:

Log DSD = Log 2.068+ 57.576 log Q………………………………………………………….4

The regression coefficient of correlation (r) value of 0.866 and coefficient of determination (r^2) of 0.749 is shown in Table 3. The equations 3 and 4 illustrated that there is a direct relationship between dissolved sediment discharge and discharge at the 0.05 level of significance as presented in Table 4. Therefore, we concluded that there is strong relationship between the regression coefficients in both cases. Furthermore, the graph of relationship between DSD and Q in Fig. 2 gave a low peak DSD scatter of 0.1 mg/s and a high peak scatter of 325 mg/s.

Table 3: Coefficient of DSD-Q Relation

Factor	Coefficient	Std.Error	T	Sig.
(Constant)	2.068	0.060	23.631	0.000
LOGQ	57.576	0.073	14.361	0.000

a. **Dependent Variable: DSD**

Table 4: Model Summary for DSD-Q Relation

R	r^2	Std.Error of The Estimator	F	Sig.
0.866	0.749	0.26446	206.248	0.000

a. **Predictors: (Constant),** LOGQ; **b. Dependent Variable:** LOG**DSD**

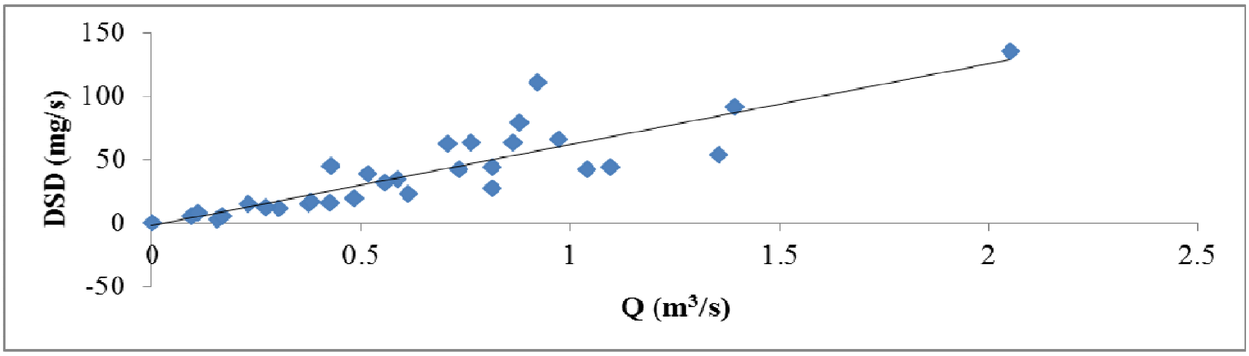

Figure 2: Graph of Relationship between Dissolved Sediment Discharge (DSD) and Discharge (Q)

Comparing this relationship with a study by Yusuf and Igbinigie (2012) where they examined the relationship between DSD and Q of Samaru stream and found that there is direct relationship between discharge and dissolved sediment discharge where they got a high values of (r) 0.901 and (r^2) 0.812 corresponding to a (r) 0.866 and (r^2) 0.749 of this study which indicates that there is a strong relationship between DSD and Q. The 2014 study was therefore found to be in agreement with the 2012 study of Yusuf and Igbinigie.

4.3 Estimation of Dissolved Sediment Yield (DSY)

In order to find the DSY for the period of study, equation 4 was used in estimating the DSD in mg/s which gave a total of 3085.1 mg/s with a varying values as low as 0.32mg/s to 238.28 mg/s with a mean value of 15.28 mg/s, as presented in the summary statistics Table 5.

Table 5: Summary Statistics of DSD (mg/s)

	STATISTICS	VALUE
N	VALID	202
	MISSING	12
Mean		15.28
Std. Error of Mean		2.22757
Std. Deviation		31.659
Variance		1002
Range		237.96
Minimum		0.32
Maximum		238.28
Sum		3085.1

while using equation 2, DSD in mg/s is converted to kg/day as displayed in the summary statistics in

Table 6 which gives a total DSD of 174,000 kg/yr varying from as low as 27.65 kg/day on the 21st and 22nd of May, 2014 to 20,600 kg/day on the 2nd of August, 2014.

Table 6: Summary Statistics of DSD (kg/day)

	STATISTICS	VALUE
N	VALID	202
	MISSING	12
Mean		861.13
Std. Error of Mean		171.11
Std. Deviation		2432
Variance		5915000
Range		20600
Minimum		27.65
Maximum		20600
Sum		174000

Table 7 gives the derived monthly distribution of DSD. It was observed that high DSD were experienced in August with peak DSD of 52% then followed by September with 28 % and April with 7 % while the lowest DSD was experienced in the month of May and October with just 3% contribution respectively of DSD.

Table 7: Regime Diagram Table for DSD (kg/day)

NO:	MONTHS	DISSOLVED SEDIMENT DISCHARGE (g/month)	FRACTION TOTAL DISSOLVED DISCHARGE (g/month)	PERCENT TOTAL DISSOLVED DISCHARGE (%)
1	Jan	--	--	--
2	Feb	--	--	--
3	March	--	--	--
4	April	11357.48	0.07	7
5	May	4872.84	0.03	3
6	June	6293.73	0.04	4
7	July	6872.05	0.04	4
8	Aug	91712.41	0.52	52
9	Sept	47977.96	0.28	28
10	Oct	4860.92	0.03	3
11	Nov	--	--	--
12	Dec	--	--	--
TOTAL		174 000	1.0	100

Lastly, in order to estimate the DSY produced, the annual total DSY of 174,000 kg/yr derived from equation 5 is divided by 1000 which gives a Channel Sediment Yield (**CSY**) value of 174 tons/km^2/yr. The amount is high and can be attributed to the anthropogenic activities upstream.

5. CONCLUSION AND RECOMMENDATIONS

The information gathered from the research of dissolved sediment delivery by the Samaru stream is of practical implications to the Kubanni basin because it shows the contribution of dissolved sediment by Samaru stream into the kubanni reservoir where one the biggest challenges to water supply to the ABU community is purification of treated water for human consumption and also, it shows the rate at which factors such as rock solubility, erosion of materials, relief and slope are being influenced by the processes of weathering and erosion to sedimentation of the basin particularly the dissolved sediment. The ongoing conservation and watershed management process by the University authority in the Kubanni basin is yielding results in regards to sedimentation however, strict compliance should be enforced because it was found that people still engaged in the earlier banned practices such as cattle rearing, soil mining for construction and irrigation farming. Also, it is highly recommended that the human activities taking place in Samaru town where the stream absorbed some of its contents be monitored. The contaminants are washed down into the ABU reservoir from the Samaru stream during the raining season there by contaminating the water.

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