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THE INFLUENCE OF DREDGING ON SEDIMENT LOADS IN THE LOWER OFIN RIVER

Tumbulto, J. W. & Gyau-Boakye, P.
Water Research Institute (CSIR), P. O. Box M32, Accra

ABSTRACT

Alluvial gold mining has been done for well over a century in the Dunkwa area in the Ofin River, a tributary of river Pra. It had long been anticipated that dredging activities would contribute significantly to the total sediment transport within this zone. This study was therefore undertaken to find the extent of contribution to the total sediment transport in this area as a result of the dredging activities. Contrary to the expectation, however, the study found out that sediment transport in the area was rather low, the most probable reason being the construction of a series of dams downstream of an operations zone.

Keywords: Alluvial mining, dredging, sediment transport, Ofin River

1. INTRODUCTION

Dredging activities generally result in the dislodging of soil particles of various sizes. Some of these end up in suspension in the water and are carried along as suspended sediment. The rest may be deposited on the riverbed or transported by rolling, sliding or skipping along the riverbed or very close to it depending upon the velocity of flow in the river and the geometry of the riverbed. This component is referred to as bed load or bed material. It is however recognised that even in the absence of dredging activities in a river, this phenomenon does occur.

This study is aimed at establishing whether or not dredging activities have significantly changed the sediment characteristics of the Ofin River in the Dunkwa area where alluvial mining involving dredging in the riverbed has been going on for well over a century. More recently, heavy machinery has been introduced in the river. These dredges are able to excavate the riverbed down to several meters depending among others upon the existing water level, the arm length and the size of the dredge.

2. MATERIALS AND METHODS

2.1 Location of the study area

The study area is defined to extend from Kaniago located south of latitude 6° 22'N (see Fig. 1) on the Ofin River down to Twifo-Praso which is located downstream of the confluence of the Birim and the Ofin Rivers. There is no alluvial mining upstream of Kaniago town. A few metres downstream of this town is located D7, one of the active dredges. There is also no dredging downstream of the confluence of the Ofin and the Birim Rivers. The study area as defined above is accessible from Obuasi through Watreso-Datano road or through Cape Coast-Twifo Praso road.

2.2 Physiography

The catchment area of the Ofin basin, especially the southern half, within which Dunkwa is located, is generally hilly. The maximum elevations within this part of the basin reach 380 m above mean sea level. Because of the hilly nature of the catchment, response to rainfall is rather fast. More than once, the dredging operations in the Ofin River were threatened by the rapid variation in water level within the river since the dredge can operate effectively within a certain fixed range of water levels.

2.3 Climate

The Climate of the area around Dunkwa is the humid tropical type, which is characterised by warm rainy periods and relatively cooler dry seasons. Like most areas in West Africa, the climate is determined by the movement of the Inter-Tropical Convergence Zone (ITCZ), which oscillates annually about the equator.

The monsoon winds, which blow over the area from the South Atlantic Ocean, bring rainfall to the area between March and November with peaks in June and October. The North East Trade winds, locally referred to as the harmattan, are experienced within short periods from December to February. Rainfall is low during this period. During the monsoon period, the sky is cloudy and the weather is relatively cool with substantial rainfall. Annual rainfall within the Dunkwa-Obuasi area is between 1008.4 mm and 2133.6mm.

2.4 Selection of sediment sampling stations

Two stations both downstream of the dredging zone were chosen at Denkyira Boadoa on Ofin (24 km downstream of Dunkwa) and on Pra, downstream the confluence of the Birim and Ofin Rivers. As a control, the Jimi River, which discharges into the Ofin near Dunkwa was sampled at Kubi, about 3 kilometres before it enters the Ofin. With respect to sediment, the water appeared relatively clear.

2.5 Field work and laboratory analysis

A field visit was made to the site between 26/08/94 and 28/08/94. During this trip, flow measurements were carried out at the selected stations and water samples were taken for sediment concentration analysis. Also, bed load

samples were taken for particle size distribution analysis in the laboratory.

The samples collected in the field were analysed for sediment concentrations. The bed load samples were analysed for bed material graduation. The evaporation method was used in determining the concentration of the suspended sediments. The bed load samples were oven-dried and sieve analyses were carried out on each of the five samples in the laboratory.

3. RESULTS AND DISCUSSION

3.1 Concentration of Suspended Sediment

The concentrations of the suspended sediments are presented in Table 1. These concentrations were used to compute the suspended sediment discharges at the five stations within the Ofin River system. The relation, which was used to compute the sediment discharges, was of the form:

$$Q_s = K C_s Q_w \qquad (1)$$

as outlined by Tilrem (1979) where,

Q_s = suspended sediment discharge in tonnes/day,

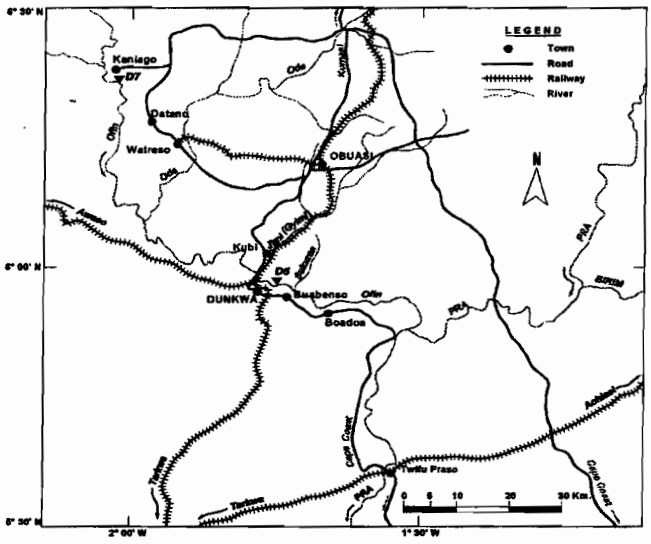
K=0.0864, a conversion factor, assuming a specific weight of 2.265 for sediment,

C_s= suspended sediment concentration in mg/l, and

Q_w = water discharge in m^3/s at the various sampling stations. The discharges, Q_w, were measured in the field using a current meter or read from a rating curve having read the gauge height in the field.

The locations of the various stations in relation to each other are shown on the map of the basin (Figure.1). Kaniago is upstream of the activity area. Buabenso is in the activity zone whereas Denkyira Boadoa and Twifo-Prasu are both downstream of the activity area. Jimi River is one of the tributaries to the Ofin, which is not influenced by the dredging activities and was considered as a second control.

Figure 1. Map of the Study Area.



3.2 Bed Material Graduation

The bed material sampled at the five stations was made up principally of sand and gravel. The distribution of the particle size class of the bed material is shown in Table 2. The general scale of particle sizes for sediments in millimetres is as follows:

Boulders	>256
Cobbles	256-63
Gravel	63-2
Sand	2.0-0.63
Silt	0.063-0.002
Clay	0.002-0.001

Table 1. Results of sediment analysis of the Ofin River within the study

Date	Station	River	Water Level (m)	Water Discharge m^3/S	Sediment Concentration mg/l	Sediment Transport Tonnes/days	Corrected Sediment Transport Tonnes/d
27/8/94	Kaniago	Ofin	-	0.2	44	0.80	0.90
28/8/94	Buabenso	Ofin	-	5.6	547	265	291
27/8/94	Kubi	*Jimi	-	1.88	112	18	20
28/8/94	Denkyira Boadoa	Ofin	-	66.2	249	1424	1566
28/8/94	Twifo-Praso	*Pra	1.37	80.373	52	361	397

Table 2. Results of Bed load Grading Analysis (Summary) in Percentage

Grading	Stations				
	Kaniago	Buabenso	Kubi	Denkyira Boadoa	Twifo-Prasu
	River Ofin	River Ofin	River Jimi	River Offin	River Pra
Gravel (2mm-60mm)	30.0	0.8	74.0	3.0	68.0
Sand (0.063-2mm)	68.2	99.0	25.5	93.5	31.5
Silt (0.002-0.063mm)	1.5	0.2	0.5	3.5	0.5
Clay (below 0.002mm)	0.3	0.0	0.0	0.0	0.0

The detailed results of the Bed Material graduation for the five stations are illustrated in Figure 2.

It is observed from Table 1 that the highest sediment transport is in the Denkyira Boadoa area, which is downstream of the activity zone. It is further noted that the highest suspended sediment concentration of 547 mg/l occurred at Buabenso near D5, an area that is within the activity zone. It was expected that the highest sediment transport could occur within this zone. However, the effects of the dams downstream of the activity zone have greatly reduced the flow and hence the rather low sediment transport in that zone. The lowest suspended sediment concentrations of the Ofin River within the study area were registered at Kaniago. This was expected since that station is upstream of the dredging zone. The Jimi River, which discharges into the Ofin River near Dunkwa and not influenced by dredging activities, also transports relatively low sediment volumes (Table 1).

A sediment-rating curve (a relationship between the suspended sediment discharge and river flow) for the Ofin River at Dunkwa exists. However, it was reported that a poor fit was obtained when the relationship was being developed. The poor fit was attributed partly to the non-equilibrium conditions created by the dredging activities upstream of the Dunkwa station (Akrasi & Amisigo, 1993).

Estimates of Riverbed slopes, mean flow width and velocity were available for the various sections, but these could not be used to estimate the bed load components of the total sediment load. This is because ideally, bed material samples representing the bed of the stream along with the channel slope and channel hydraulics for a range of discharges from low to high are needed for use in any of the bed load equations (ASCE, 1995; Ackers and White, 1973; Parker and Klingeman, 1982). The bed load percentage method was hence used to compute the bed load at the various stations (See Table 3).

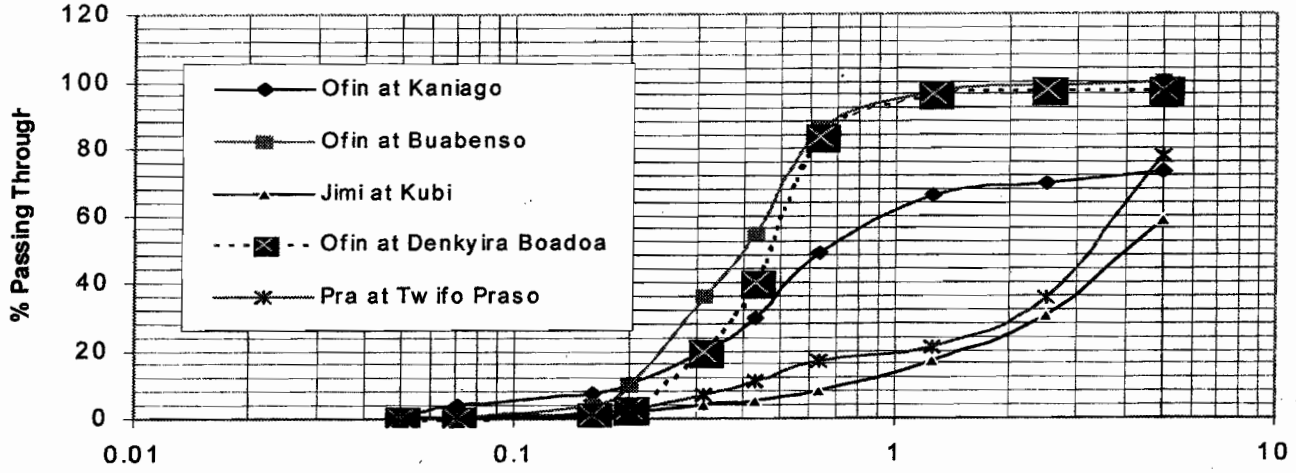


Figure 2. Grading Curves for Twifo Praso, Boadoa, Buabenso, Kubi and Kaniago

Table 3. Bed load Corrections (ICOLD, 1986)

Condition	Suspended Sediment (mg/l)	Stream bed material	Sieve analysis of suspended material	Percentage bed load in terms of suspended load
*1	<1000	Sand	20 to 50% sand	25 to 150
*2	<1000 to 7500	Sand	20 to 50% sand	10 to 35
3	>7500	Sand	20 to 50% sand	5
**4	Any concentration	Compacted clay, gravel, cobbles or boulders	Small amounts to 25% sand	5 to 15
5	Any concentration	Clay & Silt	No sand	<2

*Special sampling programme for Modified Einstein Computations required under these conditions.
**A bed load sampler such as the Helley-Smith bed load sampler may be used or computations made by use of two or more bed load equations when load material is gravel or cobble size (ICOLD, 1986).

Suspended sediment particle size distributions at Twifo Praso (Pra) and Dunkwa (on Ofin) and Buabenso station also on the Ofin have been carried out. The results are presented below:

	Clay (%)	Silt (%)	Sand (%)
Pra Twifo-Praso	64	35	1
Ofin Dunkwa	62	38	-
Ofin Buabenso	53	40	7

It was observed that the bed material is principally sand for Kaniago, Buabenso and Denkyira Boadoa whereas at Kubi on the Jimi River and Twifo-Praso on the Pra both have gravel beds with sand forming between a quarter and a third of the bed load material.

The streambed consisted of clay, gravel, cobbles or boulders and it was further observed from the suspended sediment particle size distribution that the material was principally clay and silt with little or no sand. A bed load correction factor of 10% (refer to Table 3, ICOLD, 1986) was therefore adopted in order to obtain the total sediment transport in the Ofin River system near Dunkwa. The resulting corrected sediment loads are shown in the last column of Table 1.

The suspended sediment concentrations and the sediment transport quantities within the study area are comparable with what pertains within other river basins in the country (see Table 4). However, they are higher than the background values within the alluvial mining area. The dredging activities have certainly increased the suspended sediment concentrations within the affected sections of the Ofin River but not significantly.

The construction of dams between Kaniago and Dunkwa to stabilize the river water levels have also greatly reduced the total sediment transport within this section of the river which is an advantage.

Table 4. Highest Recorded Suspended Sediment Concentration Between May 1991 and December 1992 at existing sampling stations

Stations	Sediment Concentration (mg/l)	Month of Sampling
Oda at Anwian Nkwanta	324.10	December
Ofin at Mfensi	127.10	June
Tano at Hwidiem	92.11	October
Birim at Bunso	62.0	March
Anum at Konongo	137.0	June
Oda at Ejisu	82.0	November
Pra at Dadieso	136.0	February
Densu at Densuso	189.30	June
Nakwa at Ochiso	183	December
Amissah at Mankessim	166	May
Birim at Oda	156	April
Ofin at Dunkwa	1195	February
Bonsa at Bonsaso	165	July
Tano at Jomoro	139	June
Ankobra at Prestea	140	April
Ankobra at Dominase	993	February
Pra at Assin Praso	107	November
Pra at Twifu-Praso	289	May

Source: (Akrasi & Amisigo, 1993)

4. CONCLUSIONS AND RECOMMENDATIONS

From the results of the study, it was concluded that the dredging activities have not significantly changed the sediment characteristics of the Ofin River near Dunkwa area. The construction of dams downstream of the operation/dredging zones may have contributed significantly to the rather low total sediment transport within the Ofin River near Dunkwa, contrary to expectation. It is further recommended that sediment sampling at the respective stations should be carried out on an annual basis in order to capture any changes in sediment concentrations due to the dredging operations.

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