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HYDRO-GEOMORPHIC IMPLICATIONS OF IN-STREAM SAND MINING ACTIVITY IN A TRIBUTARY CHANNEL OF ASA RIVER IN ILORIN, KWARA STATE, NIGERIA.

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ABSTRACT

Both hydrology and geomorphology of Atikeke stream, a sub drainage basin of Asa River in Ilorin has been impacted by in-stream sand mining activities. The uncontrolled sand excavation which began almost four years ago in the river channel is being largely carried out to meet civil construction needs induced by rapid economic growth and high urbanization rate in the city. The study observed that the estimated 10,125 tons of sand being yearly excavated from the study channel is seriously impacting negatively on the hydro-geomorphic environment of the catchment. Though sand mining activities in the study area have both economic and social benefits, the activity is observed to be a destructive development endeavor where physical environment including ecology suffer at the expense of economy.

KEYWORDS: Hydrology, Geomorphology, Morphology, Degradation, In-stream

INTRODUCTION

Sand mining is fast becoming an important activity in most cities in Nigeria. The activity which usually before, is carried out at the outskirt of towns can now be seen being undertaken immediately after each rainfall event along the road and inside both natural and artificial drainage channels within cities.

Though sand mining have economic and social benefit, it can also induce environmental problem. While economic benefit of sand mining can be seen in terms of employment and opportunity for wage earning, the social benefit comes inform of reduction in the rate of road accident resulting from sediment deposition along the road.

Despite the importance of sand mining in provision of raw materials for civil construction industry, the activity has accelerated environmental degradation, particularly in erosional rivers (Marcus, 1992; Collins, 1991; Kondolf and

Swanson, 1993).According to Rable, et al. (1994), the processes of prospecting, extracting, and transporting sand have great potential for disrupting the natural environment. Unscientific methods of sand mining have caused land degradation accompanied by subsidence, disturbance of water table leading to topographic disorder, severe ecological imbalance and damage to landuse patterns in around mining regions (Ghose, 1989). A study conducted by Savior (2012) revealed that illegal and excessive sand mining in the river bed of the Papagani catchment resulted in depletion of groundwater levels and environmental degradation in villages on the banks of the river. Other effects of in-stream sand excavation on the environment include reduction in quality of both surface and underground water, destruction of aquatic and riparian habitat through large changes in channel morphology and damages to bridges and other social infrastructures. Many hectares of fertile streamside land are lost annually to in-stream mining as well as valuable timber resources and wild life habitats in the riparian areas. Sand mining is thus essentially a destructive development activity where physical environment including ecology suffer at the expense of economy.

For many years back, sand, especially the ones derive from river channels have been highly sought for in civil construction activities because of its good quality. The product which can be easily mined from rivers requires no processing other than size grading. Today however, the demand for the product especially in urban centers has continued to rise due to the boom in construction industry induced by population increase and urbanization process. The proportion of people living in cities in all regions of the world is daily increasing (United Nations, 2008). According to Park (2001), by year 2030, nearly 5 billion people who represent 61% of the expected 8.1 billion world population will live in cities with accelerated impact on the environment. And because increase in world population and widespread urbanization is combining to make the interaction between man and nature very different from the situation a few decades back, there is need to examine the impact of in-stream sand mining on both the hydrology and geomorphology of a catchment as being currently done in this study. This is germane because, lack of adequate studies on this environmental sensitive issue will definitely create a major setback in wise decision making, both on the part of the people engage in mining process and authority concerned.

Ilorin, the capital city of Kwara State, Nigeria is the study area in this investigation (Fig1) while Atikeke river channel is the data collection point (Fig 2). Ilorin lies between latitude $8^0 24^1$ and $8^0 36^1$ north of the equator and between longitude $4^0 10^1$ and $4^0 36^1$ east of Greenwich Meridian. The city which has humid tropical climate experience wet season between March and October, when the Tropical Maritime Air mass is prevalent. Dry season in the city begins with the onset of Tropical Continental Air mass which is predominant between the months of November and February.

The mean annual rainfall for the city is 1200mm (Olaniran, 2002) and this exhibits double maxima pattern with peak periods in June and September. Temperature in Ilorin is uniformly high (25^0-28^0c) while evaporation values ranges between 3.1 and 7.8mm (Oyegun, 1983). The city is covered by ferruginous tropical soil (Areola, 1978) and is drained mainly by River Asa whose tributary (River Atikeke) is the case study in this investigation. River Atikeke is a first order stream and drains an area of 7.5 km^2. The mainstream length of the basin is 6.3km while the drainage density and percentage built-up of the basin are 0.93 and 65% respectively (Iroye, 2008).

MATERIALS AND METHODS

Data used in this study were sourced from both primary and secondary sources. The primary data sets were generated during the rainy season when sand mining activities was at its peak in the drainage channel (Plate1). Water and bed sediments were sampled at 1km equidistance position away from the river source. In all, a total of 6 samples each, of water and bed sediments were collected and analyzed for Total Suspended Solids (TSS) and sediment granulometry in University of Ilorin laboratories. Nature of river banks were examined for geomorphic effects at the upstream, midland and downstream segments while measurement of distance of river channel from adjacent structures were also taken at some points along the drainage channel. Sinuosity Index (SI) was computed from Ilorin topographical map sheet (1966), aerial photograph and satellite imagery obtained from Regional Centre for Training in Aerospace Survey (RECTAS), OAU Ile-Ife. These materials helped in examining changes in channel pattern.

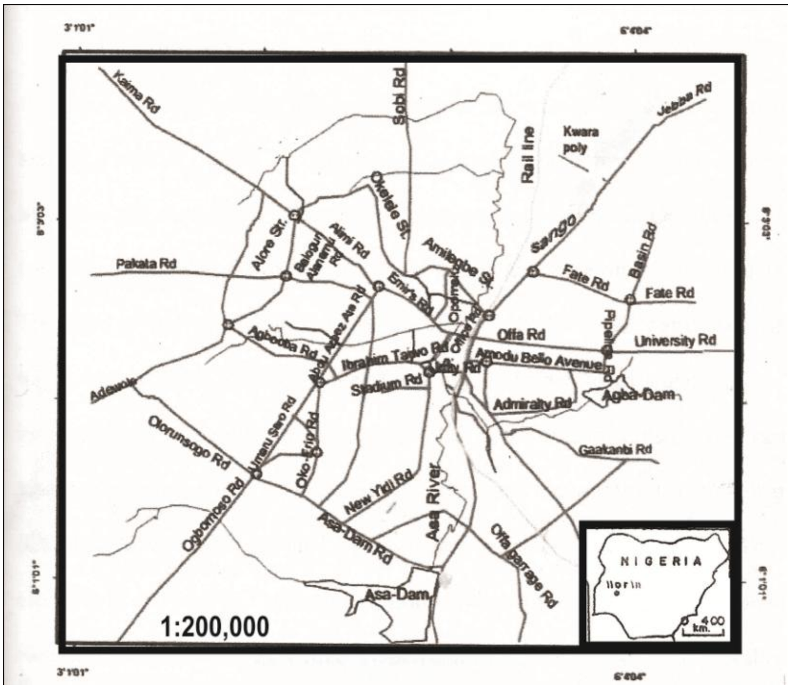

Figure 1. Ilorin Street Map
Source: Geog. Dept. University of Ilorin 1982.

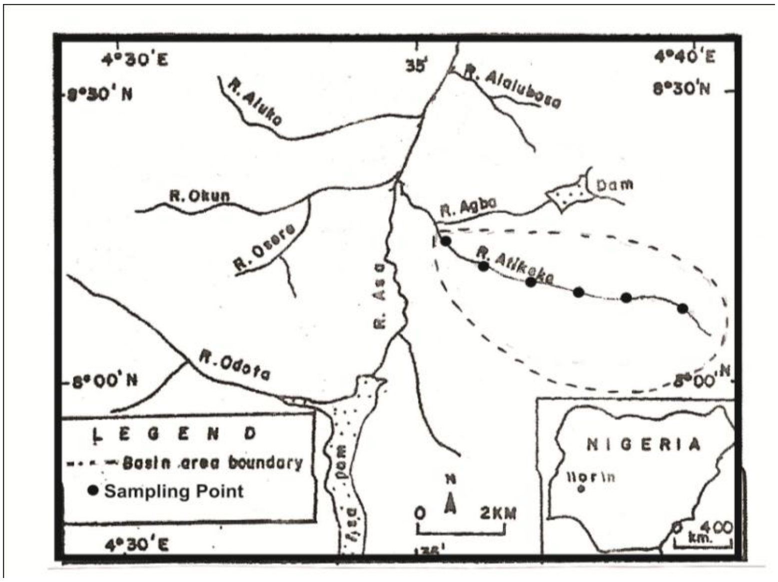

Figure 2. Drainage Map of Ilorin showing River Atikeke Catchment Area
Source: Oyegun (I986).

The sinuosity index was computed from Leopold, et. al. (1964) formula given as:

SI = CL/DL,

where
SI = Sinuosity Index
CL = Average Channel Length
DL = Average Direct Length

Oral interview was conducted on people involved in sand mining to solicit information on how long the business has been taking place in the area, the average volume of sand measured in tipper loads that is usually excavated after each rainfall event and observation noticed (both hydrological and geomorphological) since sand mining operation began in the area.

RESULTS AND DISCUSSIONS

Sand Mining Activities in the study Area

In-stream sand mining activity began in the study river almost four years ago. The activity which is yet to be regulated by authorities concerned is fast degrading the river channel and the surround areas. According to the miners, an average of twenty five tipper loads of sand is usually excavated from the stream after each rainfall event. This figure however varies depending on the duration and intensity of the rainfall.

Since the capacity of tipper used in transporting the excavated sand is 5 tons, then the average quantity of sand mined following each rainfall event from the studied stream thus amounts to 125 tons. And since Iroye (2008) earlier observation revealed that the study area records an average of 81 rainfall events in a year; this thus means that 10,125 tons of sand is annually excavated from the study stream. This is an enormous quantity going by the fact that the stream in question is a first order stream with a catchment area of 7.5 km^2. And because there is no regulation from the authorities concerned, in-channel sand mining activity is thus resulting in series of hydro-geomorphic effects both within and around the stream channel. Studies such as Femmer (2002), George (2013) and Manga *et al*., (2013) have however revealed that degree of degradation due to in-channel sand mining is dependent on a number of factors amongst which include degree of channel resistance to erosion, the scale or mining and nature of technology and sediment transport in the basin.

a

b

c

Plate 1: Sand Mining Activities in the Study Area
Source: Field Work, (2014)

Geomorphic Effects of In-stream Sand Mining in the Study Area

Extraction of sand from stream alters sediment budget creating the potential for channel instability and degradation. Table 1 present the data on spatial variation in channel width and sinuosity index of the study river.

Table 1. Spatial Variations in Channel Width and Sinuosity Index of the Study River

Distance From River Source (Km)	Channel Width (m)	Channel Segment	Sinuosity Index
1	2.7	Upstream	1.27
2	3.8		
3	4.5	Midland	1.64
4	12.8*		
5	6.4	Downstream	1.72
6	3.1		

* In-channel Mining Site
Source: Field Work (2014).

Though the channel width of the study stream generally increase downstream, the channel width at the mining site which falls at the midland segment of the river is very wide. The table shows that the mean channel width at the upstream segment is 3.5m while it is 4.8m at the downstream segment. Though the mean channel width at the midland segment is 8.6m, its width at the sand mining site is 12.8m; a value which is far greater than the average value for that segment. The in proportionate high channel width at the mining site may not be unconnected with stream bank erosion induced by mining activity which causes the banks of the stream at that point to become net source of river sediment. The channel pattern of the studied stream as shown by sinuosity index revealed a straight channel that is structurally controlled at the upstream segment. The midland and downstream segments however exhibits slight curvature.

Result of the interview conducted on the residents within the vicinity of the mining site revealed that the channel width at the mining site was not so wide before mining activities began in the area. According to them, the artificial bridge made of logs which hitherto were used in crossing the channel fell into the river a year ago when the river banks collapsed. Studies such as

Sandecki, 1989; Kondolf 1994; Femmer, 2002, Xian-Lin et al 2007 and Geeja, et al, 2013 have earlier revealed that in-channel sand mining activities usually results in geometrical changes in river channels. According to Lane (1955) and Leopold et al (1964), channel stability of a river is a function of equilibrium in water discharge, slope of the channel, quantity of sediment transport and sediment characteristics. A significant change in any of these variables such as reduction in sediment transport induced by in-channel sand mining will ultimately result in channel instability.

Observations made on the stream bed of the study river also revealed a sudden change in gradient at the immediate upstream position of the in-stream sand mining site. This change in gradient indicates the creation of a nick point; Kondolf (1998) has earlier observed that in-stream sand mining activity usually steepen channel slope locally and increase flow energy. Nick point development strongly suggests channel incision; a geomorphic process which usually takes place wherever rate of river bed extraction exceeds the natural rate of replenishment. Though incision may be caused by channelization (Simon, 1989) or increased peak flows resulting from landuse changes (Galay, 1983); its occurrence in this study is strongly linked to in channel sand mining activities.

River sand mining activities are already causing damages to both private and public properties in the study area as on Plate 2. While Plate 2a shows in-channel sand mining activity undermining the bridge that has just been recently constructed to replace the old one that collapsed two years ago; Plates 2b and 2c shows an exposed pipeline and private property abandoned due to channel encroachment resulting from in-stream sand mining activity in the study area.

a

b

c

Plate 2. Effects of In-stream Sand Mining Activities in the Study Area
Source: Field Work, (2014)

The degradation activates observed on the plates may have resulted from the “hungry” water effect of the study river as those pictures were taken at a distance of 75 meters downstream of the in-channel sand mining site. Hungry water effect takes place whenever the continuity of sediment transport within a river channel is interrupted by an action such as in-stream sand mining. The river flow downstream of such mining site become sediment starved (hungry water) and thus erodes channel bed and banks producing channel incision (down-cutting) as shown in the pictures. Williams and Wolman (1984) reports that the hungry water effect will continue in any river until equilibrium position is re-established between input and output of sediment at the mining site.

Particle size analysis (Table 2) revealed that gravel and sand contents in the channel of the studied river exhibits an inverse relationship.
While the gravel content decreases downstream, the sand content increases downstream. The upstream sand was also observed to be coarser than the downstream sand while gravel was observed to be totally absent in the downstream segment. Reason for this observation may not be unconnected with selective entrainment of medium to fine sand from the upstream segment by sand mining activity. Figure 2 depict the spatial variation in sand characteristics in the study channel

Table 2. Sand Characteristics in the Study Channel

Sampling Point	Distance from River Source (km)	% Pebble	% Granule	% Coarse Sand	% Medium Grained Sand	% Fine Sand
A	1	61.30	22.70	14.20	0.46	1.34
B	2	53.30	31.20	13.60	0.58	1.37
C	3	27.5	36.70	29.40	5.12	1.31
D	4	0.00	8.55	12.67	77.80	0.98
E	5	0.00	0.64	11.30	86.71	1.35
F	6	0.00	0.00	9.81	88.89	1.30

Source: Field Work (2014).

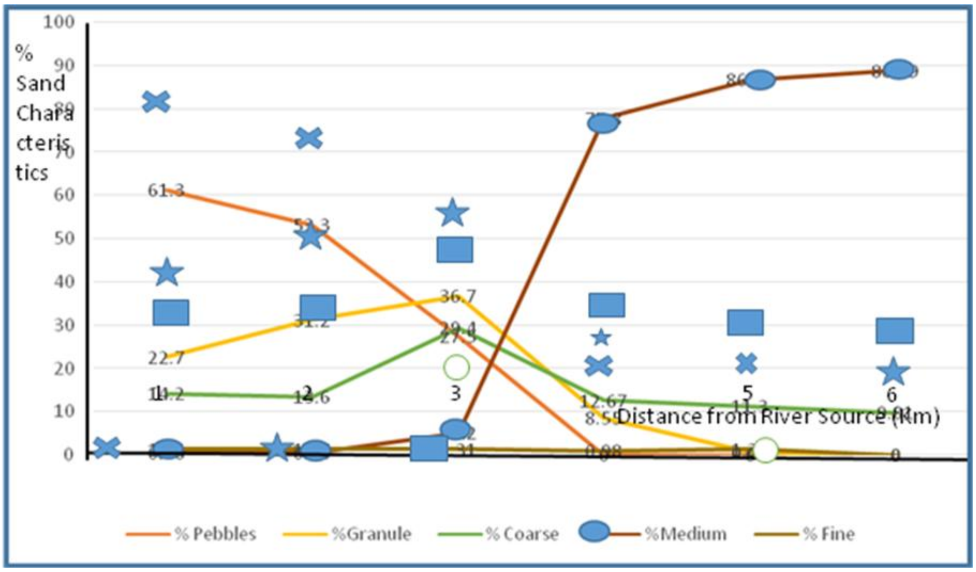

Figure 2: Spatial Variation in Sand Characteristics in the Study Area

Hydrological effects of in-stream sand mining in the study area.

Apart from the observed geomorphic effects of sand mining in the study area, hydrological processes, both within the stream channel and the riparian environment of the study stream are also being affected by in-stream mining activities. Laboratory analysis on Total Suspended Solids (TSS) indicates that in-stream mining activity is seriously impacting upon the river water quality. Table 3 shows that TSS in the study stream exhibit spatial variation. It ranges between 54.1 and 127.31 mg/l during sand mining operation. While the TSS values were relatively lower at both the upstream and downstream segments, the values were high at the midstream segment where sand mining activity is taking place.

Table 3. Spatial Variation in Total Suspended Solids in the Study Stream

Sampling Point	Distance from River Source (km)	TSS (mg/l)	River Segment
A	1	57.65	
B	2	57.61	Upstream
C	3	59.83	
D	4	127.31	Midland
E	5	95.73	
F	6	54.41	Downstream

Source: Field Work (2014).

The 127.31 mg/l at the mining site which falls at the midland segment was far greater than the mean value of 93.47 mg/l for that segment. Though the mean values of TSS substantially reduced from 93.47 mg/l at the midland segment to 75.1mg/1 at the downstream segment; the relatively low concentration at the downstream segment still pose a threat for people using the river downstream, most especially if such usage is for domestic purpose.

In–stream sand mining activity in the study river is also impacting negatively on groundwater resource of the riparian areas of the study stream. Observations made by residents living adjacent to the in-stream sand mining site revealed that depth to water have over the years been increasing in the area. Reason for this increase may not be unconnected with the lowering of river bed in the region caused by sand mining activities. The lowered of river bed increase depth to water at the mining site when compared with the surrounding catchment area; and because the groundwater table in the river catchment is now higher than the river water, storage within the catchment will start contributing water to the fallen stream bed, hence the increase in depth to water in the riparian area of the river. Figure 3 is a schematic diagram showing the effect of lowered river bed on ground water level of well close to river channel.

Another hydrological effect of in-stream sand mining activity observed in this study is soil contamination by oils dripping from trucks being used in transporting the extracted sand from the mining site. Presence of hydrocarbon such as this in the soil is highly undesirable and can result in pollution of both surface and ground water resource of the area.

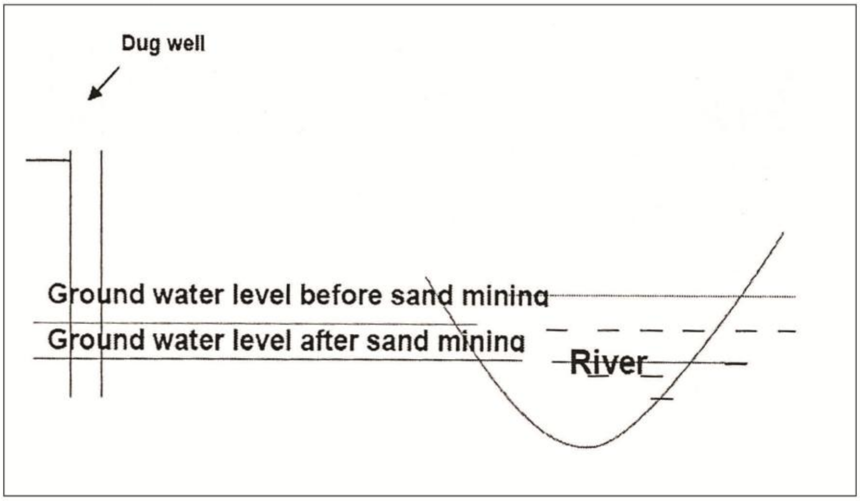

Figure 3. Schematic Diagram showing the effect of lowered river bed on groundwater Level in well close to river channel.
Source: Geeja *et al.,* (2013).

CONCLUSION

Though in–stream sand mining activity is of great importance in meeting the economic and social needs of a growing nation like Nigeria, the process of prospecting, extracting and transporting the material can induce serious environmental challenge if not well monitored. According to Kitotu and Rowan (1997), the activity can pose significant and potentially irreversible changes to hydraulic conditions and channel instability if the rate of its extraction exceeds the rate of replenishment. Based on the observation from this research, the study thus put forward to the authority concerned, the following recommendations towards achieving sustainable environment.

i. Demarcation of sand mining sites in appropriate areas,
ii. monitoring of the allocated mining sites to address environmental challenges that may arise,
iii. discouragement of mining activities through appropriate legislations in areas where it can portray danger to social infrastructural facilities such as pipeline and bridges; and,
iv. Avoidance of over mining activities which can affect depth to water in the riparian environment.

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