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Volumetric Assessment of Suspended Load Sediment of Selected Reach of River Benue in some Parts of Adamawa State

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Abstract
It was discovered that the total suspended load sediment passing a reach of river Benue at Jimeta Bridge per twenty second (20sec) was 300g, for one hour at 300g/20sec =900 X 60 mins= 54,000g or 5.4kg, for one day is 1296000kg or 129.6kg, for seven days is 9072000g or 907.2 kg and so on. Total Discharge in the dry season in the month of March on 12th, 2018 was 121.1084m^3s; total area was 373.20m^2, and mean velocity was 0.2809m /s-^{1}. In the rainy season in the month of July on 27th, 2018, the total runoff was 283.67593m^3s^2, mean velocity was 0.660741m/sec and total area was 429.33m^2. The discharge conducted on 27 July, 2018 indicated that, the erosion was higher than the discharge conducted on 12 March, 2018 due to high stream flow at higher velocity. It could be deduced that when the velocity of stream flow reduces, deposition of sedimentation increases. The Froude number of the discharge at 0.2809ms^{-2} velocity was 0.72284, the turbulence of the river was tranquil (sub-critical) because the Froude number was less than one, F_{r} (>1). That means the physical appearance of the flowing water indicated less turbid. The stream power was < 1 $Jm^{-2}s^{-1}$ and > 12,000 $Jm^{-2}s^{-1}$, it was not sufficient to move boulder materials in diameters but suspended load could pass through. The sampling procedure used was area sampling technique through equal increment of width, the same transit rate for all verticals and the same bill along the same cross-section. The indirect vertical integration method was used, where equal increment of with using the same transit rate for all verticals and the same bill along the entire cross-section was adopted. Filtration method was done by removing twenty percent (20%) of each sample and filtered it on filtering paper. After filtration, the sediment on the filtering paper was weighed. Complete instrument for discharge measurement (SK 100 suspended Derrick, sinker weight, revolution counter, Bray Stock, fish tail and tools), Inventory checklist, Sample ID forms (sampling information and identification) and labels, G. P.S., Camera, Protective clothing, Tools (hammer, spanner, axe, knife, etc.), First aid kit, Boat, distilled water, improvised suspended load sampler and Personnel were used. Therefore, people should stop drinking the water directly from the river, government should dig boreholes for the villages, and awareness about the above implications should be done.
Key words: stream flow, sediment discharge, suspended load and water quality.

Introduction

There are several methods through which Measurement of suspended sediment concentration (SSC) can be done, for example, by using conventional (laboratory analysis), optical, and acoustic methods. Measurement of suspended sediment concentration (SSC) is important in the studies of sediment transport (Angga, Henry, Tir, and Susilohadi, 2017). The ability for particles in suspension to settle out of the fluid in which they are entrained and blocked by a barrier, due to forces acting on them is termed as sedimentation (York, Patuxent, Potomac, Julie and Carl 2010). These forces can be due to gravity, centrifugal acceleration, or electromagnetism (Joanne *et al* 2011).

Stream flow is measured by making a discharge measurement (Robert, 2004). Suspended sediment is the type of sediment that is being carried in the water itself. It is measured by collecting them in bottles of water and sending them to a lab to determine their concentration (Palermo, 2005). Because the amount of sediment a river can transport changes over time, hydrologists take measurements and samples as stream-flow goes up and down during a storm (Pitlick, 2009). Once we know how much water is flowing and the amount of sediment in the water at different flow conditions, we can compute the tonnage of sediment that moves past the measurement site during a day, during the storm, and even during the whole year (USGS Water Science School, 2017). During normal flow conditions, suspended sediments are dominated by particles less than 0.0625 mm and can include colloids, clay, mud and silt. These smallest particles also form part of the deposited sediment, and can be collectively referred to as suspended sediments (Joanne *et al,* 2011).

However excessive erosion, transport, and deposition of sediment in surface waters are major problem in the world (International Atomic Energy Agency, 2003). The National Water Quality Inventory 2011 reported that sediments are ranked as a leading cause of water-quality impairment of assessed rivers and lakes (Fishman, 2012). Impairment by sediment can be separated into problems resulting from chemical constituents adsorbed onto the surface of fine-grained sediments, problems resulting from sediment quantities irrespective of adsorbed constituents, and alteration of substrate by erosion or deposition (Chen, 2013). In particular, sediment alters the physical habitat by clogging interstitial spaces used as refuge by benthic invertebrates and fish, by altering food resources and by removing sites used for egg laying (Michael, 2013). As such, sediment can affect the diversity and composition of biotic communities. Sediment in rivers can also shorten the lifespan of dams and reservoirs (Da Ouyang and James 2005). When a river is dammed and a reservoir is created, the sediments that used to flow along with the relatively fast-moving river water are, instead, deposited in the reservoir. This happens because the river water flowing through the reservoir moves too slowly to keep sediment suspended (Newton and Carvalho 2000).

Villages such as Tungan, Kapana, Janngra, Mbuno, Gereng, Kwaylna, Damare, Lugga and Pakuma that are along the river Benue are vulnerable to sediment related problems such as viscosity of water and contamination of potable water whereas the flowing water is the source of their potable water. They also use it for washing and bathing. The aforementioned problems prompted the researcher to assess the volume of suspended load that passes through river Benue at some selected reach around the study area. This study covers the aspects of water volume, velocity, width of the river and suspended loading in River Benue. The effects of sedimentation on human activities associated with the river were also observed.

The study area

Southern zone of Adamawa state is one of the geopolitical zones comprising Numan, Guyuk, Demsa, Lamurde and Tungo Local Government Areas. It is located between latitudes 09°15 and 09°15 N and longitudes 11° 15 and 11°45 E with an elevation of 125m above sea level. It covers a land area of about 3189km^2(Google image, 2016). The towns Jimeta and Yola are gap towns which are situated at a point where the Benue River carves its valley through the eastern highlands. The study area falls within the Benue trough which is generally a low lying flat terrain of 183.3-200 meters above sea level with gentle undulation and hill ranges punctuating the extensive flat flood plain at various locations notably, across the river Benue eastward, the land rises steeply to attain a maximum height of 240 meter above mean sea level. River Benue previously known as the Chadda River or Tchadda is the major tributary of the Niger River. The river is approximately 1,400km long and is almost entirely navigable during the summer months. As a result, it is an important transportation route in the region through which it flows. Some of the villages settled around the river mostly use the river as source of drinking water and for domestic activities. These villages are; Tungan, Kapana, Janngra, Mbuno, Gereng, Kwaylna, Damare, Pugange Lugga and Pakuma.

Materials/Equipment

Complete instrument for discharge measurement (SK 100 suspended Derrick, sinker weight, revolution counter, Bray Stock, fish tail and tools), Inventory checklist, Sample ID forms (sampling information and identification) and labels, G. P.S., Camera, Protective clothing, Tools (hammer, spanner, axe, knife, etc.). First aid kit, Boat, distilled water, improvised suspended load sampler and Personnel (Upper Benue River Basin Development Authority 2018).

Sampling procedure

The sampling procedure used was area sampling technique through equal increment of width, the same transit rate for all verticals and the same bill along the same cross-section. The cross-section of the river was divided in to six (6) sections (200m) each with their distinct boundaries in each sample point; simple systematic sampling was adopted and drew two samples from each section so that the total samples were twelve (12) for the whole cross-section.

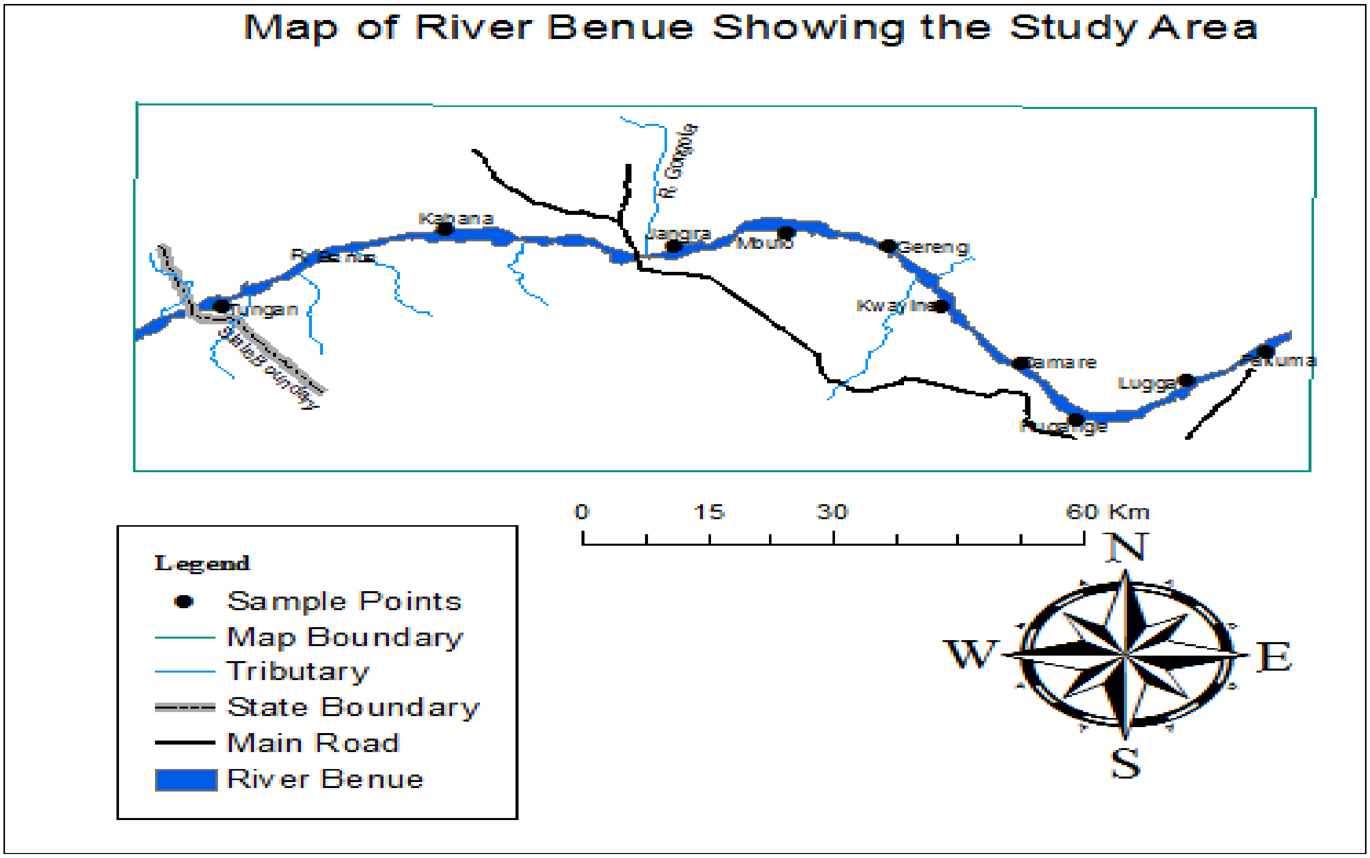

Fig. 1: Map of River Benue showing the sample points

Method of data collection

Indirect vertical integration method

The indirect vertical integration method was used, where equal increment of width using the same transit rate for all verticals and the same bill along the entire cross-section was adopted (Tahmase, 2015). During the data collection, the improvised depth integration sampler was lowered to the river bottom, then immediately raised to the surface. Lowering and rising was done at the same rate to fill the sampler to about ninety (90) percent capacity over twenty second (20sec). When the sampler was completely full, it was poured in the field blank bottle. The sampler was biased because it stopped sampling at the point at which it filled up. Therefore, proper monitoring was done to maintain at most ten (10) percent error.

Transportation and storage of sample

After collection of the sediment samples using the samplers at the field, the samples were transported to the laboratory under strict condition that did not compromise the subsequent planned analysis. This was done by using vehicle as transportation means with the sampler under strict protection condition respectively. Since the samples were mainly for physical analysis and concentration, plastic bottle made of polyethylene were used for transportation and storage. During the transportation, care was taken to; minimized the interaction between sample and external environment, treated the sample bottle with the same precaution as that of samples, the sample bottles were washed with appropriate cleaning agents.

Method of Analysis

Filtration method was done by removing twenty percent (10%) of each sample and filtered it on filtering paper. After filtration, the sediment on the filtering paper was weighed.

Fig. 2: Weighing the volume of the filter paper

Fig. 3: Removal of 200 millimeter (10%) of the suspended load sample out of the 1000 millimeter (one litter)

Fig.4: The filtration of 10% suspended load sediment sample

Fig. 5: Weighing of filtered sampled sediment

Fig. 2 shows how the volume of the filtered paper was weighed, fig. 3 200 millimeter (10%) of the suspended load sample out of the 1000 millimeter (one litter) was removed, fig. 4 The (10%) suspended load sediment sample was filtered, fig. 5 filtered sampled sediment was weighted. The volume of the filtering paper was subtracted from the filtered sediment load sample. The remaining volume of the suspended load sample was related to the one liter of the suspended load sediment sample. From the indirect vertical integrated measurement method for suspended load sediment discharge, the computation of the obtained concentration value was performed through:-total suspended load (ml) =1000, percentage filtered =10, mass of suspended load in (g) = [mass of Filter paper + suspended load retained (g)] – [mass of empty filter paper (g)], total mass of suspended load (g) = mass of suspended load 100, percent retained = suspended load retained (g) 100, total percent retained = total suspended load- percentage filtered, percent passing = percentage filtered- percent retained, total percent passing = percent passing 100.

When the suspended sediment load discharge for a day was calculated, the result was multiplied by seven (7) to obtain seven (7) days suspended load sediment discharge. For the month, the result of seven (7) days was multiplied by four (4). For the year, the result of one month was multiplied by twelve (12) months.

Result and Discussion

Flow Characteristics of River Benue

Total Discharge in the dry season was equal to $121.1084m^3s^{-2}$, Total Area was equal to $373.20m^2$, and Mean Velocity was equal to 0.2809m /s-^{1}. In the rainy season the total runoff was $283.67593m^3s^2$, mean velocity was 0.660741m/sec and total area was $429.33m^2$. Based on figure 6, the depth of the river was below the zero level, the river experienced erosion because the deepest part of the river during the measurement was 149.918m. This could be related to both the stream flow characteristics, i.e. total discharge which was equal to $121.1084m^3$/sec, total area was equal to $373.20m^2$ and mean velocity was equal to 0.2809m/sec. and total runoff was $283.67593m^3s^2$, mean velocity was 0.660741m/sec and total area was $429.33m^2$. The discharge conducted on 27 July, 2018 indicated that, the erosion was higher than the discharge conducted in 12 March, 2018 due to high stream flow at high velocity. It can be deducted that that when the velocity of the stream flow is reducing, the more deposition of sedimentation increases.

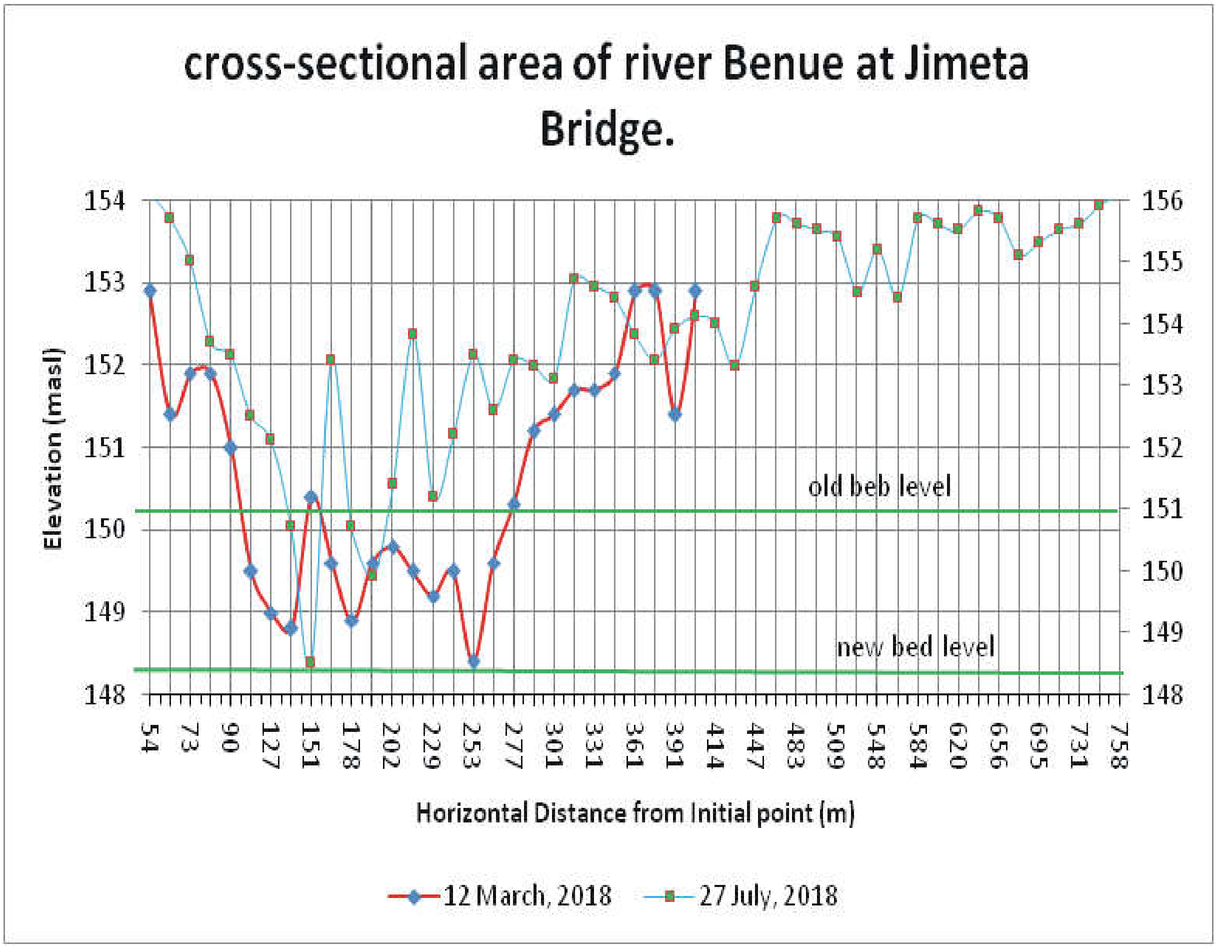

Figure 6: Cross sectional area of River Benue at Jimeta bridge

Stream turbulence of river Benue at Jimeta Bridge in the dry season

The stream turbulence of the channel reach was calculated as: $F_r = \frac{v}{\sqrt{dg}}$ Where v = 0.289ms^2, d = 1.56875m, g = gravitational acceleration (9.81m/sec).If $F_r < 1$ the flow was sub-critical (tranquil), If $F_r > 1$ the flow was supercritical (rapid), If $F_r = 1$ the flow was critical.

Therefore: $F_r = \frac{v}{\sqrt{dg}}$ z, $F_r = \frac{0.289}{\sqrt{1.56875 \times 9.81}}$ $F_r = \frac{0.289}{\sqrt{0.1599}}$, $F_r = \frac{0.289}{0.39989} = 0.72284$

Since the Froude number of the discharge at 0.2809ms^{-2} velocity was 0.72284, the turbulence of the river was tranquil (sub-critical) because the Froude number was less than one, $F_{r\,(}$>1). That means the physical appearance of the flowing water indicates less turbidity.

Analysis of Stream power of river Benue at Jimeta Bridge in the dry season

Stream power: - $\omega = pgvds$: - *Where* p = (1000gcm^{-3}), g = (9.81m/sec), v = 0.2809ms^{-1}, d = 1.56875m, s = 0.20625m. ω = $1000m^3s^{-2} \times 9.81m^{-2} \times 0.2809 \times 1.56875 \times 0.20625$.ω = 891.59667 Jm^{-2}s^{-2}. Since the stream power is < 1Jm^{-2}s^{-1} and > 12,000 Jm^{-2}s^{-1}, it is not sufficient to move boulders meters in diameter but suspended load can pass through.

Stream turbulence of river Benue at Jimeta Bridge in the rainy season

The stream turbulence of the channel reach was calculated as: $F_r = \frac{v}{\sqrt{dg}}$ Where v = flow velocity, d = flow depth, g = gravitational acceleration (9.81m/sec),If F_r< 1 the flow was sub- critical (tranquil), If F_r> 1 the flow was supercritical (rapid), If F_r = 1 the flow was critical.

Therefore, v = 0.660741m/sec, d = 2.296m, g =9.81m/sec.

$$F_r = \frac{0.66741m/\sec}{\sqrt{2.296 \times 9.81m/\sec}}, = \frac{0.66741m/\sec}{\sqrt{22.5266}}, = \frac{0.66741m/\sec}{4.746}, = 0.1406$$

Since the Froude number of the discharge at 0.660741m/sec, velocity is 0.1406, the turbulence of the river was tranquil (sub-critical) because the Froude number was less than one, *Fr<1.That* means the physical appearance of the flowing water indicate less turbidity and less erosion.

Analysis of Stream power of River Benue at Jimeta Bridge in the rainy season

Stream power: - $\omega = pgvds$, Where p = (1000gcm^{-3}), g = (9.81m/sec), v = 0.66741m^{-2}, d = 62m, s = 0.375. ω = $1000m3s - 2 \times 9.81m - 2 \times 0.66741 \times 62 \times 0.375$.ω =152,224.54 Jm^{-2}s^{-2}

Since the stream power was>12,000 Jm^{-2}s^{-2}, it was capable of moving the boulders meters in diameters.

From Table 1, Sample Number (2), Visual Classification of Suspended load, less turbid, Weight of Container was 499.26 gm, Weight of Container+ water: 2014.52 gm, Weight of water was 1515.26gm. Total suspended load (ml) =1000, Percentage filtered =10ml, Mass of suspended load (g) =0.03, Total mass of suspended load (g) = 0.03 100=3g, Percent retained =0.3, Total percent retained =30g, Percent passing =9.7%, Total percent passing = 9.7 100=970%.

From Table 1, Sample Number (2), Visual Classification of Suspended load was less turbid, weight of container was 499.26 gm, Weight (Wt). container+ water: 2014.52 gm Wt. of water was 1515.26gm. Total suspended load (ml) =1000 percentage filtered =10, pass of suspended load (g) =0.03, total mass of suspended load (g) = 0.03 100=3g, percent retained =0.3, total percent retained =30g, percent passing =9.7%, total percent passing = 9.7 100=970%.

Table 1: Suspended load Filtration Analysis

Sample Number and Name	Mass of Empty Filter Paper (g)	Total Suspended load (ml)	Percentage filtered (ml)	Mass of Filter Paper + Suspended load Retained (g)	Suspended load Retained (g)	Percent Retained	Percent Passing
1 Tungan	1.02	1,000	10	1.05	0.03	3.0	97
2 Kapana	1.02	1,000	10	1.05	0.03	3.0	97
3 Jangra	1.02	1,000	10	1.06	0.04	4.0	96
4 Mbuna	1.02	1,000	10	1.05	0.03	3.0	97
5 Gereng	1.02	1,000	10	1.03	0.01	1.0	99
6 Kwaylna	1.02	1,000	10	1.80	0.06	6.0	94
7 Damare	1.02	1,000	10	1.04	0.02	2.0	98
8 Pugange	1.02	1,000	10	1.04	0.02	2.0	98
9 Lugga	1.02	1,000	10	1.05	0.03	3.0	97
10 Pukuma	1.02	1,000	10	1.05	0.03	3.0	97

Date tested: 8^{th} August, 2018)

From table 1, sample number: (3), visual classification of suspended load was less turbid; weight of container was 499.26 gm, wt. container+ water: 2014.60 gm, wt. of water was 1515.34gm. total suspended load (ml) =1000, percentage filtered =10, mass of suspended load (g) =0.04, total mass of suspended load (g) = 0.04 100=3g, percent retained =0.4, total percent retained =40g, percent passing =9.6%, total percent passing = 9.6 100=960%.

From table 1, sample number: (4), visual classification of suspended load was less turbid; weight of container was 499.26 gm, wt. container+ water: 2014.52 gm, wt. of water was 1515.26gm. total suspended load (ml) =1000, percentage filtered =10, mass of suspended load (g) =0.03, total mass of suspended load (g) = 0.03 100=3g, percent retained =0.3, total percent retained =30g, percent passing =9.7%, total percent passing = 9.7 100=970%.

From table 1, sample number: (5), visual classification of suspended load was less turbid, weight of container: 499.26 gm, wt. container+ water: 2014.36 gm, wt. of water was 1515.10gm. total suspended load (ml) =1000, percentage filtered =10, mass of suspended load (g) =0.01, total mass of suspended load (g) = 0.01 100=3g, percent retained =0.1, total percent retained =10g, percent passing =9.9%, total percent passing = 9.9 100=990%.

From table 3, sample number: (6), visual classification of suspended load was less turbid, weight of container: 499.26 gm, wt. container+ water: 2014.80 gm, wt. of water: was1515.54gm. total suspended load (ml) =1000, percentage filtered =10, mass of suspended load (g) =0.06, total mass of suspended load (g) = 0.06 100=3g, percent retained =0.6, total percent retained =60g, percent passing =9.7%, total percent passing = 9.4 100=940%.

From table 1, sample number: (7), visual classification of suspended load was less turbid, weight of container: 499.26 gm, weight of container+ water was 2014.44 gm, weight of water: 1515.18gm. total suspended load (ml) =1000, percentage filtered =10, mass of suspended load (g) =0.02, total mass of suspended load (g) = 0.02 100=3g, percent retained =0.2, total percent retained =20g, percent passing =9.8%, total percent passing = 9.8 100=980%.

From table 1, sample number: (8), visual classification of suspended load: less turbid, weight of container: 499.26 gm, weight of container+ water: 2014.44 gm, weight of water: 1515.18gm. total suspended load (ml) =1000, percentage filtered =10, mass of suspended load (g) =0.02, total mass of suspended load (g) = 0.02 100=2g, percent retained =0.2, total percent retained =20g, percent passing =9.8%, total percent passing = 9.8 100=980%.

From table 1, sample number: (9), visual classification of suspended load was less turbid, weight of container: 499.26 gm, weight of container+ water: 2014.52 gm, weight of water was 1515.26gm. Total suspended load (ml) =1000, percentage filtered =10, mass of suspended load (g) =0.3, total mass of suspended load (g) = 0.03 100=3g, percent retained =0.3, total percent retained =30g, percent passing =9.7%, total percent passing = 9.7 100=970%.

From table 1, sample number: (10), visual classification of suspended load was less turbid, weight of container: 499.26 gm, weight of container+ water: 2014.52 gm, weight of water was 1515.26gm. total suspended load (ml) =1000, percentage filtered =10, mass of suspended load (g) =0.3, total mass of suspended load (g) = 0.03 100=3g, percent retained =0.3, total percent retained =30g, percent passing =9.7% and total percent passing = 9.7 100=970%.

Table 2: Total suspended load sediment

Sample Number	1	2	3	4	5	6	7	8	9	10	Total
Suspended load(g)	30	30	40	30	10	60	20	20	30	30	300

The result on table 2 shows that the total suspended load per 20 secs is 300g, so if you multiply 20 sec by 3, which is 1 minute = 900g, for one hour at 300g/20sec =900 X 60 mins= 54,000g or 5.4kg, for one day is 1296000kg or 129.6kg and so on.

Conclusion

Some observed behavioral characteristics of stream flow suggested the relative greater importance of bed load and suspended load at higher and low flows, that the transport process is characterized by spatial and temporal variability, neither of which can be ignored, and that adequate direct integrated sampling techniques exist to quantify characteristics of bed load and suspended load in natural rivers. At present, measurement of bed load is a time-consuming and expensive undertaking. Technology surrogate to direct sampling of bed load need to be both developing and encouraging; these indirect methods of measurement must provide information relevant to real-world needs. The ability of indirect methods to conform to observations from direct measurement should be useful in the continued development of surrogate technology.

The finding of this study findings indicated that the cross-sectional measurement of river Benue at Jimeta Bridge experienced a lot of bed load sedimentation. The present depth of the river was above the zero level (151.166). The findings indicated that the behavior of the river was sub-critical (tranquil) in the dry seasons, and not capable of transporting boulders because its stream power was not greater than 12,000 $Jm^{-2}s^{-2}$. The discharge conducted in 27 July, 2018 indicated that, the erosion was high due to the stream flow at the mean velocity 0.660741m/sec. compared to the mean velocity 0.2809m/sec. conducted in 12 March, 2018. It also indicates that, the behavior of the river was also sub-critical (tranquil), and that it was not capable of transporting boulders.

The result of the findings also depicted that suspended load sediment was low during dry season because the physical look of the water was less turbid. The average weight of the sediment was 0.3% per 1000mm (1lt) of water. That means in each 1000mm (1lt) of water, 30g was suspended load sediment. Relating this to the total discharge (121.1084m^3/sec.) as obtained from the 12 March, 2018, the amount of suspended load sediment that passed through the river channel yearly was 435456000g.

The implication of this study is that, the teaming populations of the villages around the study area (River Benue) are seriously in danger of contacting different diseases such typhoid, cholera, and to some extend there in the water found some protozoa respectively. Therefore, people should stop drinking the water directly from the river, government should dig boreholes for the villages, and awareness about the above implications should be done.

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