The sediment distribution based on types of grain size in the Cirebon and Demak waters

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Abstract. Research on the sediment distribution based on types of grain size in the Cirebon and Demak waters has been conducted. The purposes of this research were to analyze the pattern of sediment distribution based on types of sediment grain size associated with the ocean surface current and rainfall patterns. The research was conducted in January, February, and March 2017 in the waters of Cirebon and Demak. Primary data used in this research was seabed sediment data, while secondary data included daily surface current data from HYCOM (HYbrid Coordinate Ocean Model) with resolution 0.08° and rainfall data. Sediment samples were taken by purposive sampling method at three point stations from each location. Sediment samples were analysed using wet sieving method at Marine Geology Laboratory of Diponegoro University, Semarang. The results showed that sediment texture in the Cirebon and Demak waters were dominated by sand, silt, and clay. The type of sediment in Demak waters was dominated by sand, whereas in the Cirebon region was dominated by sandy silt. The pattern of sediment distribution was generally parallel to the coastline. Current velocity affected the sediment distribution, where larger types of sedimentary grains were found in areas with higher current velocities. Demak waters with strong current velocity was dominated by sand originating from various sources in the oceans which are carried by the currents and deposited on the coast. Cirebon waters with weaker current velocity and higher rainfall was dominated by sandy silt originating from the rivers that flow into the sea.

1. Introduction
The waters of Cirebon and Demak are both located in the North Coast of Java which is one of the strategic areas for fisheries and port activities. The waters of Cirebon and Demak are strongly influenced by rivers that flow into these waters. Among them, there are watershed (DAS) from the Wulan river in Demak and the Gunung Ciremai watershed in Cirebon. The presence of rivers that flow into these waters causes the entry of sedimentary material from the land to the sea. The high activity on land such as erosion, mining, aquaculture, fisheries, and garbage, which is also suspected to be one of the factors causing sedimentation in the coastal area. Sedimentation processes can affect the water depth and ecological conditions [1].
Oceanographic factors that play a role in sediment distribution in a waters are current flows, especially relating to suspended sediments [2]. Current velocity indirectly affected the bottom of the waters [3]. In estuaries with strong currents, there would be many sandy substrates found because the larger particle size settled faster, while the small size will be carried away by current and wave activity [4]. In areas with high turbulence, fractions that have macroscopic appearance such as gravel and sand would settle faster than microscopic-sized fractions like mud. This sand distribution mechanism was very dependent on two interdependent factors, namely hydraulic sorting (hydraulic sorting) and precipitation [5].

In the coastal environment, sediments are dynamic which will be experienced by erosion, transportation, and deposition in spatial and temporal scales. Investigations to understand the dynamic processes that occurred in coastal environments is necessary for future predictions of coastal evolution. Cirebon and Demak are very dynamic coastal waters and are susceptible to coastal accretion and erosion. Therefore, it is necessary to study the distribution of sediments based on the type of grain size and their relation to current conditions in the waters of Cirebon and Demak.

2. Research Methods
The research method was carried out with quantitative methods. This research was conducted in January-March 2017 in the waters of Cirebon and Demak (Figure 1). The sampling technique was carried out by purposive sampling. Then, we took samples in 3 stations (Table 1) in each waters (Cirebon and Demak waters). Then, from each stations, we repeated samplings three times in.

![Figure 1. Water and Sediment Sampling Station in Cirebon and Demak waters](image)

Seabed sediments in coastal areas were obtained directly using hands. Sediment analysis was carried out at the Marine Geology Laboratory, majoring in Marine Sciences, Diponegoro University. The method used is the wet sieving method [6]. The sieve method and the pipetting method will
produce a retained sediment weight (in grams) which will then get the percentage and type of sediment.

To support the analysis, we also analyze the monthly average surface current flow patterns during January - March 2017 in the northern waters of Java that connected Cirebon waters with Demak. Surface current flow data was used in the form of model data from HYbrid (HYbrid Coordinate Ocean Model) with a resolution of 0.080 which was processed and displayed using the GrADS (Grid Analysis and Display System) software. Rainfall data used was monthly rainfall accumulation data from BMKG in Cirebon (Penggung rain station) and in Demak (Jatisono rain station). The locations of the chosen rain station were the closest location to sediment sampling and considered to represent the condition of the waters.

### Table 1. Research Sampling Location

| Location | Station | Coordinate         | Location Information                                                                 |
|----------|---------|--------------------|--------------------------------------------------------------------------------------|
| Cirebon waters | 1  | S06.75350° E108.60440° | Coastal Mundu Village, Mundu District, Cirebon Regency. This location is adjacent to the Mundu and Kalijaga rivers, especially place for fishing activities. |
| Cirebon waters | 2  | S06.73518° E108.58736° | Surrounding coastal waters, Lemahwungkuk District, Cirebon Regency. The location is close to the National Fishery Port Kebawan and place for tourism activity. |
| Cirebon waters | 3  | S06.64807° E108.56174° | Mertasinga Village, North Cirebon District, Cirebon Regency. This location is adjacent to PPI Bondet, especially use for many activities of fishermen, agriculture and mining of natural stone. |
| Demak waters | 1  | S06.91758° E110.48329° | Bedono Village, Sayung District, Demak Regency. This location is adjacent to the port of Tanjung Mas Semarang and Kaligawe Industry. |
| Demak waters | 2  | S06.81476° E110.54371° | Purworejo Village, Bonang District, Demak Regency. This location is adjacent to the Port of Morodemak resulting in many shipping activities. |
| Demak waters | 3  | S06.74098° E110.54623° | Bungo Village, Wedung District, Demak Regency. This location are well known as a place for many fishing and agricultural activities. |

### 3. Results and Discussions

#### 3.1. Sediment Type Analysis

Sediments are fractions, minerals, or organic materials that are transformed from various sources and deposited by air, wind, ice, or by water and also include material deposited from material that floats in water or in the form of chemical solutions. Based on the results of data analysis in Table 2, it is known that sedimentary characteristics in Cirebon and Demak waters consist of sand, silt, and clay with varying percentage values. The influence of the oceans was generally dominant in the two waters bordering the Java sea area in the north. Cirebon waters generally dominated by sand and silt with almost the same percentage, while in Demak waters, sand was very dominant compared to silt and clay.
Measurement of the physical and chemical conditions of the waters during sediment sampling was shown in Table 3. The dissolved oxygen levels in the water mass are relative and varied in value, usually ranging from 6-14 ppm [7]. Overall dissolved oxygen levels in these waters ranged between 7.19 - 8.46 ppm which included normal. Normal oxygen levels at sea level range from 5.7 to 8.5 ppm [8]. The degree of acidity (pH) in the waters of Cirebon ranged from 7.31 to 11.29, while the pH in the waters of Demak ranged between 7.55 - 7.96. A productive waters that support the survival of aquatic organisms (especially fish) which range from 6-9 [9]. Based on this statement, the waters of Cirebon and Demak were still classified as safe and can support the survival life of aquatic organisms.

### Table 2. Percentage of sediment in Cirebon and Demak waters

| Location | Month   | Percentage of Sediment Grains (%) | Sand  | Silt        | Clay     |
|----------|---------|----------------------------------|-------|-------------|----------|
| Cirebon  | Jan     | 44.59 ± 4.67                     | 47.63 ± 7.11 | 7.79 ± 2.44 |
|          | Feb     | 45.72 ± 8.87                     | 42.9 ± 5.54 | 11.38 ± 4.39 |
|          | Mar     | 34.69 ± 13.57                    | 47.37 ± 10 | 17.94 ± 3.58 |
| Demak    | Jan     | 84.53 ± 6.42                     | 9.14 ± 4.21  | 6.33 ± 2.25  |
|          | Feb     | 61.52 ± 21.12                    | 23.77 ± 12.75 | 14.71 ± 7.43 |
|          | Mar     | 59.45 ± 14.82                    | 27.03 ± 10.54 | 13.51 ± 4.28 |

The measured water temperature ranged from 30.17 - 31.22°C in the waters of Cirebon and 28.50 - 30.98°C in the waters of Demak. Variations in temperature values that occurred in these waters indicate that the temperature values in these waters are influenced by external factors including weather, wind and currents [10]. Salinity in the waters of Cirebon ranges from 18.95 - 28.44‰ while in the waters of Demak it ranges between 5.78 - 16.67‰. The distribution of salinity in the sea is influenced by various factors, such as the pattern of water circulation, evaporation, rainfall and river flow [11]. According to its distribution, the salinity around the coast is generally lower than the salinity of the high seas. This is because sea water that is near the mainland still has influence from the land causing low salinity in this area [12].

### Table 3. Physical and chemical conditions of waters during sediment sampling

| Location | Month | DO (ppm) | pH     | Temp (°C) | Salinity (%/ₒₒ) |
|----------|-------|----------|--------|-----------|-----------------|
| Cirebon  | Jan   | 7.74     | 11.29  | 30.17     | 18.95           |
|          | Feb   | 7.78     | 7.79   | 30.70     | 28.44           |
|          | Mar   | 7.19     | 7.31   | 31.22     | 21.44           |
| Demak    | Jan   | 8.46     | 7.96   | 30.03     | 16.67           |
|          | Feb   | 7.53     | 7.68   | 28.50     | 5.78            |
|          | Mar   | 7.30     | 7.55   | 30.98     | 10.22           |

### 3.2. Rainfall Analysis and Surface Current Flow Patterns

Differences in seasonal conditions will give different effects on water conditions. During January to March, the west wind dominantly blows to Java region due to the west monsoon / Asian Monsoon. During June to August, the east wind dominantly blows to Java region due to the east monsoon / Australian monsoon. The rainy season in Indonesia usually occurred in December to February because of the west monsoon, meanwhile the dry season usually occurred in July until August because of the east monsoon [12]. In general, the islands of Java, including Cirebon and Demak, were strongly...
influenced by seasonal cycle variability with monsoonal rainfall patterns. In areas with monsoonal rainfall patterns, rainfall was generally very high during the west season and reaches a low point during the east season [12].

In Figure 2, it could be seen that the rainfall in the Penggung Cirebon station was 733.4 mm in January 2017, 256.9 mm in February, and 351.7 mm in March, respectively. Rainfall at the Jatisono Demak station was 436 mm in January 2017, 479 mm in February, and 325 mm in March. The accumulation of monthly rainfall in January to March 2017 in Cirebon was generally higher than the rainfall in Demak, except for February 2017. However, from the average of January to March 2017, Cirebon rainfall was higher than Demak, with a slight difference (34 mm) (Figure 2a). The average rainfall data for the last 30 years (Figure 2b) also showed that rainfall in Cirebon was higher than Demak, with a difference of 43 mm.

The current patterns were analyzed spatially and then we analyzed the current velocity in the area as in the red box (1 and 2) in Figure 3. The current movement generally seemed parallel to the coast. In general, from January to March, surface currents move from west to east. This was because the movement of surface currents follows the movement of the wind that occurred during the west monsoon (west wind). This current movement will change dynamically following the season.
Figure 3. Monthly averages surface current flow patterns for 2017 on (a) January, (b) February, (c) March in Cirebon (1) Waters and Demak Waters (2)

To obtain the current velocity at the study location, each area in the Cirebon (1) and Demak (2) waters in Figure 3 was then analyzed to get the average value of the monthly surface current velocity and produce a monthly average value (Table 4). Based on Table 3, it could be seen that the monthly average surface current velocity in Demak was higher than in Cirebon.

| Month | Cirebon waters (1) | Demak waters (2) |
|-------|-------------------|------------------|
| Jan   | 0.049             | 0.138            |
| Feb   | 0.059             | 0.168            |
| Mar   | 0.030             | 0.067            |

3.3. Sediment Distribution Analysis

In general, the results of the analysis of sediment analysis in Cirebon and Demak waters showed that there were three sedimentary fractions in the area (sand, silt, and clay) which have different weight percentages at each point and period of sampling. Surface currents in the Cirebon waters were generally weaker than in the strong current waters of Demak. In addition, Demak waters were dominated by sand in a higher percentage than Cirebon. This statement was in line with [4] which stated that waters with strong current generally have sandy sedimentary texture.

The tendency of larger granular size types in stronger currents could be caused by the nature of the current which selects the grain size that is transferred in the sedimentation process. In areas with high turbulence due to strong currents, fractions that have macroscopic appearance such as gravel and sand will settle faster than microscopic-sized fractions such as clay [13]. This was what causes Demak waters to be dominated by sediment in the form of sand. Furthermore, sediments that are dominated by sand generally originate from volcanic rocks and other sources in the oceans which are carried by currents and deposited on the edge of coastal areas. Based on this statement, it can be said that sediments in the waters of Demak generally come from the ocean.

Different from Demak Waters, Cirebon waters were dominated by sandy silt. Sediments in the form of silt and clay generally come from rivers. This was because the river carries silt and clay and will accumulate especially in the estuary area. Rainfall intensity is very influential on river discharge with a coefficient of determination (R2) of 0.8031 which means that there was about 80.31% of the discharge can be explained by the rainfall intensity factor, while the remaining 19.69% was from another factor that cannot be explained by the system [14]. The high intensity of rainfall in Cirebon has resulted in the high flow of river water that carries sediment in the form of silt and clay and other organic matter to the estuary region. Based on this condition, it could be said that the sediments found in the waters of Cirebon generally come from rivers that flow into the sea.

Furthermore, the sediment grain size distribution is influenced by several factors such as the type of transport agent, wave, tidal, local wind and episodic storms which each have different spatial and temporal characteristics [15]. Surface currents in the Cirebon and Demak were parallel to the coastline and causing longshore sediment transport. Sediment transport along the coast occurs when sand is lifted by turbulence caused by waves breaking so that it can cause erosion and accretion in coastal areas [16]. Therefore, the waters of Cirebon and Demak were generally vulnerable to erosion and accretion due to sedimentation which were influenced by hydro-oceanographic aspects, coastal morphology, and human activities [17,18].
4. Conclusions

Sediment characteristics in Cirebon and Demak waters consist of sand, silt, and clay. Pattern of surface currents flow seemed following the monsoon period. The intensity of rainfall and sea surface current affected the type of sediment on the coastal area of Cirebon and Demak. Demak waters with strong current velocity was dominated by sand originating from various sources in the oceans which are carried by the currents and deposited on the coast. Cirebon waters with weaker current velocity and higher rainfall was dominated by sandy silt originating from the rivers that flow into the sea.

Recommendations

It is expected to conduct further research in the Cirebon and Demak waters with longer time scales in order to be able to determine the effect of monsoon and other hydro oceanographic factors on sediment distribution.

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