Identification of Marine Debris and Its Distribution Using Unmanned Aerial Vehicle (UAV) on the Cirebon Coastal Area, Indonesia

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Abstract. Marine debris can be a significant problem when it enters the ocean. One of the areas, which has a marine debris problem is Cirebon Coast. Such a problem occurs due to the high human population and activities in this particular coastal area. An effective cleaning method is required to prevent this problem. However, to determine the cleaning method, comprehensive information about the debris condition is required. Therefore, this study aims to identify the dominant types of marine debris and analyze the effect of tides on the characteristics and distribution of debris on the Cirebon Coast. This study carried out marine debris identification by orthophoto obtained from a DJI Phantom 4 Pro Unmanned Aerial Vehicle (UAV)/drone. The dominant types of marine debris on the Cirebon Coast are plastic and styrofoam. Based on the aerial imagery validation results, plastic and styrofoam larger than Ground Sample Distance (GSD) are easily detected. Visually, debris in Karang Anom more than in Rawa Urip. The change in tidal height can affect debris not visible on the orthophoto at the maximum water level. In addition, the tides can also move marine debris varying from 10 to 50 cm from its previous position. The debris area at Rawa Urip Beach when slack before flood tide (55.53 m²) is larger than the area when slack before ebb tide (52.71 m²). The debris area at Karang Anom Beach at low tide (129.89 m²) is larger than when slack before ebb tide (75.79 m²). This study revealed that the factors affecting debris area on the Cirebon Coast comprise tidal height, seawater visibility, and the beach structure (slope and coast components).

1. Introduction

The location of the Cirebon Coast as one of the northern coast lanes causes the Cirebon coast to be contaminated by shipping debris besides debris from Cirebon people themselves. Marine debris defined as persistent solid material produced or processed by humans, directly or indirectly, intentionally or unintentionally, disposed of or left in the marine environment, or flowed through rivers[1].

The existence of debris in the sea has a negative impact, especially on marine ecosystems, indirectly affects human life on land. The negative effects include the destruction of coral reefs, death of fish, and beach and coastal destruction. Floating solid marine debris with macro-debris can block the sunlight which is useful as an energy source for photosynthesized aquatic plants. In other words, the presence of
Marine debris can endanger marine life\cite{2}. The threat of this debris will be more serious if the local government does not immediately handle it.

Specific actions are needed to prevent and minimize its negative impacts through monitoring and cleaning methods of debris, especially on the coastal because it related to ocean dynamics such as tides. Cleaning the coastal debris can be done before the debris entered the ocean\cite{3}. Therefore, it requires some basic information, including the type of debris and debris changes in area so the cleaning method can be determined effectively and the management of marine debris can be improved\cite{4}.

The information is obtained from coastal debris monitoring. Technological advances have proven that remote sensing is the most ideal and effective alternative to monitoring marine debris without direct contact with the debris\cite{5}. Remote sensing platforms that can be used for beach debris monitoring are UAVs or drones\cite{6,7}. Drones are unmanned aircraft controlled and have cameras that can take small images with a high resolution without direct contact with the debris\cite{5}.

In this study, marine debris monitoring using UAV was carried out on the Cirebon Coast represented by Karang Anom Beach and Rawa Urip Beach. Karang Anom Beach was chosen because it close to residential areas and has a gentle slope, while Rawa Urip is far from residential areas and has a steeper beach slope. Differences in coastal morphology and seawater dynamics (type and area) can affect the debris condition at each location\cite{8,9}.

When entering the ocean, debris will be influenced by oceanographic factors such as tides which can shift debris from one place to another, even moving away from its source making it difficult to control. Therefore, the aims of this study is marine debris identification and analysis in the Cirebon Coast related to the effect of tidal changes. Information from this study is expected to help coastal managers and authorities to monitor environmental pollution, evaluate mitigation measures and improve cleaning operations in the Cirebon Coastal environment more effectively and efficiently.

2. Method

2.1. Study Area

This research was conducted at Karang Anom Beach, Lemahwungkuk District, Cirebon City, and Rawa Urip Beach, Pangenan District, Cirebon Regency, Indonesia. These two locations are located on north of Java Island or the PANTURA route that connects Jakarta-Cirebon-Semarang-Surabaya. The study area is shown in Figure 1.

Karang Anom Beach is dominated by settlements and mangroves with coordinates 6.735° to 6.744° S 108.585° to 108.594° E, while Rawa Urip Beach is dominated by salt ponds and mangroves with coordinates 6.768° to 6.773° S 108.676° to 108.678° E.
2.2 Data
The data used in this study is secondary data derived from drone mapping results obtained from MTCRC (Marine Technology Cooperation Research Center). The data was taken on September 28th, 2020 (Karang Anom) and September 30th, 2020 (Rawa Urip). The data was obtained in 4 orthophoto and 544 RAW images. The RAW is divided into 2 study areas, 272 images and 2 orthophoto in Karang Anom Beach (at slack before ebb tide and ebb tide) and 272 images and 2 orthophoto in Rawa Urip Beach (at slack before ebb tide and slack before flood tide).

2.3 Research Method
Monitoring of marine debris in this study uses orthophoto obtained using an Unmanned Aerial Vehicle (UAV)/drone with the DJI Phantom 4 Pro type. The DJI Phantom 4 Pro drone is a professional-grade drone for aerial imaging with several advantages: longer flight duration, longer transmitter distance, more stable flight due to the presence of 5 anti-collision sensors on each side, and has high accuracy to the centimeter level[5].

Aerial imagery is done with the technique of taking pictures, the position of the camera perpendicular to the imagery area. The aerial photography area is 1-km x 300 m in Karang Anom and 500 m x 300 m in Rawa Urip. The parameters specified in this application include angle of the camera 90°, front overlap 80%, side overlap 70%, flight direction 179°, drone speed normal, and altitude or drone flying height of 80 m. The estimated flight duration is 8 minutes 30 seconds (for an area of 55 x 575 m) and 9 minutes for each location (2 missions for each location).

Taking orthophoto is adjusted to the tidal conditions. It is done to see changes in the amount of debris due to the influence of tides. The time for taking orthophoto in Karang Anom Beach is on September 28th, 2020, at 10:00 (slack before ebb tide) and 12:00 (ebb tide), while in Rawa Urip Beach on September 30th, 2020, at 11:00 (slack before ebb tide) and 16:00 (slack before flood tide).

The drone is flown at a predetermined altitude with a flight path pre-created in the Pix4D Capture app. Aerial photos obtained are then selected based on whether or not the photo is clear. Photos that are tilted or have an angle that is not upright by 90° are then set aside so the remaining photos are ready to be processed using Pix4D Mapper to obtain corrected high-resolution images (orthophoto).

After obtaining the orthophoto, the identification of debris can be carried out. Along the research study area, it was found that seven areas that have debris are open to the sea, not covered by mangroves and the tidal influence is quite high, which are coded A, B, C, D, E, F, and G (Table 1). Areas with codes A, B, C, D, and E are located in Karang Anom, while areas with codes F and G are located in Rawa Urip.

| Table 1. Code and coordinates |
|-------------------------------|
| **Area Code** | **Coordinate** |
| A    | 108.586° East Longitude and 6.737° South Latitude |
| B    | 108.586° East Longitude and 6.737° South Latitude |
| C    | 108.587° East Longitude and 6.738° South Latitude |
| D    | 108.587° East Longitude and 6.739° South Latitude |
| E    | 108.588° East Longitude and 6.740° South Latitude |
| F    | 108.676° East Longitude and 6.769° South Latitude |
| G    | 108.676° East Longitude and 6.773° South Latitude |

Furthermore, the debris in each area began to be identified and a layout was carried out. The layout technique is a technique for placing images and word so it easy to read and look interesting. The layout image contains north direction, scale bar, and scale text. The debris area calculation in this study was carried out in 7 areas that have been marked with codes A to G (Table 1) by digitizing manually using the polygon feature in ArcGIS software.
3. Results and Discussion

Four orthophoto shown different tidal conditions at Karang Anom when slack before ebb tide (see Figure 2a) and ebb tide (see Figure 2b) also at Rawa Urip when slack before ebb tide (see Figure 3a) and slack before flood tide (see Figure 3b). The red box shows areas with beaches that are open to the sea and the debris have been identified, so they are selected as ROI.

**Figure 2.** Orthophoto of Karang Anom Beach on September 28th, 2020, at slack before ebb tide at 10:00 (a) and ebb tide at 12:00 (b).

**Figure 3** Orthophoto in Rawa Urip Beach on September 30th, 2020, at slack before ebb tide at 11:00 (a) and slack before flood tide at 16:00 (b).
The tides effect on the debris area was observed in an area of 225 m² (15 m x 15 m) selected in each coded area. This area is considered to represent changes in debris condition due to the tides influence because it is open from the mangroves and faces directly to the sea so that sea waves can easily interact with the debris in the area. The debris area will be shown through a polygon with a red line.

Figure 4. The condition of debris at slack before ebb tide (1) at 10:00 WIB and ebb tide (2) at 12:00 WIB in area A, Karang Anom, Cirebon on September 28th, 2020. The scale bar shows that 1 cm on the map is equal to 1 m on actual distance.

Area A is located in Karang Anom is an area close to residential areas. The debris condition was taken twice, namely at slack before ebb tide (see Figure 4a) and ebb tide (see Figure 4b). Based on the orthophoto, the debris contained in this area is rubber, wood/bamboo, plastic, pieces of asbestos, and cloth. Debris is piled up with a natural wave barrier consisting of twigs, tree trunks or bamboo, and tires arranged in this area. This natural wave barrier is referred as permeable breakwater. In addition to functioning as a wave barrier, this natural wave barrier is made to restore mangrove habitats that are prone to abrasion and maintain amount of the sediment circulation on the coast so that hydrodynamic and ecological conditions will return to normal and stimulate the addition of land that was previously eroded by erosion. The area located in Lemahwungkuk District experienced low abrasion with an abrasion rate of 490 m²/year[10].

The debris area reaches 68 m² when slack before ebb tide and reaches 98.23 m² when ebb tide. That shows that there is a change in the debris area of 30.23 m². The debris area identified at ebb tide is greater than when slack before ebb tide. The high and low water levels (tidal) will affect the volume/amount of debris in a coastal area.

Meanwhile, the debris under the water becomes invisible because the seawater is brown, muddy, and low visibility. In this area, the debris does not move but is only covered by seawater because the wave energy and tidal currents are smaller than the downward force of the debris. As a result, the debris of large size and weight cannot be moved. The factors that cause small wave energy and tidal currents in this area are because the beach slope in the Karang Anom area is very gentle, so the intertidal zone is getting bigger and the tidal run-up height is getting lower because of the distance that the waves have to reach the peak will be longer.

The debris condition found both at slack before ebb tide and ebb tide in area B is shown in Figure 5. The debris found in Area B was in the form of pieces of wood and plastic. Most of the debris is still covered by seawater at slack before ebb tide but will be visible at ebb tide. At slack before ebb tide (see Figure 5a), the wave crests look like glass but do not break, making it quite difficult to determine the debris in this area because white debris will be disguised. Based on the Beaufort scale, an empirical measure to explain wind speed from ocean observations, this feature indicates conditions with category 2 (speed 7 - 11 km/hour) is a light breeze. As for the effect of this wind, besides making the wave crests
look like glass, they can also generate waves with an average height of 30-60 cm or what is known as ripples.

Figure 5. The condition of debris at slack before ebb tide (1) at 10:00 WIB and ebb tide (2) at 12:00 WIB in area B, Karang Anom, Cirebon on September 28, 2020. The scale bar shows that 1 cm on the map is equal to 1 m on actual distance.

With the gentle beach slope, plus a light breeze, and the wave height reaching 30-60 cm, it cannot move debris significantly. The debris area is 5.96 m² when slack before ebb tide and reach 29.67 m² when ebb tide. That means that in different tidal conditions, with an interval of 2 hours, the debris area changes by 23.71 m².

The debris in area C is shown in Figure 6. Debris in this area are tree trunks and pieces of plastic. When slack before ebb tide the debris area is 0.8 m², while at ebb tide is 0.78 m². Debris moves 50 cm from its original place within 2 hours. That means that the tides can cause debris with a small size (0.03-0.04 m²) to move at a speed of 0.42 cm/s.

Figure 6. The debris condition at slack before ebb tide (1) at 10:00 WIB and ebb tide (2) at 12:00 WIB in area C, Karang Anom, Cirebon on September 28, 2020. The scale bar shows that 1 cm on the map is equal to 1 m on actual distance.

The moving debris has characteristics such as plastic with a low density than seawater so that will float on the surface and spread over long distances in the vast ocean because it is influenced by currents, winds, and waves [11].
The debris condition in D area at different tidal conditions is shown in Figure 7. The largest debris can be identified as the smallest debris area of all study areas, an area of 0.07 m$^2$. The total debris area obtained at slack before ebb tide and ebb tide respectively is 0.22 m$^2$ and 0.2 m$^2$.

Figure 7. The condition of debris at slack before ebb tide (1) at 10:00 WIB and ebb tide (2) at 12:00 WIB in area D, Karang Anom, Cirebon on September 28, 2020. The scale bar shows that 1 cm on the map is equal to 1 m on actual distance.

That could be because access from the settlement to the beach is limited by mangroves so no debris can be brought into the area through anthropogenic activities. The tidal effect does not significantly affect changes in the debris area, which is only 0.02 m$^2$. The identified debris looks like plastic with a small size and low density. Following the previous statement, getting to this area is difficult because mangroves limit it, so the debris in this area must come from other areas, which then arrive there due to being transported by sea dynamics such as tides.

The final result is the debris in area E is shown in Figure 8. The debris identified in this area is mostly mangrove stems/roots and only a small amount of plastic. The area at slack before ebb tide is 0.97 m$^2$, at slack before ebb tide is 0.85 m$^2$, and the difference is 0.12 m$^2$. In this area, the tides do not affect debris movement but generate new debris when ebb tide. The wave energy is small because the beach slope and the waves have been damped by the surrounding mangroves (front and side).

Figure 8. The debris condition at slack before ebb tide (1) at 10:00 WIB and ebb tide (2) at 12:00 WIB in area E, Karang Anom, Cirebon on September 28, 2020. The scale bar shows that 1 cm on the map is equal to 1 m on actual distance.
The debris contained in area F is shown in Figure 9. There is very little debris in this area because this area is quite far from residential areas. The debris found in this area are plastic (blue and white) and pieces of wood. Debris at slack before flood tide increases by one at the top right. That increasing amount of debris causes a difference in condition 1 (1.44 m²) and condition 2 (1.5 m²) of 0.06 m². The tidal in this area influence debris movement as far as 10 cm. The slope in this area is quite large compared to Karang Anom so the wave energy and tidal currents become strong.

![Figure 9](image1.png)

Figure 9. The condition of debris at slack before ebb tide (1) at 11:00 WIB and slack before flood tide (2) at 16:00 WIB in area F, Rawa Urip, Cirebon on September 30, 2020. The scale bar shows that 1 cm on the map is equal to 1 m on actual distance.

The mangroves with *Avicennia* type protects the area at the front-facing the sea. Behind the mangrove there is a shrimp pond. The land allotment for salt ponds can be seen in this area but has begun to be abraded since 2010 due to the large waves and during high tide conditions, seawater can inundate the salt ponds.

In contrast to area F, although it is still in the same area, Rawa Urip, the debris in area G (Figure 10) is quite large with various sizes. When observed at different times, there was a change in the amount and area of debris. In Figure 10a, which was taken at 11:00 a.m., a motorbike and some debris were caught, but in Figure 10b at 16:00, the debris is gone. That meant a human had moved it because it is impossible to move naturally because the debris is too large to move by itself.

![Figure 10](image2.png)

Figure 10. The condition of debris at slack before ebb tide (1) at 11:00 WIB and slack before flood tide (2) at 16:00 WIB in area G, Rawa Urip, Cirebon on September 30, 2020. The scale bar shows that 1 cm on the map is equal to 1 m on actual distance.
The tides affect the debris near the sea, which causes the debris movement about 50 cm. The low density of debris can cause this when flood tide, the debris floats and pushed towards the mainland. The area at slack before ebb tide is 51.27 m² and when slack before flood tide is 54.03 m². So the difference in this area about 2.76 m². The debris in this area is thought to be in banners, plastic, and cloth. The total and debris change in each area is written in Table 3 (Karang Anom) and Table 4 (Rawa Urip).

### Table 2. Debris area in Karang Anom

| No | Area | Area at slack before ebb tide (m²) | Area at slack before ebb tide (m²) | Change of area (m²) | Total area (m²) |
|----|------|----------------------------------|----------------------------------|--------------------|----------------|
| 1  | A    | 68                               | 98.23                            | 30.23              | 225            |
| 2  | B    | 5.96                             | 29.67                            | 23.71              | 225            |
| 3  | C    | 0.78                             | 0.8                              | 0.02               | 225            |
| 4  | D    | 0.2                              | 0.22                             | 0.02               | 225            |
| 5  | E    | 0.85                             | 0.97                             | 0.12               | 225            |
|    | Total| 75.79                            | 129.89                           | 54.1               | 1125           |

### Table 3. Debris area in Rawa Urip

| No | Area | Area at slack before ebb tide (m²) | Area at high tide condition (m²) | Change of area (m²) | Total area (m²) |
|----|------|----------------------------------|---------------------------------|--------------------|----------------|
| 1  | F    | 1.44                             | 1.5                             | 0.06               | 225            |
| 2  | G    | 51.27                            | 54.03                           | 2.76               | 225            |
|    | Total| 52.71                            | 55.53                           | 2.82               | 450            |

The change rate in the debris area can be calculated by dividing the change in area per change in time from the table. With the change in debris in Karang Anom of 54.2 m² in 2 hours, the rate of change in debris is 27.05 m²/hour. The rate of change of debris in Rawa Urip with a change in the debris of 2.82 m² within 7 hours is 0.4 m²/hour.

Overall, based on orthophoto, the amount of debris on Rawa Urip beach is less than Karang Anom Beach. Rawa Urip Beach is further away from residential areas while Karang Anom Beach is not much anthropogenic activity. Anthropogenic activity is thought to be the main cause of the emergence of much marine debris in the Cirebon Coast. Whereas in areas far from settlements, the debris comes from other places, which is then carried by the dynamics of seawater such as tidal currents.

Area A is the largest debris area, a buildup of debris carried by tidal currents from the southeast. In the southeastern part of this area is a river which is one of the sources of debris. Changes in the debris are influenced by the amount, type, and debris density itself. The factors that influence the debris movement are tides, beach slopes, and natural wave barriers such as mangroves.

### 4. Conclusion

The identification results were validated to aerial imagery and debris transect method. The calculation of debris area change was done by digitizing orthophoto manually using ArcGIS software. This study shows that drones usages at 10:00 and 16:00 are effective for identifying macro-sized debris. The dominant types of marine debris on the Cirebon Coast are plastic and styrofoam. Based on the aerial imagery validation results, plastic and styrofoam larger than Ground Sample Distance (GSD) are easily detected. Visually, debris in Karang Anom more than in Rawa Urip. The debris area at Rawa Urip Beach when slack before flood tide (55.53 m²) is larger than the area when slack before ebb tide (52.71 m²). The debris area at Karang Anom Beach at low tide (129.89 m²) is larger than when slack before ebb tide...
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