

The Spatial Distribution of Bed Sediments at Krueng Cut Estuary: The Sieve Analysis Approach

Distribusi Spasial Sedimen Dasar di Muara Krueng Cut: Pendekatan Analisis *Sieve*

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Received : 4 September 2017; Received in revision: 26 October 2017; Accepted : 3 December 2017

Abstract

This research studied the characteristic of bed sediment in the estuary of Krueng Cut, Banda Aceh. Analyzing the field samples from different site of stations along the channel of Krueng Cut from upstream to estuary shows different pattern and profile of deposited bed sediment. Therefore, sorting the size of sediment is important spatially because pattern of its deposition and characteristic will illustrate how distribution patterns indicate the nature of the channel. Hence, the study aims to determain the pattern of bed sediment distribution as well as its profile spatially. To implement the intended purpose, the coring method was employed by using purposive random sampling for 15 stations of taken sampling in Krueng Cut estuarial channel. The sample of sediment was proceeded by using a 2,5 cm diameter of PVC paralon at the depth of 25 cm from the bathymetry base. Samples were analyzed using wet sieve analysis method. The result informed that the dominant of bed sediment size are medium sand found around the mouth of the river, fine sand existed along the mixing area, and very fine sand occurred in the transition zone of the channel. In the region of coastal dynamic, the sediment was dominated by medium sand size, meanwhile in the area of river dominated flow, the sediment is subject to fine sand size. Thus, the fraction of very fine sand size of sediment was found in the zona of transition.

Keywords: Krueng Cut, bed sediment, sediment fraction, sieves analysis.

Abstrak

Penelitian ini mengkaji tentang studi sebaran sedimen dasar di perairan Krueng Cut, Kota Banda Aceh yang bertujuan untuk mengetahui pola sebaran dan profil sedimen dasar. Analisis sampel lapangan dari berbagai lokasi stasiun sepanjang sungai Krueng Cut dari hulu hingga muara menunjukkan pola dan profil endapan sedimen yang berbeda. Sortiran ukuran sedimen penting secara spasial karena pola deposisi dan karakteristiknya menggambarkan bagaimana pola distribusi dari sifat sungai. Oleh karena itu, penelitian ini bertujuan untuk mengetahui pola distribusi sedimen dasar serta profilnya secara spasial. Untuk mengimplementasikan tujuan tersebut, metode coring digunakan dengan menerapkan purposive random sampling untuk 15 stasiun sampling yang diambil di Krueng Cut. Sampel sedimen diambil dengan menggunakan pipa paralon PVC berdiameter 2,5 inci pada kedalaman lebih kurang 25 cm dari dasar batimetri. Sampel dianalisis dengan metode sieve analysis menggunakan ayak basah. Hasil menunjukkan bahwa bahwa ukuran sedimen yang dominan adalah pasir ukuran sedang yang ditemukan di sekitar muara sungai, pasir halus berada di sepanjang daerah pencampuran (mixing), dan pasir yang sangat halus berada di zona transisi. Pada daerah dinamika laut, sedimen didominasi oleh fraksi pasir sedang. Sedangkan daerah dinamika aliran sungai yang dominan diperoleh sedimen fraksi pasir halus. Selanjutnya sedimen fraksi pasir sangat halus diperoleh pada zona transisi.

Keywords: Krueng Cut, sedimen dasar, fraksi sedimen, analisis sieve.

1. Introduction

Sedimentation is one of the important parameters in the distribution of materials in the bottom of the waters. The deposition and distribution of sediments in the waters can alter the depth, configuration, and characteristics of the waters vertically and horizontally. The pattern of sediment distribution and its characteristics are action of natural influenced by the movement and the anthropogenic activities

resulting in environmental effects (Girsang and Rifardi, 2014). The natural works can be currents, waves, and tides that naturally the dynamic activities (Irham and Setiawan, fishing activities, and physical activities of people around the water body (Irham, 2016).

The various forms of activity around the waters provide a direct impact on the waters such as sedimentation and erosion (Irham, 2016; Irham et al., 2013). Bed sediment as one of them, is a natural material that causes the deposition and erosion in the body of water either temporally or spatially (Irham, 2016). Erosion and sedimentation materials cause in the addition and reduction of sediment supply that harms a coastal area (Setiawan and Irham, 2017). The processes of sediment additions and reductions (erosion and deposition processes) are physically driven by flows, waves, and tides (Manengkey, 2011; Irham and Setiawan, 2017). Flows, waves, and tides are also one of the main factors causing the change of sediment type in the bottom of the waters. Nugroho and Basit (2014) explained that the current velocity affects the process of sediment transport, sedimentation and sediment distribution. Sediments of coarse size (gravel to course sand) may be found in a strong current areas whereas fine-grained sediments (fine sand to mud) are exist in the area of a weak flows (Irham and Setiawan, 2017).

The Krueng Cut is the downstream channel connected to the upstream waters of Krueng Aceh. Therefore, the sediment in Krueng Cut may come from Krueng Aceh as a main channel system and be input from Alue Naga beach directly related to Krueng Cut estuary. Irham (2016) and Irham and Setiawan (2017) argue that the sediment input and output in the water is because of the influence of land as a source material. Currents or flows, waves, and tides transport the material and the materials will deposit somewhere when the energy is no longer able to move the materials (Bian et al., 2013). Deposition and erosion create the negative impacts such as land expansion and land reduction (Irham et al., 2013).

Therefore, to understand how the pattern of spatial distribution and the characteristic of sediment profile occurring along the channel of Krueng Cut needs to be studied by employing spatial sieve analysis method. The purpose of this study is to know the distribution pattern of bed sediments along Krueng Cut fluvial channel. It is expected 2017) require such balance in the coastal areas proceeding in erosion or deposition. While the anthropogenic activities can be in the form of construction development, that the results of this study can provide the information related to the distribution of bed sediments of Krueng Cut water. Local governments may also utilize the results of this study for the purpose of making decisions if development is undertaken in this area. While for the people living in this area may utilize this study as an information for the sustainability of the community economy.

2. Methodology

2.1. Material

This research used PVC tubecore with 2.5 inch diameter for sediment sampling together with compass for sampling location and sediment bag to store the sediment before being analized in laboratorium. A set of sieve and digital weight was employed for sieving analysis.

2.2. Sampling

The sampling sites are located in the Krueng Cut river of Alue Naga Village, Syiah Kuala District, of Banda Aceh, Indonesia (Figure 1). This research was conducted from November to December 2016 and analyzed at Marine Biology Laboratory of Marine and Fisheries Faculty of Syiah Kuala University. This research uses two methods which are the purposive random sampling method in the field for sediment sampling and sieve analysis to determine the sorting of sediment in each sample location.

2.3. Data Analysis

The samples obtained from the field were analyzed using wet sieve analysis at the Marine Biology Laboratory of the Marine and Fisheries Faculty of Syiah Kuala University to determine the spatial distribution of grain sorting sediment, so that the sediment characteristics and its profile can he determined or analyzed. The wet sample from wet sieve analysis was dried at room temperature until it gets below 5% of water contained than weighed for each sorting size. Sieves analysis used was a 2 mm sieve; 1 mm; 0.50 mm; 0.25 mm; 0.125 mm; 0.063 mm; 0.038 mm. The results were weighed again and obtained the sediment distribution of each sampling according to the size of the filter.



Figure 1. Map of study area and the location of sampling station along Krueng Cut channel

Station	% of sediment weight fraction									Dominant	
	Gravel	Sand				Mud				for	
		Very Coarse	Coarse	Medium	Fine	Very fine	Clay	Silk	Total	(d) Mean size	Clasification
	4-2 (mm)	2-1 (mm)	1-0,5 (mm)	0,5-0,25 (mm)	0,25- 0,125 (mm)	0,125- 0,063 (mm)	0,063- 0,038 (mm)	0,002 (mm)	%	(mm)	
1.	1.71	1.26	4.30	14.37	62,93	9,08	4.57	1.77	100	0.024	Fine sand
2.	37.63	21.99	29.06	8.96	1.12	0.76	0.48	0.00	100	0.143	Gravel
3.	0.07	0.07	4.83	4.83	33.26	44.66	9.38	2.89	100	0.014	Very find sand
4.	0.00	0.00	2.25	10.61	10.13	39.71	20.42	16.88	100	0.010	Very find sand
5.	0.90	0.00	3.78	5.18	55.08	27.99	1.99	5.08	100	0.017	Fine sand
6.	0.94	0.21	1.77	12.73	37.16	33.51	7.20	6.47	100	0.017	Fine sand
7.	1.61	4.51	2.22	5.74	66.18	12.32	4.82	2.60	100	0.024	Fine sand
8.	1.19	0.37	2.44	28.48	50.02	9.72	1.16	6.64	100	0.023	Fine sand
9.	0.61	0.78	13.10	34.43	42.65	5.82	0.47	2.13	100	0.029	Coarse sand
10.	0.79	1.30	69.26	20.40	7.37	0.79	0.10	0.00	100	0.054	Fine sand
11.	0.55	1.10	7.69	29.85	11.54	39.33	1.88	8.06	100	0.022	Very fine sand
12.	1.49	3.09	13.92	38.84	31.79	7.46	0.94	2.47	100	0.034	Medium sand
13.	1.12	1.91	7.40	20.13	10.04	40.33	3.31	15.76	100	0.021	Very fine sand
14.	17.85	5.45	4.39	25.49	26.85	17.31	0.93	1.73	100	0.068	Fine sand
15.	5.65	2.83	11.48	30.17	29.83	17.26	1.39	1.39	100	0.040	Medium sand

Table 1. The percentage of sediment weight (%) based on Udden-Wentworth *Grain-size* scale (Wentworth, 1992).

2.4. Sediment weight calculation

The formula to calculate the percentage of fraction is shown in Eq. (1).

% of sed. Frac-i=
$$\frac{weight of sed.fraction-i}{total weight of sed.fraction} \times 100\%$$
 (1)

where the weight of sediment fraction-i is equal to the weight of each sediment fraction (g) (Folk, 1974). Meanwhile, the calculation of mean size value is determined by using the Eq. 2 as:

$$d = \sum \frac{\% \text{ of sed.fraction } \times \text{ fraction size}}{100}$$
(2)

3. Result and Discussion

The percentage analysis of the bed sediments weight at each sample is shown in Table 1. The sample taken in this study is consisted of 15 sample stations, 6 stations in estuarial area of the river and 9 stations in Krueng Cut water area. The percentage of sediment fraction from 15 sample stations has different mean grain size value. Generally, it was found that the distribution of bed sediment in this area is classified by fine sand with size of 0.25 mm - 0.125 mm. Sediments with the largest mean grain size were found at station 2. While the sediments with very fine grains (clays) was existed at station 4.

Figure 2 depicts the analysis results of the profile of bed sediment distribution in Krueng Cut water. A medium-sized sediment profile of larger than 0.25 mm is present at station 12 and 15 as shown in Figure 2a. The profile of distribution of fine sand sediments size of 0.25 mm - 0.125 mm is represented by sampling at station 1, 5, 6, 7, 8, 9 and 14 shown in Figure 2b. While the profile of sediment distribution with size of 0.125 mm - 0.063 mm (very fine sand) as shown in Figure 2c is presented at station 3, 4, 11, and 13. Furthermore, Figure 3 shows the results of the spatial analysis of sediment distribution from the distribution of medium sand, fine sand, and very fine sand. The result is represented the dominant out come of sediment produced from sieve analysis.

Based on the results of the study (Table 1), it shows that the percentage of sediment weight in each sieve has different values. The average grain size of sedimentary fraction with the largest classification is found at sample station 2 (river dynamics zone) which is 0.143 mm size with gravel classification. While the lowest average grain size value is the sample at station 4 of 0,010 mm size, where this sample area is located in the middle of study area. This location is a region that has a weak flow due to the absence of influences of currents, tide, and downstream flow. Because of its weak flow, the sediments in this area are also classified as very fine-sized sediments. Barnard et al. (2013) states that although the dynamics of currents and waves is relatively small, however, the distributions of sediment still exist so that the dominant substrate of sediment in this area may be categorized as muddy sediment. The relatively weak current and small wave conditions result in the sediment being deposited in this area and the sediments are hardly to move to other areas.

Table 1 explains that the sediments at these 15 sample stations are generally classified by fine sandy sediment of 0.25 mm - 0.125 mm size as well. This classification of fine sandy sediment is caused by the current dynamics in this area which circulate small currents of both the river flow at the upper regions as well as the influence of waves and tide from the coast in the estuary. According to Dai et al. (2013), the wave is very influential on the occurrence of sediment transport at the mouth of the river. It is found in this study that the sediment is transported into the mouth of the river, however, in that region where the wave conditions are calm then the sediment will settle. Therefore, the larger the wave the greater the sediment transports and settles in the estuary as of Davidson et al. (2013) found. The alternating current between the influence of the river flow and the dynamics of the sea causes the particles of fine sandy sediments to settle on site (Delpey et al., 2013). Ansar et al. (2014) stated that sediment particles with smaller sediment grain sizes will be easier to transport and take sometimes to settle. These behaviors occurred in this study and it shows that since most particles are smaller in size, they move more easily as a result of wave action and current movement compared to sediment particles with larger grain size as Gomes et al. (2016) found it before.

The description of the fine sandy sediment in Table 1 is obtained by the sample at stations 1, 5, 6, 7, 8, 9, and 14. The position of sample at stations 1, 5 and 9 is the area adjacent to the west of the river. At the east of the river is located at station 7 whereas the sample at stations 6, 8 and 14 are in the middle of the study site. From this random sediment collection yields a diverse range of sediment grain sizes, which gradually the



size of sediment is getting finer toward the

transition zone (Figure 3).



Figure 2. Profile of sediment fraction based on sieve size, (a) medium sand sediment fraction; (b) fine sand sediment fraction; (c) very fine sand sediment fraction

Figure 3 shows the zoning distribution of sediments in the study area. It shows that in areas close to the ocean where ocean currents begin to enter to the mouth of the river, the sediment in this area can be categorized as medium sandy sediment or zone of dynamic (zone I of Figure 4) due to the influence of the strong flow from the sea while the influence of flow from the river is less. The finding agrees to Warrick et al. (2013) that states the distribution of sediments can be spread toward the sea, parallel to the coastline or across the mouth of the river depending on the dominant of energy. If the spread of sediment in the direction of parallel or follow the the coastline, then the sediment found in the western estuary of the river is relatively larger than the one found in the eastern estuary of the river. Thus, the charred component (a collection of gravel or sand) is in the form of course sandy sediments which include medium-grained sediments. The

second zone is a fine sandy sediment zone (zone III of Figure 4) which is a circulation zone, the confluence area of river currents and ocean currents.

Soomere and Vika (2014). explained that muddy size sediment or very fine sandy sediment tends to be transported as a suspended sediment with speed and direction following the speed and direction of current. While the very fine sandy sediment zone (zone V of Figure 4) was found in the upstream area of the channel. In this area the influence of ocean dynamics has been greatly reduced while the flow from the river is sufficiently not strong, consequently the sediment is deposited in this area is very fine sandy sediment size to the silt and clay size. The farther away from the coastline, the finest size of sediment occurred. This is because of the energy that works to transport the sediment become weaker (Arisa et al., 2014).



Figure 3. The spatial distribution of fraction sediment along Krueng Cut channel

Figure 3 shows the spatial distribution of sediments in Krueng Cut with various sizes sediment fraction. Figure 3a displays the distribution of fine-grained sedimentary sand that generally occurs in the circulation area and slightly upstream site. While the spatial

distribution of very fine sand dominates the transition zone (Figure 3b) and the distribution of medium size of sandy sediment is dominating the area around the estuary (Figure 3c) where the influence of ocean dynamics is dominant. The result of sieve analysis informs that this fluvial channel has alternate strong and weak current that depends on the tide condition, so that the variation of sediment size is diverse as well in every place. The result of sediment distribution demonstrates when the high tide condition occurred; the current from downstream moves upstream and circulates in the mid area caused by the influence of currents from the river. River currents will be dominant when in a state of ebb (low tide), with the same pattern where the river flow weaken downstream and circulated in the same area. Thus it can be said that this circulation area is a mixing area where this area is a region of current meeting between the dynamics of ocean currents and river flows.

The results showed that the bed sediment classification in these waters was classified into 5 granular characteristics which are gravel on a scale of 4 mm - 2 mm, coarse sand on a scale of 1 mm - 0.5 mm, medium sand on a scale of 0.5 mm - 0.25 mm , fine sand on a scale of 0.25 mm - 0.125 mm and very fine sand on a scale of 0.125 mm - 0.063 mm. Large size of sediments tend to be found in a strong currents compared to small size of sediments. On this occasion, current is a major factor affecting transportation, deposition, and distribution of sediment.



Figure 4. The diagram of sediment size distribution in Krueng Cut

Delpey et al. (2013) states that currents and waves are the main factors determining the direction and distribution of sediments that affect the different characteristics of sediments in the bottom of waters. Different particle sources cause the presence of different characteristics and distribution of sediments. Figure 4 illustrates the distribution of sediment based on zone of sediment size. Areas with strong current influences from both marine and river dynamics show a homogeneous sediment distribution (zones I and V). In the circulation area (zone III) shows a sediment distribution which is also homogeneous because in this region the current circulation between the sea and the river occurs. While in the mixing area where the current transition changes, the sediment distribution tends to be mixed (zones II and IV).

4. Conclusion

The research concluded that there are 3 (three) dominant sediment size fractions obtained from sediment analysis. They are medium, fine, and very fine sand size of sediment. The largest percentage is generally found in the size of fine sandy sediments with a size of 0.25 mm - 0.125 mm. The spatial pattern of sediment distribution in the study area depicts the zoning of sediment distribution according to the selected size. These zonations are transition zone dominated by very fine sandy sediment, the circulation zone (the confluence of river currents and ocean currents which is uniformly distributed the sediment) dominated by fine sandv sediment, and dynamic zone dominated by medium sandy sediment due to the influence of ocean currents near by the mouth of the river as well as river flows upstream.

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