STREAM FLOW, SEDIMENT CONCENTRATION AND PARTICLE-SIZE ANALYSIS OF SELECTED CHANNEL REACH OF RIVER YEDZERAM AT WURO-GUDE, NORTHEAST NIGERIA

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Abstract

Sediment Concentrations and Particle-Size Analysis for Selected Channel Section of River Yedzeram at Wuro-Gude, North eastern Nigeria was the main objective of the research. Equipment required for field measurements of suspended load sediment and bed load sediment included improvised suspended load sampler, Helley-Smith bed load sampler, inventory checklist, Sample ID forms (sampling information and identification) and labels, G.P.S, Camera, Ranging pole, Staff, tape, and Personnel. The sampling procedure used was area sampling technique through equal increment of width, using 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 fifteen (15) sections (2m) each with their definite boundaries, after which the use of systematic sampling technique was adopted and draws one sample from each section resulted to the total samples of fifteen (15) for the whole cross-section. The samples were subjected to laboratory analysis. The results obtained indicated that the mean volume of sediments that passed through Wuro-Gude station was 4658g within 20 second. The major particle of the channel bed was medium sand consisting of 25.10%, then gravel 17.45%, fine sand 15.56%, pebbles 7.14%, cobbles 2.32%, boulders 1.61%, silt 1.60%, and 0.02% clay contents. The C_u was 0.146 which was less than 4-6, while C_c was 0.896 below the range 1-3, which indicated that the sediment sizes were not well graded. The volume of 12,033.360g of suspended load passed through River Yedzeram at Wuro-Gude channel section. This result indicated that the volume of water that passed through Wuro-Gude was averagely turbid. It was recommended that; Awareness on the turbid nature of water that pass through Yedzeram channel around Wuro-Gude should be done, so as to reduce the level of negative effects of contaminated water on human and properties, secondly, there is a serious lack of hydrologic and morphometric records and data in the area. Therefore, much data gathering by appropriate agencies in the areas like Geomorphology, Hydrology, Geology, Soil science and Soil engineering required from relevant related fields is required. Dredging of the river channel should be done so as to remove the accumulated bed load particles that are presently cemented in the river. This will result to smooth flow of the water in the river.

***Keywords*:** Bed Load, Bed-Load Sampler, Channel, Fine Material, Particle Diameter, Sediment, suspended load sediment and Total Sediment Discharge.

Introduction

Appropriate prediction of sediment load concentration being carried by streams has a vital importance of water resources quantity and quality studies and management of the water resources projects (Osman, 2015). In the other way round, sediments carried by flow affects the economic life of facilities and changes ecologic and hydraulic equilibrium in the river system (Bin-rui, 2018). In most of the river systems, fine materials are transported in suspension and are termed the suspended sediment load (Matthew, 2014). Bed particles are materials moving in the bed layer, this motion occurs by rolling, sliding, and, sometimes, by jumping (Hans, 1950). Sedimentation is the tendency for particles in suspension to settle out of the fluid in which they are entrained and come to rest against a barrier due to their motion through the fluid in response to the forces acting on them, these forces can be due to gravity, centrifugal acceleration, or electromagnetism (Joanne, *et al* 2011). The fine fraction incorporates both the organic and mineral particles of diameters > 0.45 μm and < 2000 μm (Gray 2014). During normal flow conditions, suspended sediment is dominated by particles less than 0.0625 mm and can include colloids, clay, and mud and silt (Sanjeev, & Xu, 2017). Particles within this range account for the majority of material eroded from the landscape and subsequently transported by rivers and streams (Ulrich, 2020). When sedimentation occurs in excess, it directly affects the health of a waterway, decreasing its life-supporting capacity (Janine, & Frank, 1995). Sedimentation of water bodies is a global geomorphic phenomenon that possesses threat to the morphological structure of the waters and concern on the sustainable functions of the bodies as vital water resources (Oliver, 2016). Sediment-laden rivers and streams pose substantial environmental and economic challenges (Christopher, 2012). Excessive sediment transport in rivers causes problems for flood control, soil conservation, irrigation, aquatic health, and navigation, and transports harmful contaminants like organic chemicals and eutrophication-causing nutrients (Bin-rui, 2018).

The smallest particles also form part of the deposited sediment, and can be collectively referred to as 'suspendible sediments' (Joanne, *et al* 2011). Larger particles deposited on the streambed are collectively referred to as 'bed load' (Joanne, *et al* 2011). The movement of sediment is dependent on channel morphology and flow (Hubert, 1999). For example, higher water velocities are able to transport larger particles. Consequently, sediments are a sink as well as a source of contaminants in the aquatic environment (Marianne, *et al* 2019; Zhou, & Tong, 2007). Stronger flows increase the lift and drag on the particles, causing them to rise, while larger or denser particles likely to fall through the flow (Da, *et al* 2005). When soils erode, sediments are washed into streams and rivers. Sediments in waterways are often high in areas where river banks are grazed by livestock, on farms with steep slopes cleared of trees, and where there is a lack of riparian vegetation. Grazing along river banks removes or damages existing vegetation, increases compaction of the soil, and damages the banks of a waterway (Taihoro, 2013).

One cause of high sediment loads from slash and burn and shifting cultivation of tropical forests (Victor, 2019). When the ground surface is stripped of vegetation and then seared of all living organisms, the upper soils are vulnerable to both wind and water erosion (Balasubramanian, 2017). In a number of regions of the earth, entire sectors of a country have become erodible (Ongley, 1996). Sedimentation is characterized by particles that settle discretely at a constant settling velocity down to the point source (Salvatore, *et al* 2020). They settle as individual particles and do not flocculate or stick to other during settling. For instance this is common to sand and silt materials which are characterized by particles that flocculate during sedimentation and because of this their sizes are constantly changing and so also their settling velocities (Joanne, *et al* 2011).

Natural processes responsible for the formation of bed sediments can be altered by anthropogenic activities (Mark, 1998). Many man-made materials have entered bodies of water through atmospheric deposition, runoff from land, or direct discharge into the water (Roger, *et al* 2006). Human activities, including urban development, overgrazing of land, deforestation, quarrying, forestry, excavation, agriculture, can accelerate the delivery of sediment to in-stream, downpour of sediment particles on rivers, or disrupt the natural downstream progression (Kevin, & Philip, 2009). These activities accelerate the delivery of sediment to streams, thereby increasing the quantity of smaller particle size in the channel or disrupt the natural downstream progression (Joanne, 2006). Sedimentation is very important, without it we wouldn't have any dinosaur fossils (Christoph, *et a*l 2018). It is the building up of layers of small particles like sand or mud. The easiest place to see this is the beach. A beach is made up of lots of sand which have been deposited, or left behind, by the sea. Sand and mud come from inland because rivers erode them from the land and bring them towards the sea. As the water slows, it can't carry as much and so sand and mud are dropped. The bigger the grain of sand, the sooner it is dropped. If you look at a cliff you will often see layers which make the cliff look like a layer cake, these layers are caused by sedimentation. Over a long period of time, the grains of sand and mud build up and up, forming the layers (Aaronfaunch, 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 (Henley, Patterson, Neves, & Dennis, 2000). As such, sediment can affect the diversity and composition of biotic communities. Furthermore, sedimentation and soil erosion causes substantial (large) waterway damages and water quality degradation, and remains as one of the main environmental concerns and very costly in sediment removal or dredging (Russell, 2011). Hence, the need for river sedimentation studies towards providing solution to aforementioned alterations of the fluvial rivers in the world is evitable.

Methodology

Location and Extent of the Study Area

River Yedzeram is one the rivers that flows its water into Lake Chad. It has a total length of about 330 km (Uba topographical sheet 156, Edition 1., 1974). It takes its source from the Hudu Hills south-east of Mubi and flows northwards into the Chad, (Adebayo, & Dayya, 2004, extracted from Yonanna, 2007). The study area is located between longitudes 13° 11' 12"E, and 13° 30' 00"E of Equator, and between latitudes 10° 06' 30"N, and 10° 26' 54"N Greenwich Meridian Time (GMT) (Figure 1). The study area lies within the tropical zone, comprising of both wet and dry climate symbolized as Aw in the Coppin's climate classification (Jones, & Bartlett, 2012).

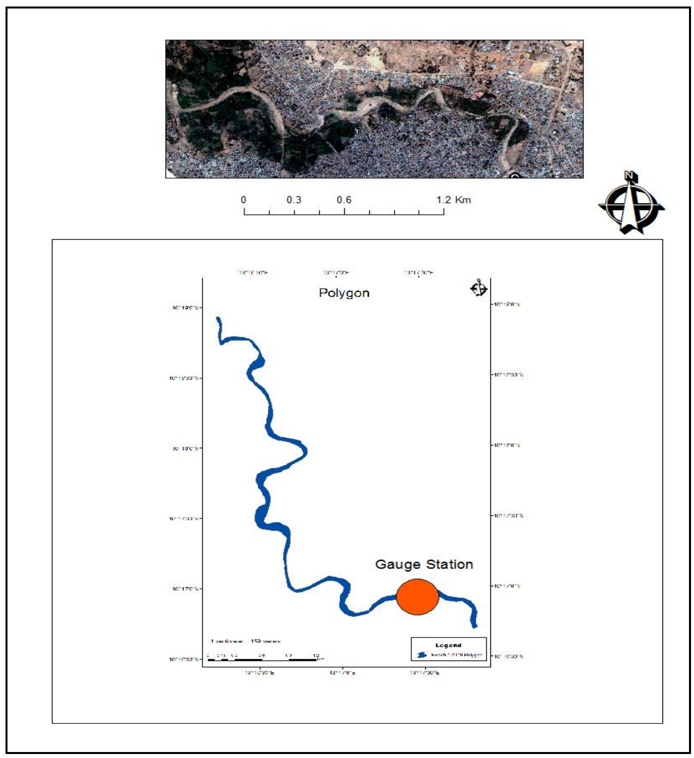

Figure 1: The studied area.
Source: Researchers work 2019

The radiation of the study area is high in that the temperature is warm as from May to October, while hottest months are the months of Match, and April. Basement complex rock is the dominant rock in the North Eastern part of Nigeria particularly the Hard Crystalline rock within the study Area (Tukur, 2014).). The hard crystalline rock form series of orogenic cycles within the mobile belts of Central Africa (Opeloye, & Dio, 1999). The origin of the rocks were Gneisses, migmatites and quarzites, but later on wiped out by the late proterozoic and pan-Africa period, and replaced by older Biotite granite, Biotite, porphyroid-granite, and alkaline granite (Yonanna, 2006). The study area is dominated by upland and lowland landscapes (of heights up to 305m and 152m above sea level, respectively) with some few outcrops of hills around Vimtim in Mubi (Yonanna, 2006). The soils of the entire study area fall under the class of ferruginous tropical soils of granitic parent material (Adebayo, & Dayya, 2004).

Materials and Methods

Equipment used for the field measurements of bed and suspended loads sediment included improvised suspended load sampler, Helley-Smith bed load sampler, Staff, Ranging pole, inventory checklist, Sample ID forms (sampling information and identification) and labels, G.P.S., Camera, tape, and Personnel (plate 1&2).

Plate 1 and 2 materials and instrument
Source: Researchers work 2019

Sampling procedure for suspended and bed load sediments

Area sampling technique through equal increment of width, using the same transit rate for all verticals and the same bill along the same cross-section was used as explained by (Brisset, Old,. & Wren, 2005). The cross-section of the river was divided in to fifteen (15) sections (2m) each with their definite boundaries. After division, systematic sampling technique was used to draw one sample from each section resulted to fifteen (15) total samples for the whole channel cross-section.

Method of suspended load sediment collection

The sample was collected and kept separately every week for the complete rainy season starting from May to November. Each sample was analyzed and concentration curve for all the samples was produced. During taking the suspended load samples, the improvised depth integrating sampler was lowered to the river bottom then immediately raised it to the surface, lowering and rising was done at the same rate to fill the sampler to about ninety (90) percent capacity. When the sampler was completely filled, it was poured in the field blank container. 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 (Mehrdad, Hossein, Vijay & Amir, 2015).

Method of Bed Load Sediment Collection

During taking the bed load sample, the bed load sampler was sank into the bed of the river, and allowed it to settle for about twenty (20) seconds as suggested by (Government of India & Government of the Netherlands, 2003), after the bed load sampler has been oriented to the flow of the river (plate 3). Then the bed load materials entered the sampler through the inlet and the divergent flows within the sampler reduced the flow velocity allowing the sediment to accumulate. Affine mesh at the rear of the sampler allowed water to pass through, but not the bed load sediments. After the appropriate measured time-interval (20s) as suggested by (Government of India & Government of the Netherlands, 2003), the sampler was removed and the trapped sediment was removed for weighing in the laboratory (plate 4).

Plate 3 and 4: bed load sediment collection Source: Fieldwork 2019

Source: Researchers work 2019

Transportation and Storage of Sample

The samples were transported to the laboratory under conditions that could not compromise the sediment 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 bags made of polyethylene were used for transportation and storage. During the transportation, care was taken to; minimize the interaction between samples, and containers/implements, minimize the interaction between sample, and external environment, treat the sample containers with the same precaution as that of samples, wash the containers and implement with appropriate cleaning agents, and ran appropriate analytical blanks which was referred to every sample.

Quality Assurance and Quality Control for Sample Preparation

The sample identity and the element distribution in the original sample were maintained until the time of analytical determination (plate 5 & 6). Appropriate and unambiguous labeling system was designed, implemented, and strictly followed in the analytical laboratory. The transformation applied to the samples was documented in a laboratory logbook with careful registration of date, identity, label, operator, and the type of transformation and any observation of relevance to the interpretation of the final result. Parameters affecting the analytical result were monitored by calibrated instruments and equipment.

Plate 5 Plate 6:

Quality control for sample preparation

Source: Fieldwork 2019

Laboratory Test

Bed load sediment Analysis procedure

The samples were dried through placing them on an open space where air dried them as suggested by (James & Brian, 1985). The mortar and the pestle were used to gently break up any big clumps of the sediment. Any individual pebbles or pieces of gravel were noted. Each empty sieve was weighed and recorded the result (plate 7).The samples were weighed out to the nearest gram on an analytical balance (plate 8). Record the weight of the given dry sediment sample.

Plate 7 Plate 8

Source: Fieldwork 2019

All the sieves were assembled in the ascending order of sieve numbers (plate 9). The sediment samples were carefully poured into the top sieve, and place the cap over it. The sets of sieves with the sediment were placed on the shaker to shake them very well (Plate 10). The stack was removed from the shaker and carefully weighed and recorded the weight of each retained sediment (plate 11). In addition, the weight of the bottom pan with its retained fine sediment was weighed, and recorded. The Amount of Material Retained on the Sieve was determined.

Plate 9

Plate 10

Plate 11

Source: Fieldwork 2019

The mass of sediment retained on each sieve was obtained by subtracting the weight of the empty sieve from the mass of the sieve + retained sediment, the weight retained on the data sheet was recorded as the mass as suggested by (Qatar University Geotechnical Engineering, 2000). The sum of these retained masses should be approximately equals the initial mass of the soil sample. The percentage retained on each sieve was determined. The percent retained on each sieve was calculated by dividing the weight retained on each sieve by the original sample mass. The total weight of each size fraction present in the sediment sample was determined by subtracting each collected sieve weight from the previous weight of container plus sediment. Gram size analysis was conducted to determine the sand, silt and clay contents of the channel bank material. The analysis involved the use of 10mm, 4. 75mm, 2.36 mm, 1.18mm, 0.6mm, 0.3mm, 0.15mm and 0.075mm stack sieves as suggested by (Geotechnical Test Method, 2015).

Calculation of coefficient of Uniformity (C_u) and Coefficient of Curvature (C_c)

The percent passing (or percent finer) was calculated by starting with 100 percent and subtracting the percent retained on each sieve as a cumulative procedure (Yun, 2006). Quantity passing = Total mass - Mass retained. The percent retained was calculated as; % retained = Mass retained/Total mass. Quantity passing = Mass arriving - Mass retained.

The coefficient of uniformity (C_u) and coefficient of curvature (C_c) using the following equations.

$C_u = \frac{D_{60}}{D_{10}}$ While $C_c = \frac{D_{30}^{\;2}}{(D_{60} \times D_{10})}$ (equation 1) as postulated by (Elizabeth, Melissa, and Scott, 2007).

Coefficient of uniformity here we said is C_u which is equal to D_{60} by D_{10} and Coefficient of curvature as (D_{30} square) by (D_{60} into D_{10}). Effective particle size is indicated as D_{10} which indicates that 10 percent of the particles are finer and 90 percent of the particles are coarser than this size. C_u shows whether the sediment is well graded or poorly graded. C_c complements C_u to evaluate whether the sediment was well graded or poorly graded, or gap graded (Elizabeth, Melissa, & Scott, 2007).

Suspended Load Sediment Sample Analysis

The volume of the filter paper was weighed on electronic weighing machine (Ayoola, Victor, & Olaitan, 2018) (plate 12). Filtration method was used by removing fifteen percent (15%) (Plate 13) of the suspended load sample out of the 250 millimeter and filtered it on filtration paper as put by (Yun, 2006) (Plate 14).

Plate 12

Plate 13

Plate 14

Source: Fieldwork 2019

The filtered sampled sediments were dried in oven and weighed (plate 15). After drying, the sediment on the filtering paper was weighed (plate 16).

Plate 15

Plate 16

Source: Fieldwork 2019

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 and recorded.

Computation of Suspended Load Sediment Discharge

From the indirect vertical integrated measurement method for suspended load sediment discharge, the computation of the obtained concentration value was performed through:-

1. Total suspended load (ml) =250
2. Percentage filtered =15
3. Mass of suspended load in (g) = [Mass of Filter Paper + Suspended load Retained (g)] – [Mass of Empty Filter Paper (g)]
4. Total mass of suspended load (g) = Mass of suspended load ×100
5. Percent retained = Suspended load Retained (g) ×100
6. Total percent retained = total suspended load- Percentage filtered
7. Percent passing = Percentage filtered- Percent retained
8. 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.

Plotting of Logarithmic Curve of the Size Distribution:

The information was used to plot logarithmic curves of the size distribution of the silt, clay, Coarse sand, Medium sand, Find sand, gravel, pebble, cobble and boulder fraction of the sample as described previously, through that the grain distribution was determined. D_{10}, D_{30}, and D_{60} from the graph, which corresponded to the particle size for 10% finer, 30% finer and 60% finer (Pramanik, & Hasan, 2017).

Table 1: Sieve Size and Grain Type

S/N	Sieve Size	Sediment Type
1	10mm	Boulder
2	4.75mm	Cobble
3	2.36mm	Pebble
4	1.18mm	Gravel
5	0.600mm	Coarse sand
6	0.300mm	Medium sand
7	0.150mm	Find sand
8	0.075mm	Silts
9	Pan	Clay

Source: Adopted from Horiba (2019).

Results and Discussion

Texture (grain size) analysis of the channel particle samples revealed that the volume of the sediment that pass through Wuro-Gude station was 4658g within 20 second. The major nature of the channel bed indicated that coarse sand was 29.20%, followed by medium sand 25.10%, then gravel 17.45%, fine sand 15.56%, pebbles 7.14%, cobbles 2.32%, boulders 1.61% and silt 1.60%, and 0.02% clay contents (table 2). This implies that the channel bed of Yedzeram at Wuro-Gude majorly consist of coarse sand.

This implies that channel bed of Yedzeram majorly consist of medium sand without clay. The results obtained from textural and data analysis revealed that the bed of the channel is mainly sand deposit derived from the erosion processes operating in the drainage basin.

Table 2: The Samples of Grain Size Characteristics of Yedzeram at Wuro-Gude Channel Bed.

Sieve Type	Wight Retain (gm)	% Wight Retain (gm)	Cum. % Wight Retain (gm)	% Passing (%)
10mm	38	1.76	1.76	98.24
4.75mm	43	1.99	3.74	96.26
2.36mm	140	6.47	10.21	89.79
1.18mm	327	15.11	25.32	74.68
600µ	600	27.73	53.05	46.95
300µ	619	28.60	81.65	18.35
150µ	376	17.38	99.03	0.97
75µ	21	0.97	100.00	0.00
Pan	0	0.00	100.00	
Total	2164			

Source: Fieldwork 2019

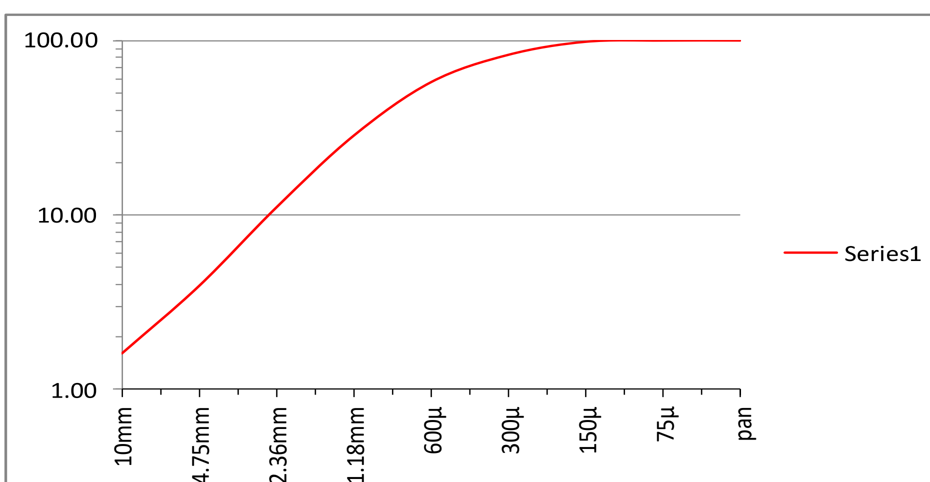

Figure 2: Logarithmic curve of Grain Size of Wuro-Gude Channel section

Source: Fieldwork, 2019

The coefficient of uniformity (C_u) and coefficient of curvature (C_c) using the following equations.

$C_u = \frac{D_{60}}{D_{10}}$ While $C_c = \frac{D_{30}{}^2}{(D_{60} \times D_{10})}$ (equation 15), revealed from the Grain Size Distribution Curve that:

% Pebbles= 11.07_ D_{10}= 2.435 mm
% Gravel = 28.52_ D_{30}= 1.108 mm
% Coarse Sand = 57.72_ D_{60}= 0.563 mm

$$C_u = \frac{0.563}{2.435} \qquad C_C = \frac{(1.108)^2}{(0.563 \times 2.435)}$$

$$= 0.146 \qquad = \frac{1.227664}{1.370905} \quad 0.896$$

Since the C_u = 0.146 is less than 4-6, C_c = 0.896 is below the range 1-3, then the sediment sizes are well graded (Sivakugan, 2000). This mean that the sediments in the reach are uniformly graded because the particles are of equivalent size and you can see that the curve is a steeper curve that represents uniformly graded or a uniform fully graded sediment.

The Nature of Suspended Particles of Yedzeram Channel at Wuro-Gude Sample Station

Table 3: The Samples of suspended load Characteristics of Yedzeram Channel Bank at Wuro-Gude

weight of cylinder (250cm³)	Weigh of Cylinder + water (cm³)	weight of water (cm³)	% of water filtered (cm³)	Volume of water Filtered	weight of filter paper	weight of Filter paper + sediment	mass of sediment load (g)	% weight of sediment
189.41	437.5	248.09	25% = 10	24.809	1.36	1.37	0.01	1.25
189.41	435.8	246.34	25% = 10	24.634	1.35	1.39	0.04	0.50
189.41	440.2	250.74	25% = 10	25.074	1.35	1.37	0.02	2.50
189.41	437.4	248.00	25% = 10	24.800	1.35	1.37	0.02	2.50
189.41	438.2	248.81	25% = 10	24.881	1.36	1.38	0.02	2.50

From table 3, total suspended load obtained was 1241.98cm^3, Percentage filtered was 124.198cm^3, and total Mass of suspended load retained by filter paper was 2.72855g. This indicates that in every 20 second, 1241.98cm^3 volume of water that pass through Wuro-Gude channel contain an approximate of 2.72855g of suspended load. In a minute, volume of 8.3565g can pass through the channel. In an hour the volume of 501.390g can pass through the channel. In a day, the volume of 12,033.360g can passes through the channel, in week the volume of 84,233.520g can pass through the channel, in a month the volume of 336,934.080g. In a year, the volume of 4,043,208.960g of suspended load can pass through River Yedzeram around Wuro-Gude. This result indicated that the volume of water that passes through Wuro-Gude is averagely turbid. It could not be used directly for washing clothes and bathing.

Conclusion

This study revealed that the major grain size particle characteristics of Yedzeram channel at Wuro-Gude are coarse sand, pebble and cobble. The suspended load sediments that occurred within the channel and the influence of the suspended load on the land use activities around the river Yedzaram at its middle course are immense.

Recommendations

1. Awareness on the turbid nature of water that pass through Yedzeram channel around Wuro-Gude should be done, so as to reduce the level of negative effects of contaminated water on human and properties.
2. There is a serious lack of hydrologic and morphometric records and data in the area. Therefore, much data gathering by appropriate agencies in areas like Geomorphology, Hydrology, Geology, Soil science and Soil engineering required from relevant related fields is required.
3. Dredging of the river channel should be done so as to remove the accumulated bed load particles that are presently cemented in the river. This will result to smooth flow of the water in the river.

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