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# THE SPATIAL DISTRIBUTION AND CHARACTERIZATION OF SEDIMENTS AND THE BOTTOM MORPHOLOGY OF THE HYDROELECTRIC LAKE IN AYAMÉ 2 (IVORY COAST)

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***Abstract***

*A sedimentological study was carried out at the lake of Ayamé, with the purpose of determining, by using granulometric and mineralogical characteristics, the origin, the transport process and the space distribution of sediments. In the lake of Ayamé one distinguishes in the downstream sector a prevalence of mud and fine sands. In the upstream sector sands are mainly middle to coarse in size. The muds are localized in the vicinities of the banks, while sands are found in the principal channel of the lake. The minerals found in the sediments are heavy minerals (amphibole, tourmaline, diopside and epidote) and light minerals (quartz and feldspaths). The morphoscopy of the quartzes revealed the prevalence of rounded and bright particles, representing a lake transport over a relatively long distance.*

***Keywords:*** *Dam; Lake; Grain size; Mineralogy; Morphology; Ayamé, Cote d'Ivoire*

## Introduction

The flow of sediments into watercourses reflects processes of erosion and transport of particles on the watershed [1]. In several countries, erosion, sediment transport in the drainage system of watersheds and their deposition in reservoirs of dams pose delicate problems to operators whose resolution is very expensive [2-4]. Thus, the existence of lakes or artificial dams, for example, can change the amount of sediments transported and subsequently estimate basins erosion rates [5]. Nevertheless, only a steady ratio between the deposition of sediments and their takeover by the river itself would imply that the determination of the solid flow is a direct measure of the erosion rate of its watershed. So, the knowledge of the quantity and the nature of the substances carried by the river is an asset both for the management of the watershed and for the coastal environment, because, although it is not well documented yet, the

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effects of the morphogenic transport of fine particles in suspension are not negligible in the bed of rivers [6]. In Ivory Coast, dams have been the subject of several studies dealing primarily with the physico-chemical and biological characteristics of water [7-9]. However, few studies have examined the morphology of the substances and the nature of the sediments that fill those reservoirs [10-14]. Nevertheless, those studies have shown that those dams represented major assets that support the development of the country and that they were threatened by siltation problems.The particles carried by currents of water accumulate in lakes and dams and may form barriers to their migration farther on, thereby reducing the storage capacity of reservoirs. Therefore, the prediction of these phenomena is essential so as to predict their intensity and to define the actions needed to be undertaken in order to reduce their harmful effects, because the study of the sediment volumes transported by the courts of water is particularly important for their management frame, or for the construction of hydraulic structures,such as reservoirs or dams [15, 16]. However, despite the dangers inherent in the filling of lakes over time, no sedimentological studies have been conducted on the hydroelectric dam Ayamé 2 [17]. As part of a good management of this water-holding and filling phenomena, which may involve the reduction of water storage capacity, we conducted the presentstudy , to evaluate the flow of sediments in the hydroelectric lake in Ayamé 2. This study aimed to evaluate the vulnerability of the hydroelectric dam Ayamé 2, for a better evaluation of its water storage capacity and of its hydroelectric potential.

## Location, geological and climatic framework

Bia is a river that starts in Ghana, north of Chemraso. Of the 290 km of its course, only 120 km are in Ivory Coast. The Bia Basin is a transboundary river basin with an area of about 1500 km². Bia gets one important tributary in Ghana, the Sui, from the left bank. Two other notable tributaries, Tamin, from the right bank and from the left bank, Tioma, flow into the dam of Ayamé 2 in Aboisso, specifically in the southeast of Ivory Coast. The hydroelectric exploitation of Bia has two waterfalls, an upstream fall at Ayamé I and a downstream fall in in Ayame II, comprising the lakes formed by the hydroelectric dams Ayamé I and II, the oldest dams in Ivory Coast , built in 1959 and 1965, respectively. The hydroelectric dam Ayamé II (between 3°9.540' west longitude and 3°4.942' north latitude) is a sluice dam, 4 km from Ayamé I (Fig. 1), the hydraulic characteristics depend on those of Ayamé I, with a much smaller area of 7 $km^2$. According to the work of Guillaumet (1971) and Girard et al. (1971), Bia flows entirely under dense forest with an average flow of 82 $m^3/s$ before flowing into the Aby lagoon [18]. The terrain of the Bia watershed is more or less degraded by erosion are printed between strips high surfaces oriented SW-NE. The relief is represented by a digital terrain model with gradients ranging from 1 to31% (Fig. 2).

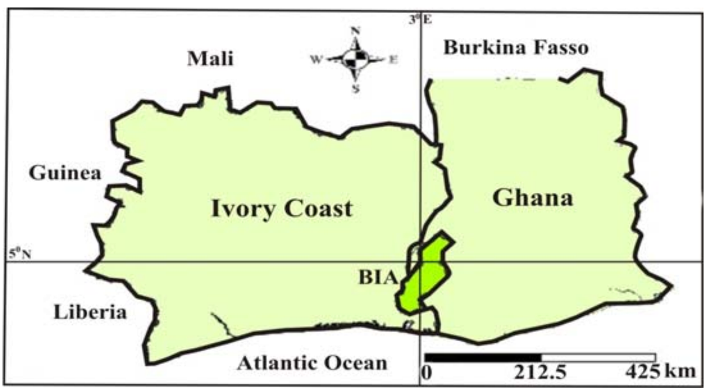


**Fig. 1.** Presentation of the study area

Bia has a transitional equatorial regime and that regime is characterized by the doubling of its annual flood, which is easily explained by the seasonal distribution of rainfall. The first period of high water predominates and occurs in June-July and the second in October-November. A period of low water is observed in August-September and another, even lower, extends from December to March [19].

The vegetation of the Bia Basin has undergone significant changes due to the intensification of agriculture and to high population pressure [20]. This vegetation belongs to the Guinean area, with a rain sector characterized by evergreen rain forests, that is to say, the defoliation never affects the whole. The type of geological formations which outcrop in watersheds affects the distribution of surface runoff. To the north of the basin consists mainly of shales while in the south it consists of granitic intrusions and volcanic rocks within shale formations. This basin is formed of impermeable rock, which often has a high drainage density that encourages runoff of surface waters at the expense of infiltration.

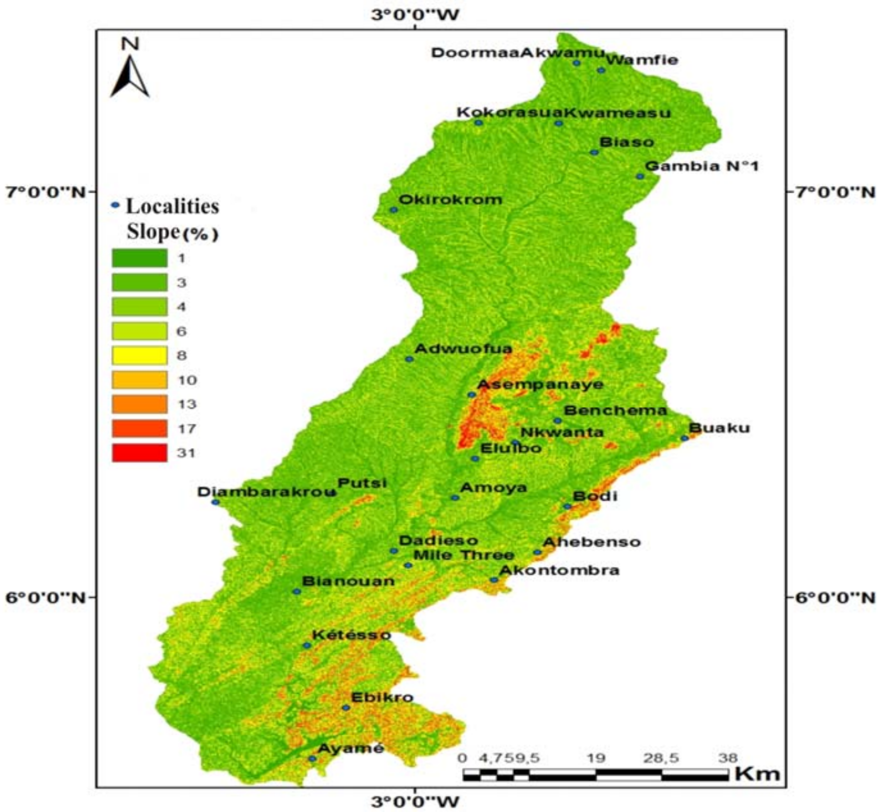


**Fig. 2.** Map of the slopes of the Bia Basin

## Methods

To determine the particle size characteristics of the sand in the lake, 48 sediment samples were collected by using a Van Veen grab sampler in all four hydrological cycles (Fig. 3). Sediments were analyzed according to the technique described by Saaidi (1991). Organic materials and shell debris were eliminated by using hydrogen peroxide 30% and 50% hydrochloric acid. After removal of the fraction smaller than 63 microns, each sand sample underwent a dry particle size analysis on a column of 16 mesh screens (AFNOR standard) [21-

23]. The sands of the lake were characterized by their average grain size (Mz), their skewness (Sk) and classification index (So), determined by using Folk's method (1974). Sedimentological maps and positioning maps were produced by using the ArcView 3.3 and SURFER 8.2 software. [3,4, 24-30].

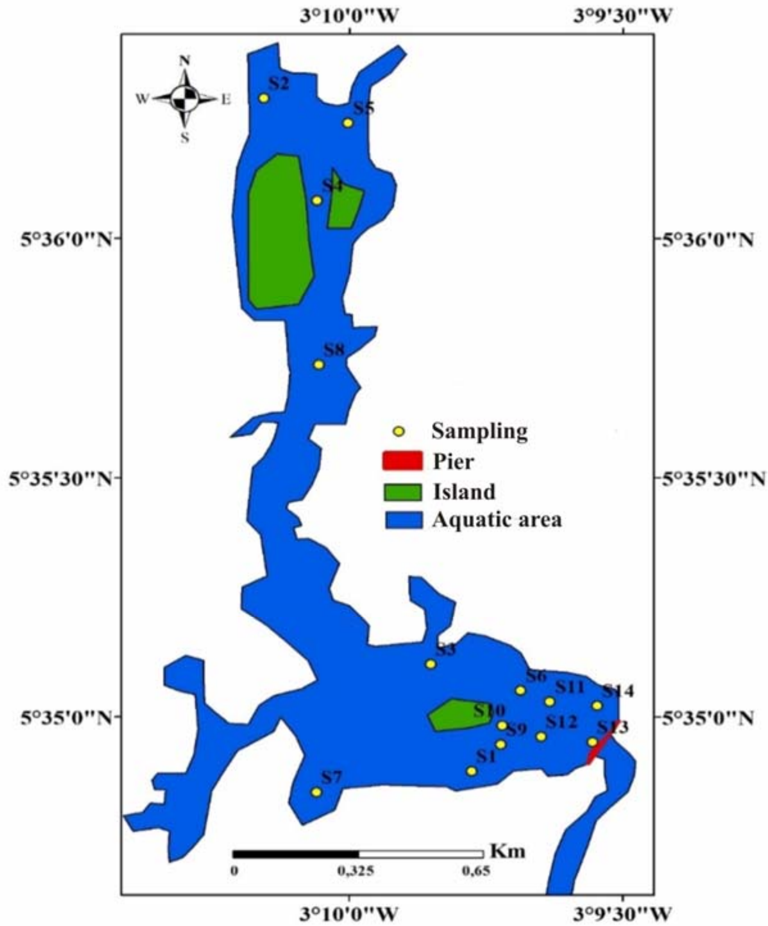

**Fig. 3.** Sediment sampling stations in Lake Ayame 2

To determine the depositional environment we used diagrams as Friedman (1967) and Moiola and Weiser (1968) [31, 32]. It was similar to the river environment, the type of environment and dune beach, or river type of environment. Finally, to determine the mode of transport of sand in the lake, the Visher (1969) test was applied to all of the sediments [33].

## Results

### *Description and mapping of shallow sedimentary facies*

The particle size of sand contained in the sediments reveal that the grains are very fine to coarse (Sample 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10) (Table 1). The color is yellowish-brown sands of variable shades. Some samples contained plants and sediments of shell fragments. The vases vary in color and are located southeast of the lake (Sample 11, 12, 13 and 14). Fluid vases are blackish and very rich in organic matter. Mud cream has a grayish color and is rich in organic matter.

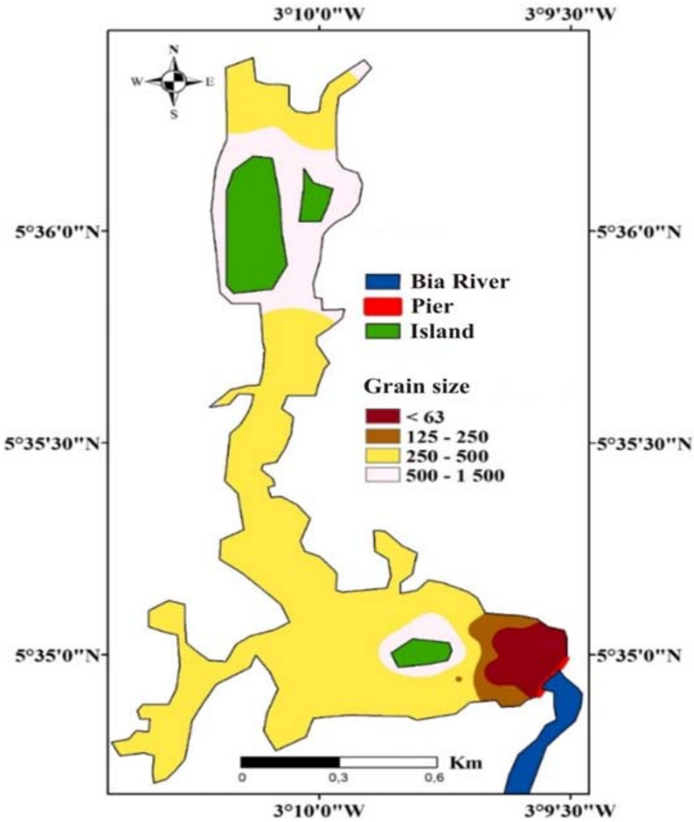


**Fig. 4.** Spatial distribution of sediments in Lake Ayame 2 (µm)

**Table 1**. Particle size analysis of lake surface sediments reveals two lithological facies: sands and vases.

| No | Positions | | Sedimentary facies | Mz | Ecart- | Sk | M |
|---|---|---|---|---|---|---|---|
| | Longitude | Latitude | | (µm) | type | | |
| 1 | 481953.03 | 616940.34 | Medium sands, highly skewed toward the ends, moderately classified | 323.33 | 0.87 | 0.77 | 250 |
| 2 | 481085.71 | 617066.47 | Sables means, highly asymmetric to the purposes, poorly sorted | 420.00 | 1.02 | 0.38 | 250 |
| 3 | 481231.59 | 617590.45 | Medium sands, highly skewed toward the ends, moderately classified | 416.67 | 0.95 | 0.52 | 250 |
| 4 | 481431.54 | 619137.77 | Coarse sand, unbalanced towards the coarse, poorly sorted | 1340.00 | 1.30 | -0.16 | 2000 |
| 5 | 481536.66 | 619436.00 | Medium sands, highly skewed toward the ends, moderately classified | 373.33 | 0.85 | 0.62 | 250 |
| 6 | 481657.20 | 617085.91 | Fine sands, highly skewed towards coarse, very well classified | 205.00 | 0.29 | -0.84 | 160 |
| 7 | 481429.73 | 616859.47 | Medium sands, highly skewed toward the ends, moderately classified | 430.00 | 0.77 | 0.96 | 250 |
| 8 | 481356.72 | 618115.87 | Sables means, almost symmetrical, moderately classified | 436.67 | 0.91 | -0.04 | 250 |
| 9 | 482136.26 | 617209.95 | Fine sands, highly skewed toward the ends, moderately classified | 243.33 | 0.76 | 0.62 | 125 |
| 10 | 482322.45 | 617085.04 | Coarse sand, unbalanced towards the coarse, poorly sorted | 1366.67 | 1.44 | -1.05 | 5000 |
| 11 | 481844.82 | 617273.87 | Vases blackish fluid; rich in organic matter | < 63 | (-) | (-) | (-) |
| 12 | 482090.56 | 617061.90 | Greenish fluid mud; presence of plant debris and shellfish | < 63 | (-) | (-) | (-) |
| 13 | 481653.13 | 617097.65 | Gray sandy mud of black olive to olive moderately classified misfiled | <63 | (-) | (-) | (-) |
| 14 | 482377.85 | 617192.6 | Vases blackish fluid; rich in organic matter | <63 | (-) | (-) | (-) |

Ech. Sample; (-) Unidentified parameters Mz: average particle size; Sk: skewness; So: asymmetry of sand grains; M: fashion

***Spatial distribution of content size fractions***

Spatially, sediment distribution is uneven in the lake (Fig. 4). The medium to coarse sands are found in the islands. The medium sands are in the vicinities of the banks, fine sands and vases in the vicinities of the dam and sometimes near the dam, around islands. The average grain size of the sand is between 205.00 microns and 1366.67 microns. The standard deviation is between 0.29 and 1.44 with an average of 0.85. This indicates that the sands of the lake are classified as moderately misclassified. The asymmetry indices (skewness) extend from 0.84 to 0.96 indicating a strong asymmetry to small sizes.

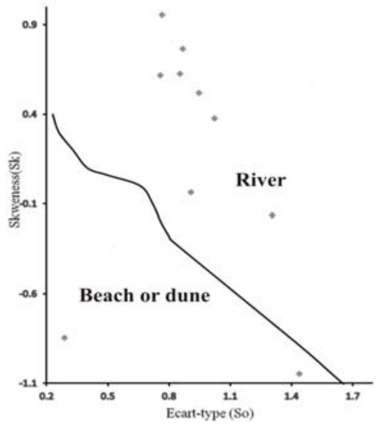


**Fig. 5.** Diagram Visher (1969) indicating the sediment transport mode

***Sediment transport mode***

The gradation of the sands in lake Ayamé 2 has several paces (Fig. 5). The application of the Visher test (1969) to the lake sediments indicates that the sands are mainly transported by saltation (about 75%). The bed load transport coming into the background represents a relatively small proportion (about 15%) and so does the transport suspension which represents only about 10%.

***Sedimentary deposit of Environment***

The diagrams of Friedman (1967) and Moiola and Weiser (1968) applied to the sands in lake Ayame 2 reveal two (2) depositional environments. It was similar to the river environment. In this component, the dispersion of the sand grains is mainly in the fluvial domain (Fig. 6). The proportion is around 80% in the type river domain. Then there is the type of river environment. In this graph all sediments are scattered in the river type field. No points will be found in the beach or dune-like domain (Fig. 7).

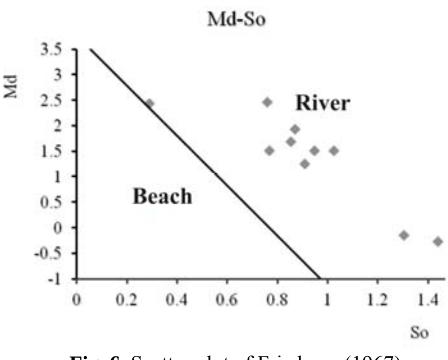


**Fig. 6.** Scatter plot of Friedman (1967)

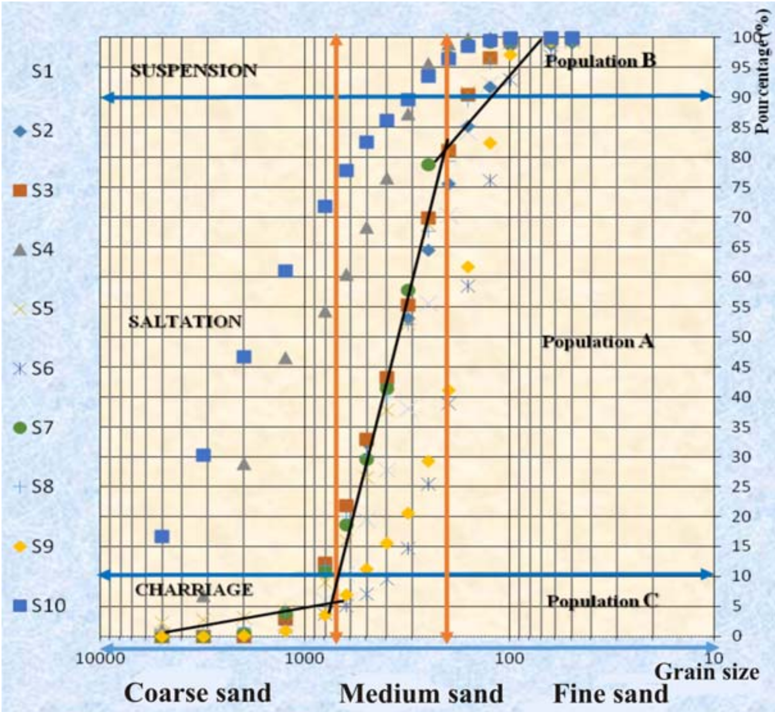


**Fig. 7.** Scatter plot of Moiola and Weiser (1968) between billion-So (μm)

***Morphometry of quartz***

The average indices of asymmetry of the quartz grains of the sands in lake Ayamé 2 are between 0.75 and 0.95, with an average of 0.68. Flattening ratios are between 1.01 and 3.08. The overall average is 1.39. However, we noticed that the flattening indices are close to a (Site 2, 3, 4, 8, 9 and 13) and highest in all the indices of asymmetries (Table 2). The indices indicate that the particle size is related to the shape of the grains. According to N'Guessan et al., 2008, when the sediment grain size is growing, quartz minerals have an almost spherical shape, because the indices of asymmetry and kurtosis, respectively, approach the value of 1(un) [34].

**Table 2.** Description of the Quartz morphometry in Lake Ayamé 2

| Site | Longitude | Latitude | Flattening Index | Index asymmetry |
|---|---|---|---|---|
| 1 | 481953.03 | 616940.34 | 3.08 | 0.95 |
| 2 | 481085.71 | 617066.47 | 1.05 | 0.85 |
| 3 | 481231.59 | 617590.45 | 1.15 | 0.75 |
| 4 | 481431.54 | 619137.77 | 1.25 | 0.86 |
| 5 | 481536.66 | 619436.00 | 2.16 | 0.79 |
| 6 | 481657.20 | 617085.91 | 2.39 | 0.94 |
| 7 | 481429.73 | 616859.47 | 2.25 | 0.86 |
| 8 | 481356.72 | 618115.87 | 1.34 | 0.64 |
| 9 | 482136.26 | 617209.95 | 1.00 | 0.78 |
| 10 | 482322.45 | 617085.04 | 3.37 | 0.79 |
| 11 | 481844.82 | 617273.87 | 1.04 | 0.84 |
| 12 | 482090.56 | 617061.90 | 3.02 | 0.83 |
| 13 | 481653.13 | 617097.65 | 1.01 | 0.77 |
| 14 | 482377.85 | 617192.6 | 2.26 | 0.79 |
| Average | | | 1.88 | 0.81 |
| Maximum | | | 3.08 | 0.95 |
| Minimum | | | 1.01 | 0.75 |

***Mineralogy***

Mineralogical analysis of the samples of lake sands identified a mineralogical spectrum characterized by a set of heavy and light minerals (Fig. 8). Heavy minerals found in the sand fraction are mainly garnet nesosilicates (3%). There are also inosilicates, represented by amphibole (2%) and pyroxene (5%). The cyclosilicate is represented by the yellow tourmaline (3%) and the sorosilicate is represented by epidote (2%). From the light minerals we found tectosilicates, represented by quartz (55%) and feldspar (18%). We also found phyllosilicates represented by mica (12%).

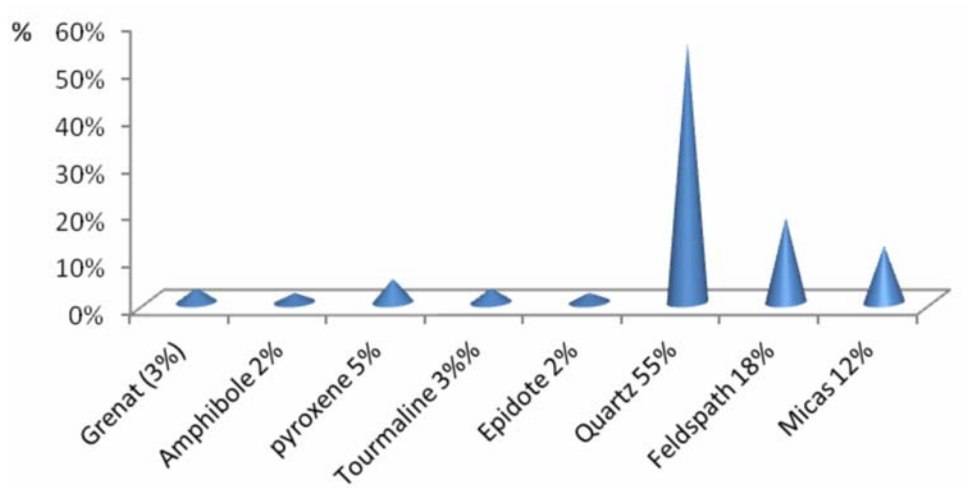


**Fig. 8.** Procession of mineralogical sediments of the estuary of the Comoé river

## Discussion

Overall, the results we recorded in Lake Ayame 2 revealed that the sediment grain size presented a homogenous distribution and were mainly medium.. Unlike the study of Meledje et al (2014) who found a heterogeneous distribution of sediments in Lake Ayame 1 and that of Adopo et al. (2014a,b) conducted in the estuary of the Comoé river [24, 25, 35]. This can be explained by insufficient sampling over the entire lake. Indeed medium sands are located in the vicinity of the banks, the coarse sands in the vicinity of the islands, and we encountered fine sands and vessels in the vicinity of the dike. The presence of fine sands may be explained by the fact that the mode of deposition of sediments in this area is dominated by settling. The vases formed due to the decomposition of aquatic plants and vegetation, submerged by rising waters, as indicated by the dead wood that was observed in the lake [36].

Indeed, Lake Ayame, like the other lakes in Ivory Coast was formed without deforestation before impoundment [20]. According to our results, the sediment sources are numerous and according to Saadi's (1991) lithological point of view, the united frequency curves and the bimodal, respectively, reflect the existence of two particle sizes and two sources in lake Ayamé 2, which is in agreement with the Sk-Md Moiola and Weiser diagram (1968), in which the sediments of Lake Ayame 2 would come from inland and coastal dunes, with a dominant mode of transport which is saltation in a fluvial depositional environment [37]. The procession of mineralogical sediments is characterized by heavy minerals (amphibole, tourmaline, pyroxene , mica and epidote) and light minerals (quartz and feldspar). Quartz is the most abundant mineral (55%). These minerals are as those found by Broche et al. (1977) in the region of Taabo and the upper Bandama watershed [38-43]. Yagé et al. (1996) found similar proportions in this lake [13].

## Conclusion

This study was conducted in order to evaluate the flow of sediments in Lake Ayame 2, in the area of Aboisso, in the southeast of Abidjan. Our intent was to characterize the sediments and their spatial distribution in Lake Ayame 2. The particle size analyes of the sediments show that they consist of vases, fine sand, medium sand and coarse sand. The sands present in the sediments of Lake Ayame are mainly means purposes and are misclassified. Their distribution is not uniform in the lake. Vases and fine sands were mainly found in the deep areas, near the dam and in areas heavily occupied by invasive aquatic plants. In contrast, medium sand banks meet the neighborhoods, while coarse sands are located in the vicinities of the islands. The findings of this study show that the facies of Lake Ayamé 2feature a silting with a very important contribution of particulate flows that may result, in the long run, in a filling of the reservoir of Lake Ayame 2.

## References

[1] O.B. Yapo, *Evaluation de l'Etat Trophique du Lac de Buyo (Côte d'Ivoire)*, **Thèse de Doctorat Unique**, Université d'Abobo-Adjamé, Côte d'Ivoire, 2002.

[2] C. Galy-Lacaux, R. Delmas, G. Kouadio, S. Richard, P. Gosse, *Long-term greenhouse gas emissions from hydroelectric reservoirs in tropical forest regions,* **Glob Biogeochemical Cycles, 13**(2), 1999, pp. 503-517.

[3] A. Mihu-Pintilie, G. Romanescu, C. Stoleriu, *The seasonal changes of the temperature, pH and dissolved oxygen in the Cuejdel Lake, Romania*, **Carpathian Journal of Earth and Environmental Sciences, 9**(2), 2014, pp. 113-123.

[4] S. Wu, A. Wiessner, M. Braeckevelt, U. Kappekmeyer, R. Ding, J. Müller, P. Kuschk, *Influence of nitrate load on sulfur transformations in the rhizosphere of Juncus effusus in laboratory-scale constructed wetlands treating artificial domestic wasewater*, **Environmental Engineering and Management Journal, 12**(3), 2013, pp. 565-573.

[5] N. Filizola, *Transfert Sédimentaire Actuel par les Fleuves Amazoniens*, **Thèse de Doctorat**, Université de Toulouse III, U.F.R. Sciences de la Vie et de la Terre, Toulouse, 2003.

[6] A.V. Wognin, S. Monde, K. Affian, A. Coulibaly, K. Aka, *Modèle de circulation des eaux dans l'estuaire du fleuve Bandama en Côte d'Ivoire*, **Sud Sciences & Technologies, 15**, 2007, pp. 5-12.

[7] N.P. Manizan, A. Ouattara, G. Gourene, M. Dosso, *Influence des caractéristiques physico-chimiques sur la distribution spatio-temporelle des densités bactériennes dans le système fluvio-lacustre de la Bia, sud-est de la Côte d'Ivoire*, **Revue Ivoirienne des Sciences et Technologie, 15**, 2010, pp. 201–210.

[8] A. Ouattara, *Photosynthetic activity of phytoplankton in the hydroelectric dam Ayamé I (Ivory Coast)*, **African Agronomy, 19**(1), 2007, pp. 63-70.

[9] P. Assemien, J. Filleron, L. Martin, J.P. Tastet, *The quaternary of the littoral zone of Côte d'Ivoire*, **Bulletin de Liaison de l'Association Sénégalaise pour l'Etude du Quaternaire de l'Ouest Africain, Dakar, 25**, 1970, pp. 5-78.

[10] T. Felföldi, S. Ramganesh, B. Somogyi, G. Krett, L. Jurecska, A. Szabó, L. Vörös, K. Márialigeti, I. Máthé, *Winter planktonic microbial communities in highland aquatic habitats*, **Geomicrobiology Journal, 33**(6), 2015, pp. 494-504.

[11] K.L. Kouassi, *Hydrologie, Transport Solide et Modélisation de la Sédimentation dans les Lacs des Barrages Hydroélectriques de Côte d'Ivoire: Cas du Lac de Taabo*, **Thèse de Doctorat**, Université d'Abobo-Adjamé, 2007.

[12] K.L. Kouassi, A.V. Wognin, T. Gnagne, Y.A. N'go, J-R. Courivaud, P. Kassy, M. Deme, K. Aka, *Caractérisation des sables et morphologie du fond du lac du barrage hydroélectrique de Taabo (Côte d'Ivoire)*, **Science et Nature, 4**(1), 2007, pp. 93-103.

[13] P. Yagé, Z.B. Digbehi, C.B. Sombo, K. Aka, *Essai de caractérisation sédimentologique et minéralogique et origine des sables aux embouchures des fleuves Sassandra et Bandama (Sud-Ouest de la Côte d'Ivoire)*, **Journées de l'hydrotechnique, 24**, 1996, pp. 363-374.

[14] A. N'go, *Etude de l'Érosion des Sols de la Région de Buyo: Analyse des Facteurs et Essai d'Évaluation des Risques par la Télédétection et les Systèmes d'Information Géographique*, **Thèse de 3ème Cycle**, Université d'Abobo-Adjamé, Côte d'Ivoire, 2000.

[15] T. Okacha, M. Abdelkader, A.T. Med, *Mise en place d'un système d'information géographique pour le suivi et la quantification de l'érosion hydrique: application au basin versant de l'Isser (Tlemcen)*, **Sécheresse, 13**, 2002, pp. 175-179.

[16] M. Bessenasse, A. Kettab, A. Paquier, G. Galeas, P. Ramez, *Simulation numérique de la sédimentation dans les retenues de barrages: cas de la retenue de Zardezas, Algérie*, **Revue des sciences de l'eau/Journal of Water Science, 16**(1), 2003, pp. 103-122.

[17] S.O. Ryding, W. Rast, **Le Contrôle de l'Eutrophisation des Lacs et Réservoirs**, , Masson, Paris, 1994.

[18] G. Girard, J. Sircoulon, P. Tourcheboueuf, *Overview on hydraulic systems. The natural environment of the Ivory Coast*, **Memoires ORSTOM, 50**, 1971, pp. 109-155.

[19] K. Aka, *La Sédimentation Quaternaire sur la Marge de Côte d'Ivoire: Essai de Modélisation*, **Thèse de Doctorat d`Etat ès Sciences Naturelles**, Universite Abidjan (Côte d'Ivoire), 1991.

[20] K.S. Konan, K.L. Kouassi, K.F. Konan, K.I. Kouame, K. Aka, D. Gnakri, *Evaluation des charges solides et caractérisation hydrochimique des eaux du lac du barrage hydroélectrique d'Ayamé 1 (Côte d'Ivoire)*, **Bulletin de l'Institut Scientifique, Rabat, Section Sciences de la Terre, 35**, 2013, pp. 17–25.

[21] Afnor (Association Française de Normalisation), **Qualité de l'au. 6ème Édition. Analyses Organoleptiques, Mesures Physicochimiques, Paramètres Globaux, Composés Organiques**, Tome 2, Paris, 1996.

[22] J.P. Bricquet, G. Mahé, F. Bamba, M. Diara, A. Mahieux, T. Des Tureaux, D. Orange, C. Picouetn, J.C. Olivry, *Erosion et transport particulaire par le Niger: du bassin supérieur à l'exutoire du delta inférieur (bilan de cinq années d'observation)*, **International Association of Hydrological Sciences, 246**, 1997, pp. 335-346.

[23] A. Bouanani, *Hydrologie, Transport Solide et Modélisation: Etude de Quelques Sous Bassins de la Tafna (NW –Algérie)*, **Thèse de doctorat d'Etat**, Université de Abou Bekr Belkaid Tlemcen, 2004.

[24] K.L. Adopo, G. Romanescu, A.I. N'Guessan, C. Stoleriu, *Relations between man and nature and environmental dynamics at the mouth of the Komoé river, Grand-Bassam*

*(Ivory Coast)*, **Carpathian Journal of Earth and Environmental Sciences, 9**(4), 2014, pp. 137-148.

[25] K.L. Adopo, A.C. Akobe, E.M. Amani, S. Monde, K. Aka, *Analyse sédimentologique et paléoenvironnements des sédiments superficiels de l'estuaire du fleuve Comoé (Grand-Bassam, Côte d'Ivoire)*, **Afrique Science, 10**(4), 2014, pp. 46-157.

[26] G. Romanescu, **Complexul Lagunar Razim-Sinoie. Studiu Morfohidrografic**, Ed. Universitatii „Alexandru Ioan Cuza", Iasi, 2006.

[27] G. Romanescu, *Alluvial Transport Processes and the Impact of Anthropogenic Intervention on the Romanian Littoral of the Danube Delta*, **Ocean andCoastal Management, 73**, 2013, pp. 31-43.

[28] G. Romanescu, O. Bounegru, C. Stoleriu, A. Mihu-Pintilie, C. Nicu, A. Enea, O. Stan, *The ancient legendary island of PEUCE - myth or reality*? **Journal of Archaeological Science, 53**, 2015, pp. 521-535.

[29] G. Romanescu, C. Stoleriu, *Seasonal Variation of Temperature, pH and Dissolved Oxygen Concentration in Lake Rosu, Romania*, **CLEAN – Soil, Air, Water, 42**(3), 2014, pp. 236-242.

[30] C.C. Stoleriu, G. Romanescu, A.M. Romanescu, A. Mihu-Pintilie, *Morpho-bathymetrical conditions and the silting rate in Stanca-Costesti reservoir (Romania)*, **Wulfenia, 22**(2), 2015, pp. 451-470.

[31] G. Friedman, *Dynamic processes and statistical parameters for size frequency distribution Compared of beach and river sands*, **Journal of Sedimentary Petrology, 37**, 1967, pp. 327-354.

[32] R.J. Moiola, D. Weiser, *Textural parameters: an evaluation*, **Journal of Sedimentary Research, 38**(1), 1968, pp. 45-53.

[33] G.S. Visher, *Grain size distributions and depositional processes*, **Journal of Sedimentary Petrology, 39**(3), 1969, pp. 1074- 1106.

[34] Y.A. N'Guessan, S. Monde, K. Aka, *Sedimentological Analysis and Paléoenvironement of the Surface Sediments of the Adjin and Potou lagoons*, **European Journal of Scientific Research, 19**(2), 2008, pp. 391-404.

[35] N.H. Meledje, K.L. Kouassi, Y.A. N'go, I. Savane, *Caractérisation des apports sédimentaires et morphologie du lac du barrage hydroélectrique d'Ayame 1 (Sud-Est Côte d'Ivoire)*, **International Journal of Biological and Chemical Sciences, 8**(3), 2014, pp. 1290-1307.

[36] R.L. Folk, W.C. Ward, *Brazors river bors, a study in significance of grain size parameters*, **Journal of Sedimentary Petrology, 27**(22), 1957, pp.3-26.

[37] E. Saaidi, **Traité de Sédimentologie. Pétrographie, Environnements Sédimentaires**, Edition Ellipses, Casablanca, 1991.

[38] J. Broche, R. Cassanova, G. Loup, **Atlas des Minéraux en Grain. Identification par Photographies en Couleurs**, Société pour le développement minier de la Côte d'Ivoire, 1977.

[39] E. Sevianu, A.N. Stermin, C. Malos, K. Reti, D. Munteanu, A. David, *GIS modeling for the ecological restoration of a nature reserve: Legii lake and valley (NW Romania) - A case study*, **Carpathian Journal of Earth and Environmental Sciences, 10**(4), 2015, pp. 173-180.

[40] D. Wrzesiński, A. Choiński, M. Ptak, R. Skowron, *Effect of the North Atlantic Oscillation on the Pattern of Lake Ice Phenology in Poland*, **Acta Geophysica, 63**(6), 2015, pp. 1664-1684.

[41] O. Pintilie, C. Andries, A. Cosma, M. Zaharia, G. Drochioiu, V. Vasilache, I. Sandu, *The Influence of Dinitrophenolic Pesticides on the Viability of Plants*, **Revista de Chimie 66**(9), 2015, pp. 1321-1326.

[42] D. Komínková, J. Nábělková, T. Vitvar, *Effects of combined sewer overflows and Storm water drains on metal bioavailability in small urban streams (Prague metropolitan area, Czech Republic)*, **Journal of Soils and Sediments, 16**(5), 2015, pp. 1569-1583.

[43] D. Banaduc, S. Rey, T. Trichkova, M. Lenhardt, A. Curtean-Banaduc, The Lower Danube River–Danube Delta–North West Black Sea: A pivotal area of major interest for the past, present and future of its fish fauna — A short review, **Science of the Total Environment, 545**, 2016, pp. 137-151.

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