Characteristics of beach sediment in Araban Bay, Simeulue Island, Indonesia

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Abstract. The purpose of the study was to evaluate the characteristics of sediment at Araban Bay. The sediment samples were collected on February 2016 from seven stations along the Araban Bay using the tube-corer with a diameter of 3 inches and 20 cm of depth from the surface. All samples were analyzed using wet sieve method. Based on the analysis, all the samples have a mode of distribution on 3φ or fine sand fraction. Finer grain of sediments was found at stations 4 and 5, which also categorized as moderately well sorted. Distribution of sediment at the bay showed a slight trend of regular pattern that leaded from west to east.
Key Words: Aceh, Araban Bay, beach, sediment, grain size.

Introduction. Araban Bay is located on the southern coast of Simeulue Island, Central Simeulue Subdistrict, Aceh Province, Indonesia; facing to the Indian Ocean in the south, Simeulue-Cut Island in the southwest, and adjacent to Ujung Lambajo in the east. Most of this sublittoral area has a hard substrate where the hard coral and rubble were found around this area. Some tsunami events have given impact to Araban Bay since the biggest impact was the uplifted of the near shore in some area in the western coast of Simeulue (Foster et al 2006; Fujino et al 2014; Meltzner et al 2012, 2015). This bay has also been affected by anthropological activity, within ship traffic, urban run-off, and fish landing site.

Located in the eastern part of the Indian Ocean, Araban Bay certainly gets the influence of the dynamics from Indian Ocean. Wyrtki (1973) showed the water circulations in the Indian Ocean, near to Araban Bay, and their variation depends on seasonal changes. Diansky et al (2006) using high resolution data illustrated that during the winter monsoon (from November to March), the circulation of Indian Ocean near to Simeulue island was moved toward the northeast, whilst summer monsoon (from May to September) the water masses moved toward the southeast.

The sediment statistical approaches were very commonly used and developed to assess the environmental conditions of sediment until the recent period (Weltje & von Eynatten 2004; Wachecka-Kotkowska & Kotkowski 2011; Weltje 2012; Eamer & Walker 2013; Dong et al 2015; Purnawan et al 2018a). Grain-size characteristics and their distributions are fundamental for quantitative description of study area (Nordstrom 1977; Mclaren & Bowles 1985; Purnawan et al 2015), since the unevenness of particle size distribution gives a number of clues to their provenance, transport history, depositional condition, and hydrodynamic process.

In a coastal environment, the deposition process of sediment becomes complex as the interaction of various parameters (Roberts & Wang 2012; Eamer & Walker 2013; Montreuil et al 2014). Those parameters include waves, current, coastal tides, season, and sediment discharged from the river, they particularly give variation in sediment settlement processes (Staub et al 2000; Curtiss et al 2009; Vila-Concejo et al 2014; Gensac et al 2016; Verstraeten et al 2017). Deviations of beach morphology, particularly over a relatively short time-scale are most likely induced by wave-height, tides, and wind variation (Matias et al 2010; Beetham & Kench 2014).

This study was carried to assess the sediment distribution of coastal bed at the Araban Bay. The information on sediment characteristics of this area can permit the assessment of sediment distribution that occurred and the relation to their deposition processes. The goal of this study was to deduce the characteristic of sediment beds in Araban Bay from analysis of quaternary sediment.

Material and Method

Description of the study sites. The field survey was arranged during February 2016. Sampling station on the Araban Bay was divided into seven locations, which was considered to represent the study area (Figure 1). No data was collected from the southeast tip of Araban bay (Ujung Lambajo), as the sea bed was covered by a massive substrate of coral. Each of sediment samples were collected by 3 Inches PVC core into 20 cm of thickness from near-shore (wave shoaling zone).

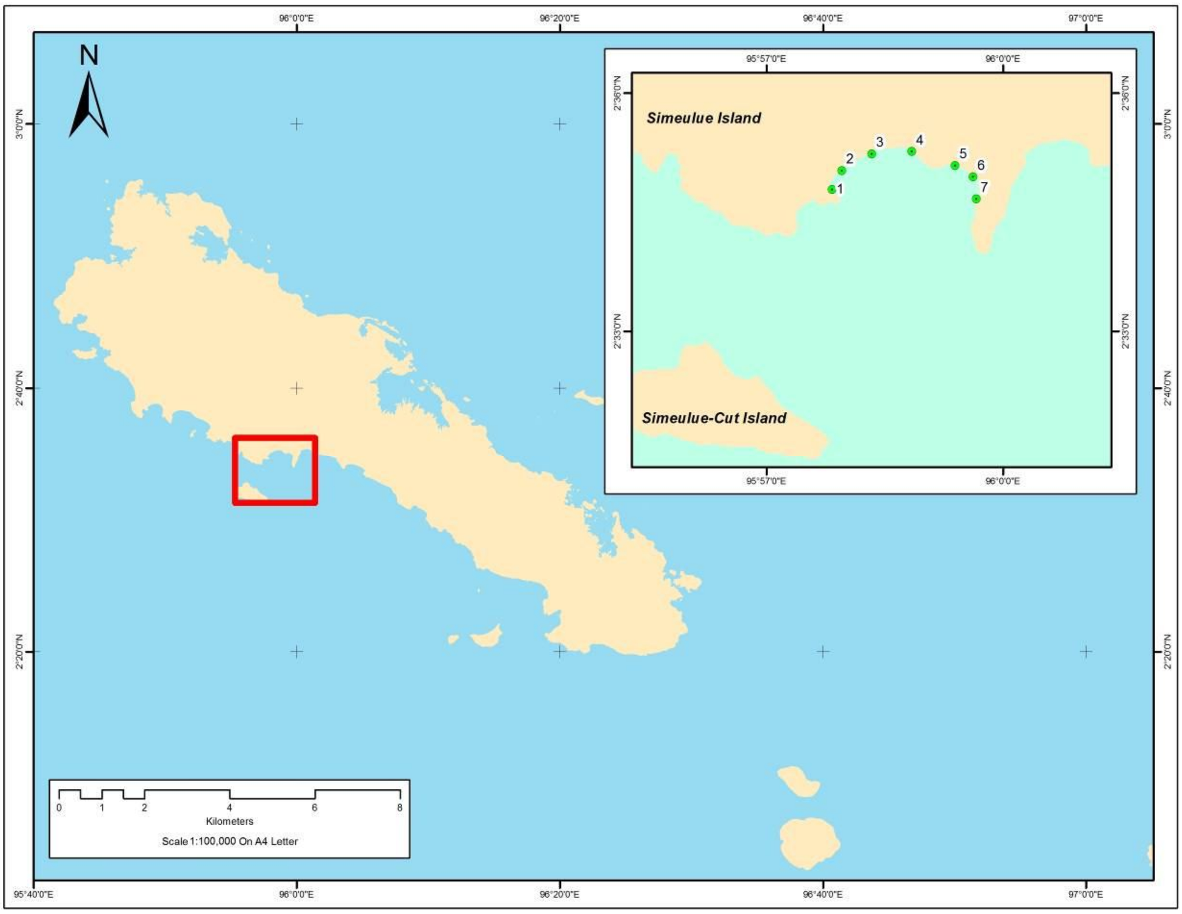

Figure 1. The location of sediment sampling at Araban Bay, Simeulue Island, Indonesia.

The obtained samples were then dried to remove its moisture. Approximately 200 grams of dried samples were prepared to further proceed using a wet sieve method, referred to ASTM C136/C136M-14 (2014), which were consisted of seven mesh sizes of: -1 φ; 0 φ; 1 φ; 2 φ; 3 φ; 4 φ; 5 φ and pan. The dried weight of each fraction was tabulated for granulometric analysis.

Statistical analysis. Statistical parameters were calculated following Folk and Ward formula by using the phi-transform value (phi (φ) = -log d), where d is the grain size in millimeters). These statistical parameters (consisting of mean, standard-deviation or sorting, skewness, and kurtosis) calculations are as follows:

Mean grain size (Mz):

$$Mz = \frac{\varphi 16 + \varphi 50 + \varphi 84}{3}$$

Sorting (S):

$$S = \frac{\varphi 84 - \varphi 16}{4} + \frac{\varphi 95 - \varphi 5}{6.6}$$

Skewness (Sk):

$$Sk = \frac{\varphi 16 + \varphi 84 - (2 \cdot \varphi 50)}{2 \cdot (\varphi 84 - \varphi 16)} + \frac{\varphi 5 + \varphi 95 - (2 \cdot \varphi 50)}{2 \cdot (\varphi 95 - \varphi 5)}$$

Kurtosis (Ku):

$$Ku = \frac{\varphi 95 - \varphi 5}{2.44(\varphi 75 - \varphi 25)}$$

Results. The samples properties obtained from the study sites are physically visibly as bright colored, as results of silica-carbonate sediments that are commonly found around coral reefs, with little presence of coarse grains. Based on grain-size distribution (Table 1), fraction of phi = 3 was found as dominant at all stations, then followed by phi = 2 and phi = 4, respectively. The coarser fraction (-1*φ* to 1 *φ*) was absent at station 4 and 5, hence the fact was relatively similar compared to station 1. Samples from station 7 consisted of all seven fractions, the only station in this situation. Further, the condition at station 7 (in line to sorting condition) was found as the poorest among other stations.

Table 1

The distribution of sediment size (%)

St.	*Mesh size (φ)*							*Total*
	-1	*0*	*1*	*2*	*3*	*4*	*5*	*(%)*
1	0.0	0.0	7.4	26.4	57.4	8.8	0.0	100
2	3.0	4.2	5.6	9.0	70.8	7.4	0.0	100
3	2.8	3.0	6.6	16.8	57.2	13.6	0.0	100
4	0.0	0.0	0.0	12.4	75.6	12.0	0.0	100
5	0.0	0.0	0.0	9.2	69.6	15.6	5.6	100
6	2.4	3.6	6.4	20.0	64.4	3.2	0.0	100
7	3.2	4.4	7.6	19.2	50.0	10.8	4.8	100

The highest value of calculated mean grain size (in phi scale), which is also described as finest size of sediment, was found at station 5. Figure 2 shows that the sediment distribution in the inner area of Araban Bay has fine sediment compared to the outer area of Araban Bay. Values of sorting parameters were ranged from 0.55 (moderately well sorted) to 1.18 (poorly sorted). Better sorting conditions were found around stations 5 and 6 (Figure 3). Skewness analysis at research location indicated that this parameter showed various conditions. The skewness value was ranged from -0.46 as very coarse skewed, up to 0.19 as fine skewed (Figure 4). While kurtosis described the peakedness of the distribution curve, which ranged from 1.07 to 2.23, categorized as mesokurtic to very leptokurtic (Figure 5).

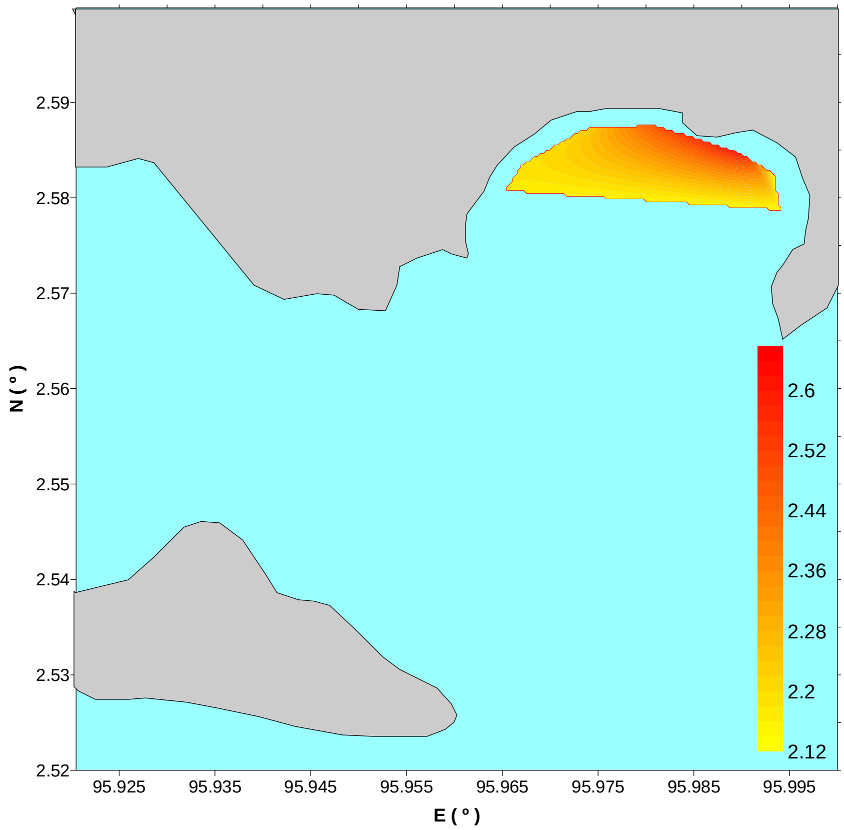

Figure 2. Calculated mean grain-size value (phi) of Araban Bay sediment.

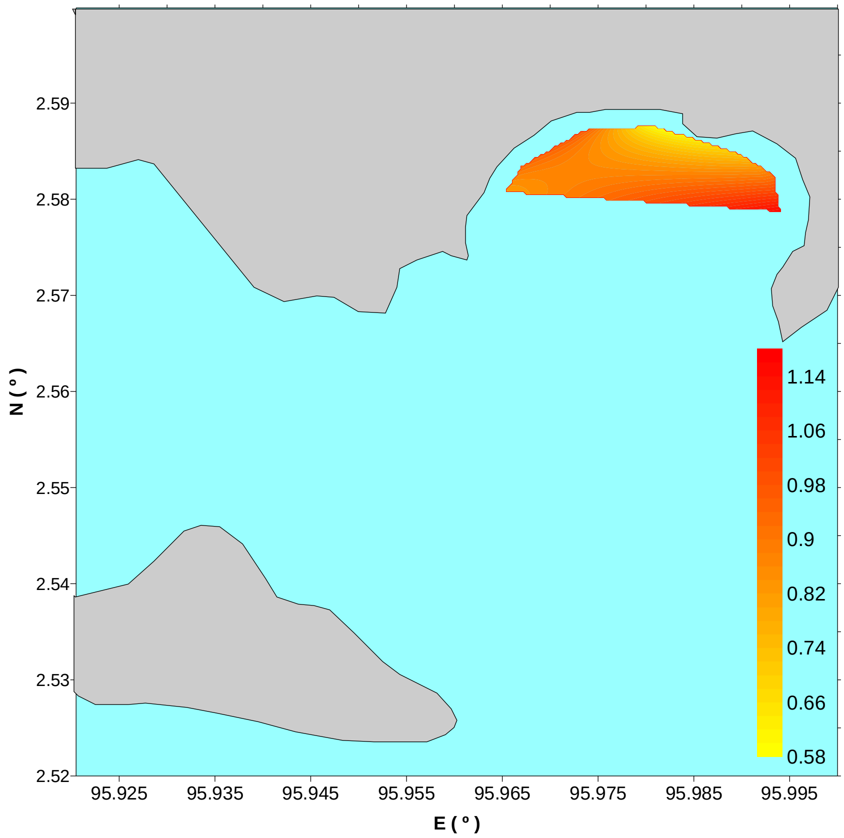

Figure 3. Calculated sorting value of Araban Bay sediment.

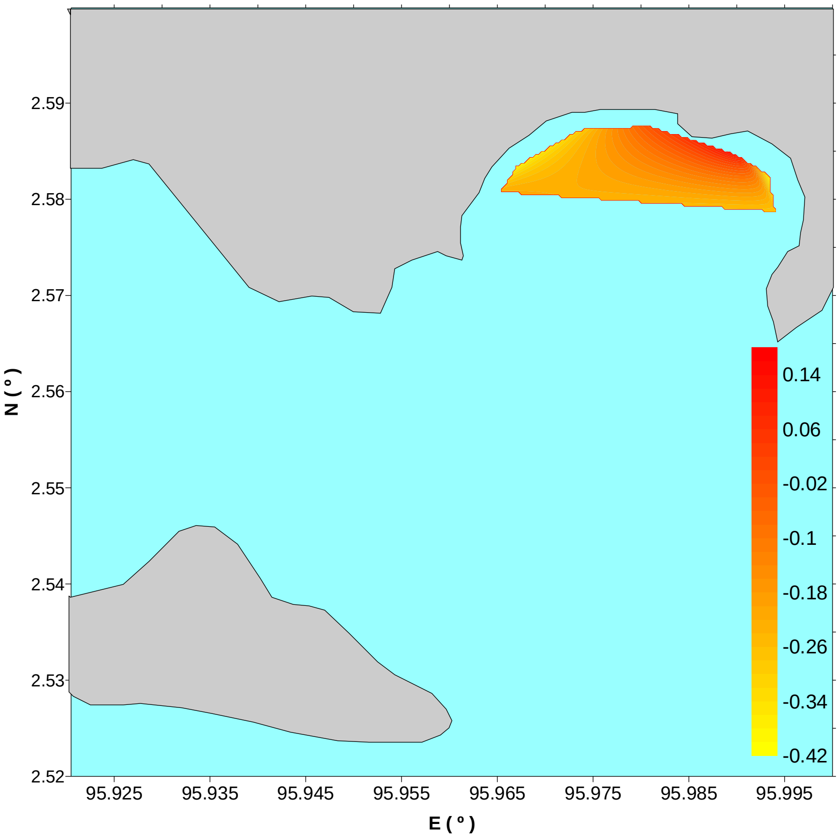

Figure 4. Calculated skewness value of Araban Bay sediment.

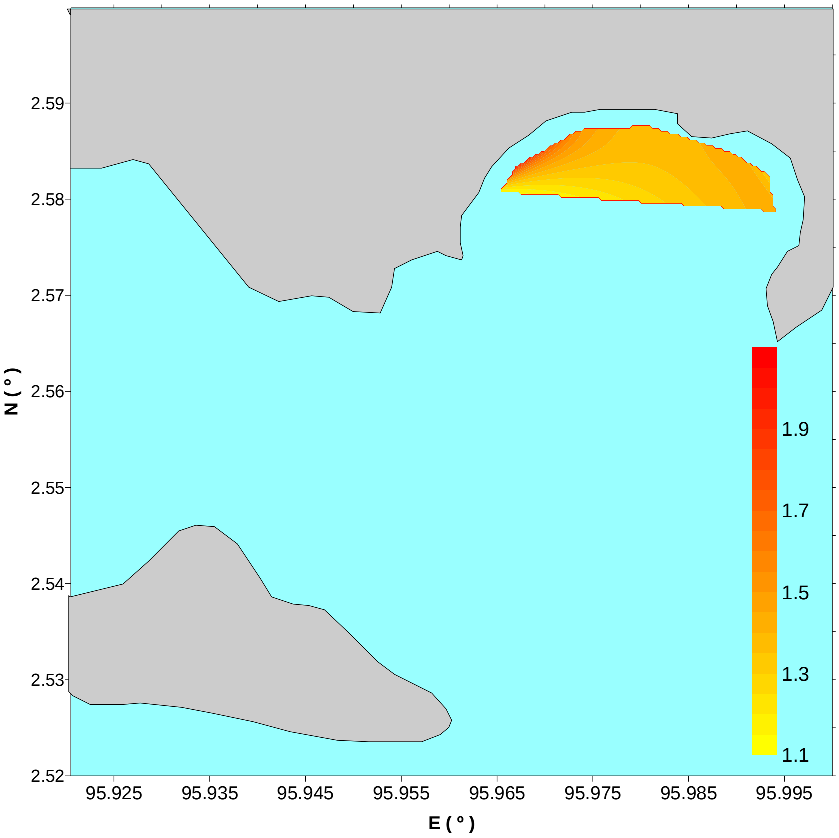

Figure 5. Calculated kurtosis value of Araban Bay sediment.

Discussion. Sediment grain size differences are closely related to the origin of sediment sources where sediment in outer bay is generally coarser than sediment in the inner bay region. Sediment found in coastal waters comes from various sources. The information obtained from the community states that the eastern side of Araban-Bay has experienced a lifting of seafloor that is associated with phenomena after the tsunami. The result obtained from the phenomenon is the presence of some areas of coral reefs rising above sea level. In the eastern half of Araban-Bay, located around station 7, coarse sandstone with silica-carbonate constituents is more common.

Variation in grain size distribution of Araban Bay may distinguish the energy level at depositional environment (Nordstrom 1977; Purnawan et al 2018b). Coarse-size sediments can be transported by high-energy transport agents, whilst certain energy level moves the grain from original location to depositional area (Wachecka-Kotkowska & Kotkowski 2011). So the presence of coarse sediment particles in some stations can be interpreted that the water area has a high energy level. The position of the station near the outer of the bay have conditions that are dealing with the open seas, where the waters have powerful currents and waves (Jeanson et al 2013). Southern oceanic conditions with stronger currents cause the sediment of coarse-grained fraction (sand-pebbles) rapidly precipitate, whereas the finer fraction cannot settle and is carried to calmer aquatic zone. Conditions in a more protected aquatic area, most likely a bay, would allow for finer-grained sediment to be settled. This condition can be seen in Figure 2, which indicates that the finer grain is found in the area of the inner bay.

The analysis results of the other statistical parameters of sorting, skewness, and kurtosis may explain the condition that exists in Araban Bay. Horizontal distribution of sorting parameters indicates a poorer-sorted condition that formed on the outer bay and shifts to a moderately sorted and moderately-well sorted condition on the inside of the bay (Figure 3). Better sorting conditions are the implications of the low energy variations that occur in the inner site of the bay. The energy entering the bay has been reduced, so the energy obtained is lowering (Verney et al 2013; Delpey et al 2014; Purnawan et al 2016). The process would deliver a relatively steady sea state on the inner bay area at most of the time.

The skewness parameter also describes the process of sediment distribution formed on the Araban Bay. The skewness conditions in the Araban Bay region resulted in very coarse skewed to fine skewed category. Symmetrical and fine-skewed categories are found at stations 4 and 5 which are located in the inner bay (Figure 4). This also may be affected by some of the tributaries discharge that is found around the inner area, thus adding finer grains that accumulate in the coastal area not far from the river mouth/estuary (Curray 1994). Slight number of coarser grained of the silica-carbonate sediments in the eastern bay contributed to addition to curve tail which lead to the coarse skewed shape.

Whilst station 1 has the lowest kurtosis value which categorized as mesokurtik, the horizontal distribution of the kurtosis value is seen to remain higher in the west (Figure 5). This is also influenced by station 2 which has the highest kurtosis value of 2.23, followed by station 3 which has a value of 1.52, where both stations are categorized as very leptokurtic. Futhermore, the kurtosis value for station 4-7 did not show any significant difference, as they are categorized as leptokurtic.

Such variations in the sediment distribution indicate the possibility of a slightly regular pattern along the Araban Bay that leads from west to east. Thereby it is associated with the mean grain size, skewness, sorting and kurtosis conditions, as had discussed earlier, it can be presumed that the process of sediment distribution found in Araban Bay refers to the specific seawater flow which affects the distribution of sediment in Araban Bay. The circulation of seawater and transport was not highlighted in this research yet the location of Araban Bay adjacent to the Indian Ocean is allegedly contributing to generate the process of sediment distribution in the Araban Bay coast. Based on Diansky et al (2006), we presume that the circulation regime of Indian Ocean toward northeast during winter monsoon result in high exposure to Araban Bay. In case of summer monsoon which moved toward southeast, the energy might be lowered by the position of Simeulue-Cut Island and Simeulue main land before it reaches Araban Bay.

Conclusions. All sediment samples obtained from Araban-Bay have a sediment size distribution mode located at 3φ or fine sand fraction. The inner shore of the bay has characteristic of fine-grain size, better sorted, and fine skewed. While on the outer of Araban Bay, sediments characterization are found as coarser in mean grain size, poorer sorted, and coarse skewed. The horizontal distribution of the kurtosis parameter showed a higher value in the western part of the bay.

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