

Granulometric analysis at Lampulo Fishing Port (LFP) substrate, Banda Aceh, Indonesia

S Purnawan^{1*}, I Setiawan¹, H A Haridhi^{1,2}, M Irham¹

¹Marine Science Department, Faculty of Marine and Fishery Sciences, Universitas Syiah Kuala, Banda Aceh, Indonesia.

²Earth System Science Program, Taiwan International Graduate Program (TIGP), Academia Sinica and National Central University, Taiwan.

*Corresponding Author: syahrulpurnawan@unsyiah.ac.id

Abstract. The study of sediment granulometry was completed at Lampulo fishing port (LFP). The LFP is a main fishing port in Aceh Province, Indonesia, located at 5°34'35" N; 95°19'23" E. The purpose of the research is to study and construct the environment condition of the bottom substrate. The data was taken by incorporating coring method at 10 stations using purposive random sampling. The wet sieve method was used to analyze the grain size for geostatistical analysis. The geostatistical parameters analysis in this study is classified as mean, sorting, skewness and kurtosis. The result informs that the types of sediments are sand, sandy clay and clayey sand for all stations. Station 1, however, is found as the coarsest compares to the other stations. All of the sediment collected at each station displays moderately sorted to poor sorted, while kurtosis values may be categorized as very leptokurtic. The results of the sediment parameters indicate that the environment of harbor pool was in a stable state, related to a sheltered condition.

Keywords: grain-size, granulometry, Lampulo fishing port, sediment

1. Introduction

Grain size is the most fundamental property of sediment clastic particles. The knowledge of particle size distribution contains numerous clues to their origin, hydrodynamic process, and the environment in which they were deposited. Material transport and deposition can be affected by tidal flow, wave activity, currents and anthropogenic activities [1], [2], [3], [4], [5], [6], [7], [8]. Therefore grain size analysis provides important information to the sediment provenance, transport history and depositional conditions, which can be done with a quantitative approach of the clast types present [9], [10]. Furthermore, sediment budgets reflect the origin, weathering processes, erosion or abrasion and the transportation and material deposition process [11], [12], [13], [14], [15].

The Lampulo Fishing Port (LFP) became main loading and unloading site for many fishing boats from around Aceh Province, Indonesia, causing vessel traffic level is high. On this occasion, the information about sediment aspects is very limited, since it was just operated on January 7th 2014, yet it is crucial for the activity within the port. Determinations of the sediment distributions are necessary for predicting and controlling sedimentation in harbors [16], [17], [18], [19], [20], [21], [22]. Sediment transport in harbors can be important for maintaining navigation channels, dredging harbors, and preventing coastal erosion [23], [24]. Sediment analysis in LFP also described by [25] in mini thesis, but performed by different methods as ours. That study carried out sediment samples using the



sediment-grab sampler and sieved by dry technique, compared to coring method and wet sieves technique as ours, which ensures more appropriate sampling process.

The objective of the present study was to obtain insight into the grain-size parameters of LFP sediments and their statistical relationships. Detailed investigation concerning spatial variability is required in order to have a better understanding of the sedimentation processes in LFP. Granulometric analysis performed to assess the statistical parameters of the sediment grain size as well as mean, standard deviation (sorting), skewness, and kurtosis.

2. Research and Method

This study located at LFP, Aceh, Indonesia ($5^{\circ}34'35''$ N; $95^{\circ}19'23''$ E). LFP area of approximately 111 hectares and has seawall by its surroundings. The data collection was done during October 2013, at ten stations that indicated by number in Figure 1. The determination of each station location is based on a representative condition at LFP. Station 1 represents natural beach facies, station 2 located in berthing pool, while station 9 and 10 represent open-coast facies.

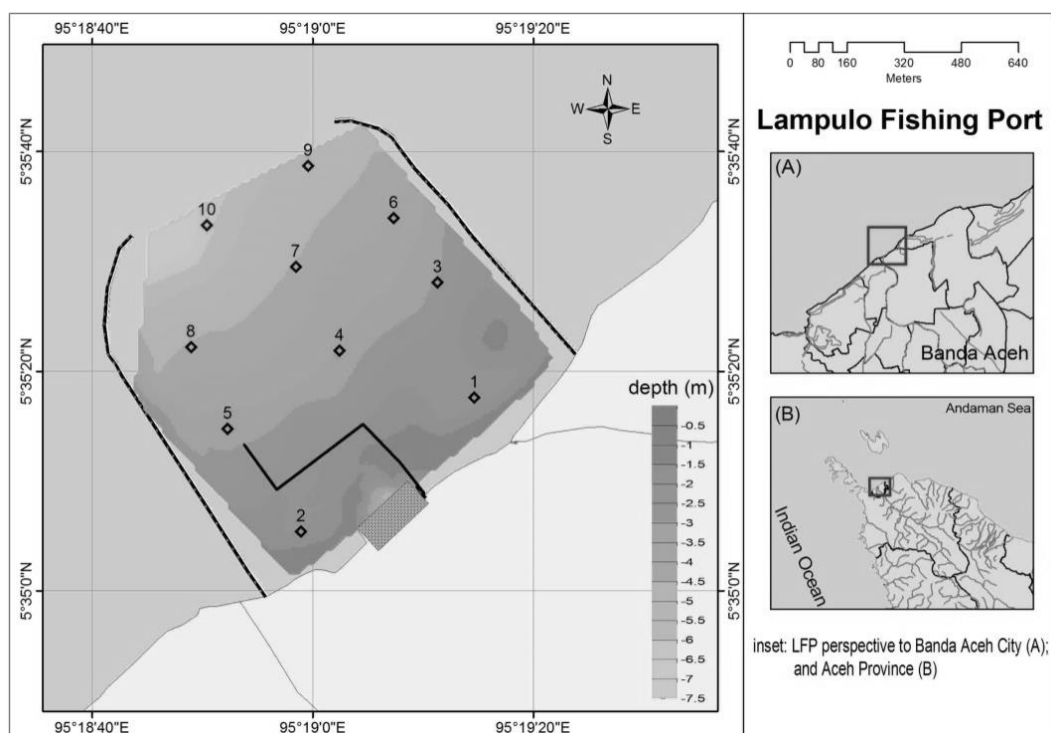


Figure 1. Sampling station at Lampulo Fishing Port (LFP). The map contain information of bathymetry in LFP.

Coring method was used to collect the sediment sample, and it is done by a diver at all stations. The core sample has a diameter of 2.5 inches, and the sediment thickness was set to 15 cm to be collected in each coring.

Six sets of sieves were used to analyze the particle size distribution of sediment sample, i.e. 1 mm, 0.5 mm, 0.25 mm, 0.125 mm, 0.075 mm and 0.038 mm, referred to Udden-Wentworth scales. Wet sieving technique was applied to all samples based on American Society for Testing Materials (ASTM) procedure, D4823-95 [26]. The sediment types classification of samples is derived from folk triangle. Sedimentological characteristics were analyzed by statistical method by using of moment method. The statistical analyses were used in measuring the grain sizes are mean (m_z), sorting (σ_a), skewness (Sk_a), and kurtosis (K_a), with formulas as follows:

$$m_z = \frac{\sum f m_m}{100} \quad (1)$$

$$\sigma_a = \sqrt{\frac{\sum f (m_m - m_z)^2}{100}} \quad (2)$$

$$Sk_a = \frac{\sum f (m_m - m_z)^3}{100 \sigma_a^3} \quad (3)$$

$$K_a = \frac{\sum f (m_m - m_z)^4}{100 \sigma_a^4} \quad (4)$$

Where, f is weight frequency (%) in each class, m_m is median of each class in ϕ value ($\phi = -\log_2 d$).

3. Results and Discussion

3.1. Sedimentological characteristic

Table 1 shows the sieve result of the grain size distribution at each station. In general, we found that the sediment samples were divided into sand to silt. The weight percentage of each class determines the type, which follows the Folk triangle. Through all the stations, we found that sand was found as predominant in LFP bottom, where as some portion of silt, compared to [25] which was found a considerable portion of silt. We suggest that different sampling method led to the different result, where sediment-grab only carried sediment from thin upper layer in the bottom. Most of our sediment samples were categorized as silty sand which is found at six stations, i.e. station 2, 3, 4, 7, 8 and 9 respectively, sand in stations 1 and 10, where as sandy silt in stations 5 and 6.

Table 1. Granulometric analysis.

St.	Percentage of sediment weight							Types
	>1.00	0.500-1.00	0.250-0.500	0.125-0.250	0.075-0.125	0.038-0.075	<0.038	
1	41.90	18.10	19.05	9.52	2.86	6.67	1.90	Sand
2	3.00	1.00	1.00	50.00	27.00	9.00	9.00	Silty sand
3	0.99	0.99	1.98	30.69	33.66	26.73	4.95	Silty sand
4	2.44	4.88	4.88	35.37	13.41	18.29	20.73	Silty sand
5	0.00	1.32	6.58	26.32	9.21	10.53	46.05	Sandy silt
6	1.02	6.12	19.39	10.20	7.14	10.20	45.92	Sandy silt
7	1.16	2.33	1.16	11.63	39.53	25.58	18.60	Silty sand
8	1.69	0.85	0.85	60.17	8.47	22.03	5.93	Silty sand
9	1.09	3.26	4.35	42.39	13.04	21.74	14.13	Silty sand
10	12.16	16.89	28.38	35.81	4.05	2.03	0.68	Sand

References: classification of grain size follows the Udden-Wentworth scale. Very coarse sand (>1.00 mm); coarse sand (0.500-1.00 mm); medium sand (0.250-0.500 mm); fine sand (0.125-0.250 mm); very fine sand (0.075-0.125 mm); coarse silt (0.038-0.075 mm); and silt (<0.038 mm). Sediment types were determined based on the Folk diagram.

3.2. Statistical analysis of sediment grain size

Mean grain size is the arithmetic average of grain size in represented sediment samples. The variation of mean grain size, defines the differential energy condition, which is effected to their deposition. Mean grain size value at station 1 indicates the coarsest grain of the entire station (Table 2). Based on the field observations, it is known that station 1 is located near to the coastline (SE of the LFP), where the wave height is tend to slightly increase and breaks as it came to shallower water (see bathymetry in Figure 1) [27]. High energy level may transport a smaller grain size to move from its original locations

[28]. While at the other stations generally can be described as having low energy level conditions, as the LFP has seawalls in almost surrounding area.

Table 2. Sediment statistical parameters.

Station	Mean (ϕ)	Sorting	Skewness	Kurtosis
1	0.8022	1.5711	1.0370	3.2262
2	2.9573	1.1305	-0.1799	5.0436
3	3.2576	0.9667	-0.5244	4.8704
4	3.2364	1.4828	-0.2850	2.6965
5	3.9273	1.4539	-0.4209	1.7354
6	3.6443	1.8067	-0.5074	1.7446
7	3.6641	1.1457	-0.7900	4.8678
8	2.9694	1.0576	0.0829	4.3264
9	3.1790	1.2808	-0.0517	2.9057
10	1.5200	1.1850	-0.0784	2.8767

The examining of sorting parameter shows that entire LFP was categorized as poorly sorted, while station 3 was the only categorized as moderately sorted. The lower sorting (σ_a) values correlated to a better sorting process of the sediment sample. Those sorting values indicate that there are fluctuating energy in the LFP. Since the LFP condition is a semi-closed water, with the breakwater at its surroundings, it is supposed that the entrance in the north that is still quite wide opened and provide energy input from the offshore. This sorting condition indicates mixing between coarse grains and fine grains on the bottom of the water [29], allegedly caused by changes in water conditions that were previously in the form of coastal waters which then changed into a harbour. Coarse grains are generally found from coastal waters while the accumulation of fine granules as a result of the small grain deposition process [30]. Deposition of fine grains indicates that the energy retained in LFP waters is relatively quiet, in line with semi-enclosed LFP since the breakwater is created around the LFP. The existence of this breakwater might have been eliminated the energy transferred from the open sea.

Descriptions of skewness and kurtosis result analysis also support the previous statement. Most locations have a skewness value that was negative (coarse skewed), where several have near symmetrical, and only station 1 was positively skewed. The numbers of locations that have negatively skewed conditions argue that there is a fine grain settling process in LFP. Although there are still positively skewed conditions in a number of locations, the semi-closed port conditions allow for the accumulation of fine grain deposits which will then redirect the curve of sediment distribution to a negative direction. This trend is also confirmed by the leptokurtic sediment character, which indicates that the distribution of sediments is highly concentrated around the mean value, which results in a very peaked distribution curve.

In general, it can be said that sediment characteristics in LFP indicate a stable condition, although at station 1 indicated there is still a slightly larger energy. The addition of the breakwater to the still-open area can add stability levels of water and sediments within the harbour pool.

4. Conclusion

Sediment grain size analysis that conducted at LFP observed the sediment is classified into three types, i.e. sand, silty sand, and sandy silt. The statistical analysis of sediment grain size shows the coarsest grain size is observed within station 1 with a mean value of 0.8022. Then it is stated that most of the stations in LFP were in a poor sorted, negative skewed and very leptokurtic, in which conclude as LFP environments support the occurrence of fine sediment deposition as a result of low-energy aquatic environment.

Acknowledgment

We would like to thank the UPTD LFP and Marine and Fisheries Department of Aceh that allow us to collect several samples at the LFP sites. Thanks also to Irwansyah, who help a lot along the data collection and analysis.

References

- [1] Abdulkarim R, Akininbagbe E A, Imo D O, Titocan M I, Ibitola M P, Faleye B R, Shonde O O, Jimoh O R, and Abe O B 2011 Sedimentological variation in beach sediments along the barrier lagoon coastal system, Lagos, South West Nigeria *Nature and Science* 9 19-26
- [2] Barnard P L, Schoellhamer D H, Jaffe B E, and McKee L J 2013 Sediment transport in the San Francisco Bay Coastal System: An overview. *Marine Geology* 345 3-17
- [3] Amrouni O, Hermassi T, Jaouad S A and Messaoudi S 2014 Contribution of Grain-size Trend to Sediment of a Microtidal Beach. Case of the Gulf of Tunis Bay (Cape Ferina-Cape Gammarth, Tunisia) *Research Journal of Environmental Sciences* 8 161-77
- [4] Purnawan S, Haridhi H A, Setiawan I, and Marwantim 2015 Parameter statistik ukuran butiran pada sedimen berpasir di muara Kuala Gigieng, Kabupaten Aceh Besar *Jurnal Ilmu dan Teknologi Kelautan Tropis* 7 15-21
- [5] Li Y, Wolanski E and Zhang H 2015 What processes control the net currents through shallow straits? A review with application to the Bohai Strait, China *Estuarine Coastal Shelf Science* 158 1-11
- [6] Kim H J, Suh S W, Seok J S, and Park W K 2017 Sedimentation for a Flood-dominant Estuarine Harbor Induced by Anthropogenic Activities *Journal of Coastal Research* S179 339-343
- [7] Clayton J A, and Pitlick J 2008 Persistence of the surface texture of a gravel-bed river during a large flood *Earth Surface Processes Landforms* 33 661–673 doi:10.1002/esp.1567
- [8] Van Maren D S, and Winterwerp J C 2013 The role of flow asymmetry and mud properties on tidal flat sedimentation *Continental Shelf Research* 60S S71-S84
- [9] Wachecka-Kotkowska L, and Kotkowski P 2011 Grain-size distribution analysis of quaternary sediments from the southern part of the Lodz region in Poland: a computational-methods approach *Geologos* 17 205–19
- [10] Mao L, Cooper J R, and Frostick L E 2011 Grain size and topographical differences between static and mobile armor layers *Earth Surface Processes Landforms* 36 1321–34 doi:10.1002/esp.2156
- [11] Jafarzadeh M, and Hosseini-Barzi M 2008 Petrography and geochemistry of Ahwaz Sandstone Member of Asmari Formation, Zagros, Iran: implications on provenance and tectonic setting *Revista Mexicana de Ciencias Geológicas* 25 247-60
- [12] Saniah, Purnawan S, and Karina S 2014 The characteristics and mineral content of coastal sand from Lhok Mee, Beureunut and Leungah, Aceh Besar District *Depik* 3 263-70
- [13] Armstrong-Altrin J S, Ramasamy N, Yong I L, Juan J K and Leslie P C 2014 Geochemistry of sands along the San Nicolás and San Carlos beaches, Gulf of California, Mexico: implications for provenance and tectonic setting *Turkish Journal of Earth Science* 23 533-558
- [14] Purnawan S, Setiawan I, and Muchlisin Z A 2015 Sediment grain-size distribution in the Lake Laut Tawar, Aceh Province, Indonesia *AACL Bioflux* 8 404-10
- [15] Chikin A L, and Chikina A L 2011 Modeling the silt transport and deposition in approach channels in the Taganrog Bay *Vestnik Yuzhnogo Nauchnogo Tsentra RAN* 7 45–48
- [16] Kian R, Velioglu D, Yalciner A C and Zaytsev A 2016 Effects of Harbor Shape on the Induced Sedimentation; L-Type Basin *Journal of Marine Science and Engineering* 4:55
- [17] Caceres R A, Zyserman J A, and Perillo G M E 2014 Analysis of Sedimentation Problems at the Entrance to Mar del Plata Harbor *Journal of Coastal Research* 32 301-14
- [18] Gorlova A A, and Makarov K N 2017 Sediment Deposition in Artificial Harbors and Approach Channels *Power Technology and Engineering* 50 473–9

- [19] Kuklev S B, Divinskii B V, and Kozachinskii Y S 2012 Predicting sediment deposition in maritime approach channels by mathematical simulation. *Gidrotekhnika* 3 55–57
- [20] Delile H, Mazzini I, Blichert-Toft J, Goiran J P, Arnaud-Godet F, Salomon F, and Albarède F 2014 Geochemical investigation of a sediment core from the Trajan basin at Portus, the harbor of ancient Rome *Quaternary Science Reviews* 87 34-45
- [21] Lepland A, Boe R, Lepland A, and Totland O 2009 Monitoring the volume and lateral spread of disposed sediments by acoustic methods, Oslo Harbor, Norway *Journal of Environmental Management* 90 3589–98
- [22] Coch N K 2016 Sediment Dynamics in the Upper and Lower Bays of New York Harbor *Journal of Coastal Research* 32 756-67
- [23] Supiyati Suwarsono, and Setiawan I. 2011. Sediment transport cause of Port Superficiality of Bengkulu Baai Island with diskritisation model of oceanography dynamics *Dinamika Teknik Sipil* 11 172-80
- [24] Van Maren D S, Van Kessel T, Cronin K, and Sittoni L 2015 The impact of channel deepening and dredging on estuarine sediment concentration *Continental Shelf Research* 95 1-14
- [25] Rinanda S, Study of Bottom Sediment Characteristics for Sediment Transport Potency in Fisheries Port of Lampulo *Thesis Universitas Syiah Kuala* p 37 2015
- [26] ASTM. D4823–95. *Standard Guide for Core Sampling Submerged, Unconsolidated Sediments* (West Conshohocken: ASTM International) p 14. 2008
- [27] Measures R, and Tait S 2008 Quantifying the role of bed surface topography in controlling sediment stability in water-worked gravel deposits *Water Resources Research* 44 W04413 doi:10.1029/2006WR005794
- [28] Delpey M T, Arduin F, Otheguy P, and Jouon A 2013 Effects of waves on coastal water dispersion in a small estuarine bay *Journal of Geophysical Research* 119 70-86
- [29] Venkatramanan S, Ramkumar T, Anithamary I, and Ramesh G 2011 Variations in texture of beach sediments in the vicinity of the Tirumalairajanar river mouth of India *International Journal of Sediment Research* 26 460–70
- [30] Gibson S, Abraham D, Heath R, and Schoellhame R D 2009 Vertical gradational variability of fines deposited in a gravel framework *Sedimentology* 56 661–76 doi:10.1111/j.1365-3091.2008.00991.x