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The Influence of Meteorology-Oceanography Factors on Spatial Distribution of Oil and Grease Pollutant in Donan Estuary, Cilacap

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ABSTRACT

Donan Estuary is one of the watershed impacted by anthropogenic activities which more particularly from industry and shipping releasing environmental pollutants i.e. oil and grease. Analysis of oil and grease distribution due to meteorology-oceanography factors used spatial analysis method from primary data was taken on June 2017. This research aims to understand the spatial distribution of the concentration of oil and grease in Donan Estuary and to access the influence of wind (meteorology factor) and current (oceanography condition) on oil and grease distribution. Our research showed oil and grease concentrations varied among the studied area. The higher concentration of oil and grease were found at station 3 while lower concentration was observed at station 12, closed to Penyu Bay. Accordingly, such differences might be due to the different sources of pollutants and different meteorology-oceanography parameter characteristics that affect oil and grease distribution. For instance, oil and grease concentration was inversely proportional to current velocity. Based on tidal current, oil and grease were move forward to the South, West and South East at low tide and move to North and West at high tide. We noted that the direction of wind gave the low influence to oil and grease movement. The high concentration of oil and grease in each station were followed by Total Suspended Solid (TSS) enhancement. On the other hand, temperature has an effect on evaporation process of oil and grease volatile fraction.

Keywords: *donan estuary, oil and grease, spatial analysis, meteorology-oceanography.*

1. Introduction

Donan river and estuary has highly impacted by the industrial area including oil refinery industry and other anthropogenic activities. Aside as an Industrial area, it is an administrative area with seaports that functioning as shipping lanes or trafficking of commodities trade that can be a potential as sources of pollutants (Widhayanti et al., 2015).

Pollutants as a result of industrial activity in Cilacap becomes a factor of increasing the discharge of various kinds of pollutants that are spread through the river to the sea. There is a lot of kind of pollutant that contaminate the water, one of them is oil and grease. The term "oil and fat" usually refers to chemicals, mainly containing aliphatic and aromatic hydrocarbons (Syakti, 2016), derived from various sources ranging from crude oil and industrial derivatives to vegetable oils (Mendiola et al., 1998; Syakti et al., 2013) and fats and oleochemical derivatives. Due to the low biodegradability, the main contaminants of concern are oils and fats derived from petroleum (i.e., derived from fossil fuels) and derivatives that have found extensive industrial use (Abdullah et al., 1994).

Oil and grease are generally classified as serious types of hazardous pollutants particularly when entering into the aquatic environments where they pose high toxicity to the aquatic organisms and other ecological damages

(Mendiola et al., 1998; El- Gawad, 2014). Sedimentation, biota and its decomposition process contributed substantially to the oil and grease distribution and fate in the waters column. (Battacharya, 1999; Irwin et al., 1997). The characteristic of oil and grease are organic compounds that are less soluble in water (Tatem et al., 1978; Wake, 2005), so the presence of oil and grease compounds in the water will tend to form a separate layer on the top of the water. The presence of oil and grease from industrial waste and shipping scattered in the waters causes the formation of oil coatings that affect pollution problems such as decreased light penetration and photosynthesis (Alade et al., 2011), disturbed oxygen fixation resulting in lower dissolved oxygen (DO) levels that disrupt organism activity (Mohini et al., 2014).

The concentration of oil and grease in the water are spatially affected by chemical parameters (Behera et.al., 2014), that drift passively with the ocean current. As pollutant, Oil and grease in sea water are a chemically and physically active substance, interacting both with sea water, air and (suspended) sediment (Murawski and Nielsen, 2013). They are dispersed in the waters related to environmental factors i.e the currents and the wind (Wang et al., 2005; Husseien et al., 2009). The purpose of this research is to determine the concentration of oil and grease spatially and how the current (physical oceanography), wind (meteorology) influencing to oil and grease distribution.

2. Materials and Methods

The observation and survey method were used in this research. Observations were conducted in the form of water sampling from the Donan estuary area (Figure 1), which was carried out three times sampling for 1 month with a one-week time span at 12 stations. The Purposive Random Sampling technique was used to determine station point.

2.1. Data preparation

Oil and grease

Twelve sampling points were chose to analyse the oil and grease extent (Figure 1). 2000 mL of waters were sampled and pH was conditioned using sulfuric acid (H_2SO_4) to pH <2 and then stored in refrigerant prior for the analyse. Methods of oil and grease analysis are in accordance with SNI 06-6989.06-2004 (Gravimetric Method) (EPA, 2010; Astono et al., 2014). The calculation of oil and grease content is dealing with SNI 06-6989.06-2004 (Method Gravimetry) were defined following the equation :

$$\text{Oil and grease concentration in } (mg.L^{-1}) = \frac{(A - B) \times 1000}{mL \text{ sample}}$$

where :
A = weight conical flask + residu (mg);
B = weight of pre weighted conical flask (mg).

Total suspended solid (TSS) and temperature

TSS samples were stored quickly to a preset 4^oC temperature that serves to minimize microbiological decomposition of solids. The method used for the analysis of TSS parameters in accordance with SNI 06-6989.3-2004 (Method Gravimetric). Meanwhile, the calculation of TSS was defined following the equation,

$$\text{TSS per Litre} = \frac{(A - B) \times 1000}{mL \text{ sample}}$$

where :
A = filter weight + dry-weight of particle trap (mg);
B = filter weight (mg).

Temperature was measured by Conductivity Temperature Depth (CTD) and recorded automatically. CTD was released into the waters until it reaches the bottom of the water and was lifted again when it reaches the bottom of the water. Data record was downloaded using the SeaCast program in the form of Microsoft Excel Comma Separated Values (.csv).

Wind and current

Wind data was obtained from Indonesian Agency for Meteorological, Climatological and Geophysics (BMKG). Data was downloaded from wind wave program by inputting location data and data time required then after finished data will be available in excel format. The data was sorted as needed and processed using WRPlot software to get wind direction dominance. The resulting data was a picture of a wind rose diagram.

Current was measured by Current Meter AEM213-D and recorded instantly at a depth of 0.5-2.0 meters. It was downloaded using AEM213-D Communication programs in the form of Microsoft Excel Comma Separated Values (.csv) file.

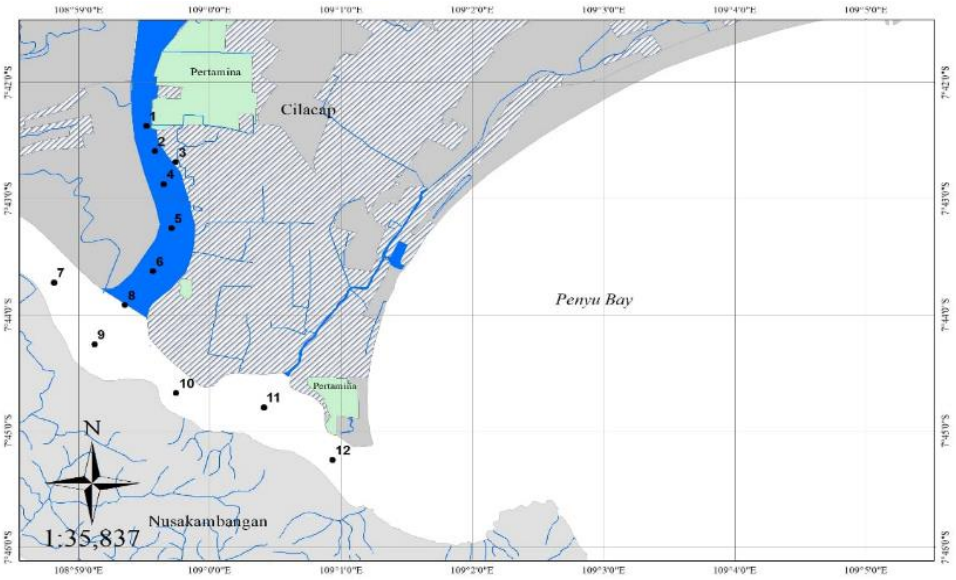


Figure 1. Sampling site of oil and grease in donan estuary, Cilacap

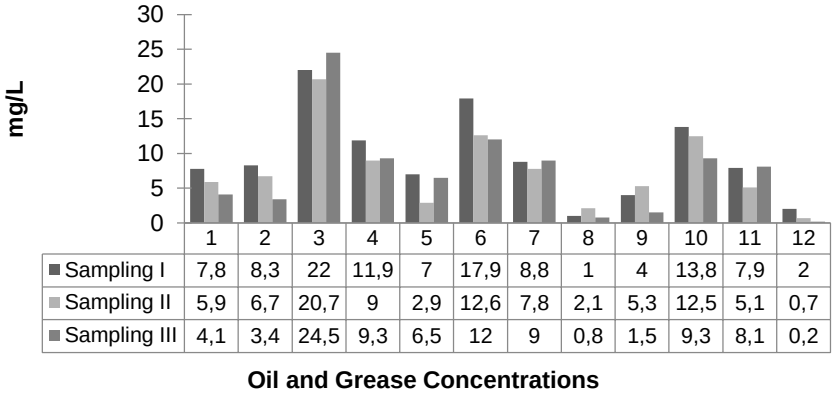
2.2. Spatial distribution of oil dan grease

Spatial distribution of oil and grease are displayed using ArcGIS 10.3. The concentration values were inserted into the map according to the coordinate data. Furthermore, they are interpolated with IDW method (Pramono, 2008) and visualized in the form of a color pattern on each station that illustrates the concentration value of oil and grease.

3. Results and Discussion

3.1. Distribution of oil and grease in Donan Estuary

The concentrations of oil and grease based on laboratory analysis showed a different value for each observation. There might be due to the different activities and sources of pollutants in each location. Moreover, aquatic physicals factors have an important influence on the presence of oil and grease in the waters. The difference among oil and grease concentration in each station was shown in Figure 2.



	1	2	3	4	5	6	7	8	9	10	11	12
Sampling I	7,8	8,3	22	11,9	7	17,9	8,8	1	4	13,8	7,9	2
Sampling II	5,9	6,7	20,7	9	2,9	12,6	7,8	2,1	5,3	12,5	5,1	0,7
Sampling III	4,1	3,4	24,5	9,3	6,5	12	9	0,8	1,5	9,3	8,1	0,2

Figure 2. Oil and grease concentration in Donan Estuary. Sampling I in June 8th II in June 15th, an III in June 20th , 2017

Based on the graph, it can be seen that the concentration of oil and grease spread over each station was different. The average value of the highest concentrations of oil and grease found in station 3 of 22.4 $mg.L^{-1}$. It is related with the estuary of Kali Panas (Station 3) is near from the outfall of the waste disposal of a refinery site. The waste waters were flowing from Kali Panas to Donan River. In these locations, the water characteristics are different from the upstrem stations. When sampling at station 3, the water at that location tends to be warmer than other stations. In addition, in the waters are very smell of waste oil. While the lowest concentration was at station 12 located before Penyu Bay has an average of 0.9 $mg.L^{-1}$. Significant concentration differences at stations 3 and 12 are possible due to the different sources of pollutants, different water depth characteristics that affect oil and grease distribution.

On other stations, the tendency of concentration was lower than station 3 but higher than at station 12. Station 1 and 2 are a refinery site area before estuary of Kali Panas has a tendency of oil and grease concentration which has smaller than station 3 located at the estuary of Kali Panas. The average concentrations of oil and grease at stations 1 and 2 are 5.9 $mg.L^{-1}$and 6.1 $mg.L^{-1}$, respectively. Stations 1 and 2 contain shipping activities, either bringing sand or tourists. In addition to the fishing activities of the fishermen, the location was traversed by Pertamina shipping.

Station 4 has an average concentration of 10.6 $mg.L^{-1}$. The concentration of oil and grease at the station tend to be smaller compared to station 3 and greater than station 1 and 2. It's possible that the location has still affected by the waste stream from the estuary of the Kali Panas even though the location was a residential free mangrove area, shipping activities in those locations are more high than stations 1 and 2. In addition, this station is a dredging location has been conducted by a cement factory. Station 5 was a station in the Navigational District water area. In this region was a docking place. The average concentration of oil and grease in this station was 5.4 $mg.L^{-1}$ respectively. The concentration of oil and grease in this region tend to be lower than station 6.

While at station 6 was a port area has an average concentration tends to be higher than stations 4 and 5 that is 14.1 $mg.L^{-1}$. It's possible that the presence of such oil and grease is related to shipping activities in ports and waste disposal settlements. In this region, shipping activities were dominated by big vessel that leans and begins shipping activities to the high seas. Station 7 has an average concentration of 8.5 $mg.L^{-1}$, the concentration of this station tends to be lower than the previous station but station 7 was still affected by shipbuilding activity at station 6 and settlement activity.

The concentration of oil and grease stations 8 tend to be lower than the upstream stations, the grease oil concentration at this station has an average of 3.9 $mg.L^{-1}$. Sampling at station 8 at the location of the waters west of Donan Estuary toward to Segara Anakan Lagoon with a depth of 1-2 meters. The low concentrations of oil and grease at this location may not have too many shipping activities, some fishing vessels, sand transport vessel and tourist transport vessels that travel at that location.

Station 9 was a station located on the coast of Nusakambangan island crossing directly with the mouth of the Donan River with an average concentration of 3.6 $mg.L^{-1}$. The concentration of oil and grease in this station tend to higher than station 8. Station 10 was the location of cement factory activity and has an average concentration of 12.03 $mg.L^{-1}$. It has influenced by large vessel and fishing vessels activities. The concentration of oil and grease tend to high compared to the previous station, it were caused movement of oil and grease have traped by the cement factory construction so that the pollutants tend to gather at station 10.

In contrast to station 11 which was a sampling site in the fishing port area with consecutive concentrations of 7.03 $mg.L^{-1}$. The concentration of oil and grease were lower than station 10. The presence of oil and grease in the region has influenced by the flow so that the pollutant moves freely and spreads.

According to Minister Decree No. 51 from the Minister of Environment (Kepmen LH, 2004), the standard quality of allowed oil and grease in waters is below 1 $mg.L^{-1}$. However, the observation results showed that the concentration of oil and grease at the site was predominantly above the standard quality threshold already set. Overall, the presence of oil and grease in the waters has linked to the source of pollutants, but the oil and grease in the waters undergo several processes called weathering of oil (Mukhtasor, 2007). Weathering oil was a process of spilling oil that spills results from a

number of chemical and physical processes that alter the composition. Oil will experience weathering process in different ways. Some processes, such as in the natural dispersion of oil into the water, cause parts of the oil to leave the water surface, and the remainder, such as in evaporation or water formation in oil emulsions, result in oil remaining on the surface and staying for a long period (persistent). Oil and grease in aquatic environments form thin layers as well as increased evaporation. The loss of some volatile material causes more solid, heavy and drowned oil (Pikkarainen and Lemponen, 2005).

Spatially, the distribution of oil and grease in the waters of the Estuary of the Donan River presented in Figure 3. The interpolation of oil and grease distribution illustrated with different patterns and colours on each station depicting the concentration.

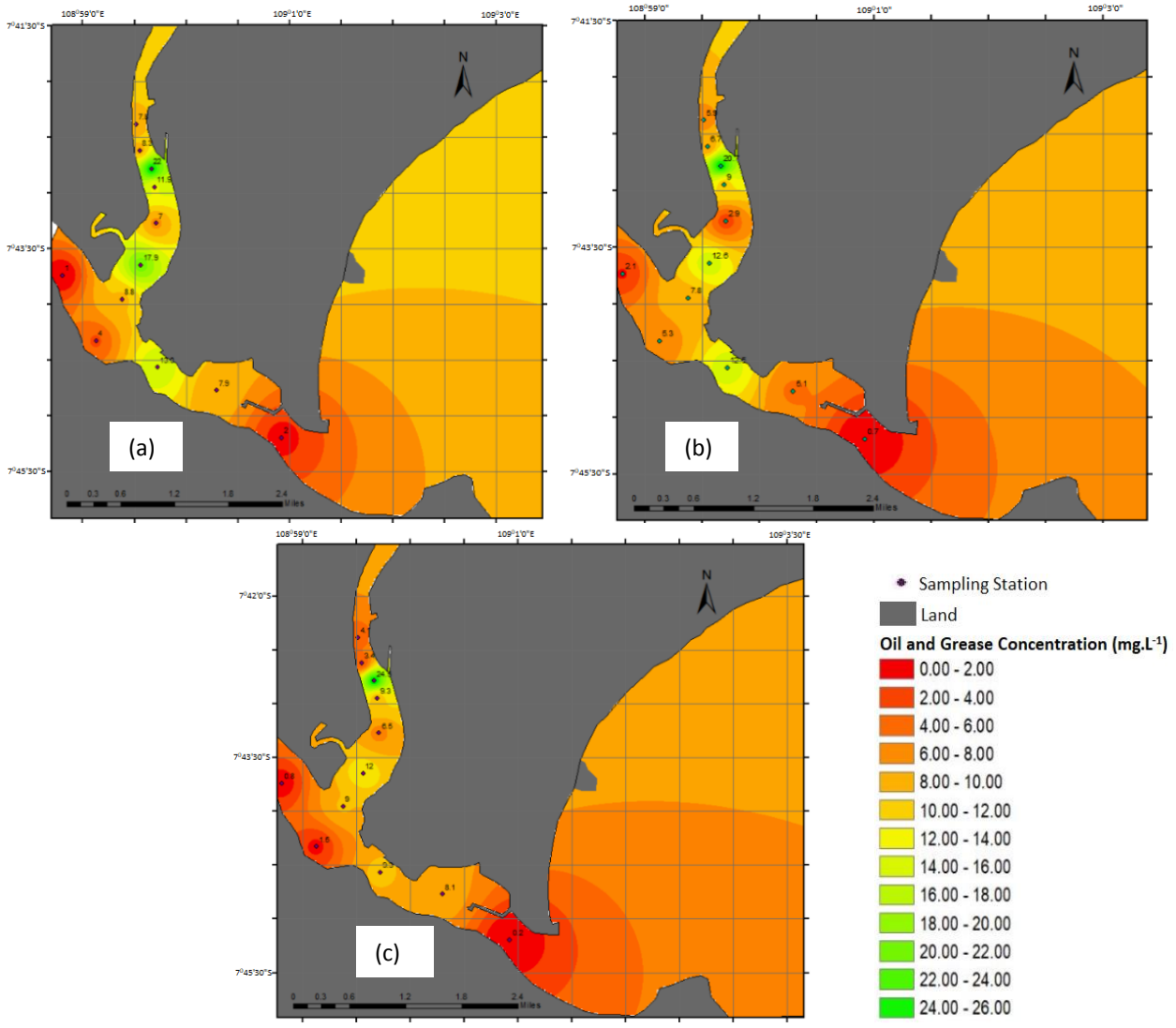


Figure 3. Current Distribution at Donan Estuary, Cilacap (a) June 8th, 2017 (b) June 15th , 2017 (c) June 20th , 2017.

Based on the map pattern distribution of oil and grease in the waters of Donan Estuary, pollutants tend to spread. It was because the water base varies and the influence of tidal currents that make oil and grease was moved and make a variety of chemical physics processes. Oil and grease in the waters of Donan Estuary spread influenced by the factor of tidal and wind currents.

2.3. Current effect to oil and grease movement

Current has an important influence on the distribution of oil and grease in the waters. The current movement is influenced by the type of tidal and basic water conditions. Tidal types are known to be a semi-diurnal type (Cahyo, 2012). Data retrieval was carried out on the condition towards the tide until it becomes low tide in the morning until afternoon starting from station 1 to station 12. The result of current velocity measurement at Donan Estuary is about 0.01 - 1.2 $m.s^{-1}$ with average 0.3 $m.s^{-1}$. The current generated by the tides in the research area tends to have an alternating direction in accordance with the tide that occurs. Maximum tidal velocity is formed at station 12 located before Penyu Bay coastal waters of 1.2 $m.s^{-1}$ in full-moon condition.

The condition of the sea level recedes or to the ebb and flow of the current from the mouth to the sea, the current velocity reaches a greater or greater value. While the sea surface conditions to the tide, the current moves into the estuary. The current condition of the waters based on the results of the study has been illustrated in the map of oil and grease distribution has been shown in Figure 4. The direction of current distribution in each sample has a different direction.

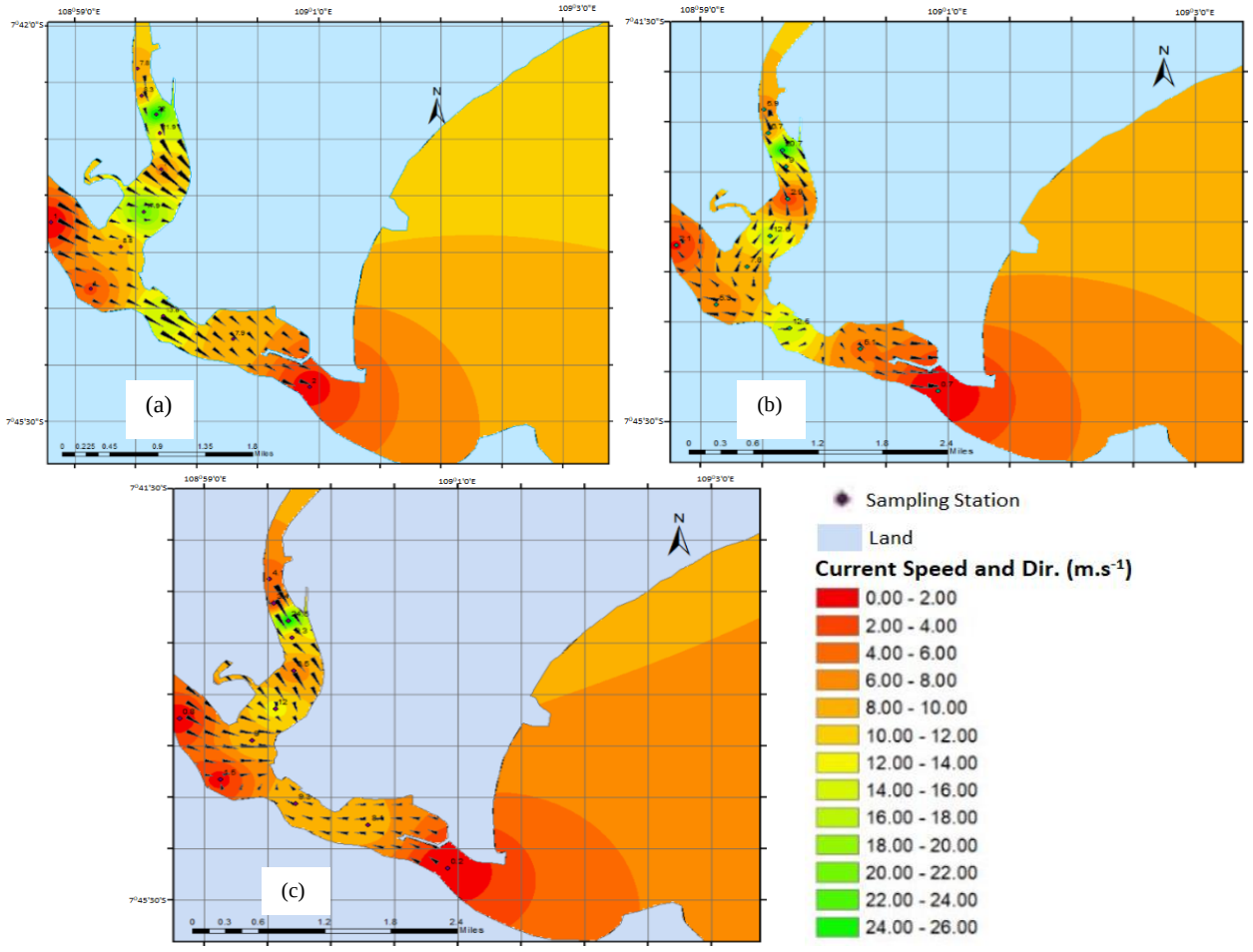


Figure 4. Current condition in Donan Estuary (a) June 8th, 2017 at ebb current, (b) 15 June 2017 pada leading to spring, (c) 20 June 2017 leading to ebb current

The first sampling site showed that the condition of the sea level toward low tide, the current move into the estuary tends to move south and then turn eastwards on the Donan River because the flow from the tiller moves eastward to the ocean. However, at station 9 around the confluence of the river and Segara Anakan, there is a flow of currents to the southeast of this matter possible flow through a narrow location and there are several structures of buildings and activities of ships that lean in the port on this area.

The current condition in the first sampling tends to be drawn only towards the pairs because when sampling is faster than second and third sampling. The second sampling condition of ocean currents from the sea to the Donan River, to the north and to the northwest, with a relatively lower speed compared to the conditions to recede, while the sea surface conditions recede the current move from the estuary to the sea with flow velocity reaches greater value or the maximum tend to move south and east out into the oceans and at the basin of the area before the Penyu Bay turns to the northeast of the current from the mainland to the sea obstructed by a shallow and deep shallow boundary structure.

The condition of the current movement in the third sampling, the current moves to the southeast of the Donan River and from the direction of the tiller moves eastward and turns at the confluence of the river this is because from the direction of the sea there is a condition toward the pairs that bring in the flow to the west. This difference in direction of flow occurs because the difference in sampling time was carried out starting from the first sampling when the condition goes to low tide, and on the second sampling occurs on the condition to the pairs and plug in the first 9 stations to describe the moving currents from the estuary towards the moving sea to the southeast and at the 10th station begins to change to recede so that at station 10 current has been moved from the estuary to the sea. Meanwhile, on the 3rd sampling conducted on the condition to go down to the pairs. Taking from the first station until 8 at low tide condition, then at station 9 happened to a condition of pairs, there was a change of direction of current from station 9 to 12 because of current came from sea to estuary.

Based on the results of the study obtained when the current velocity decreases, the concentration of oil and grease increases at the station. While current velocity increases the concentration of oil and grease at the station decreases (Figure 5). As in station 1, the average oil concentration is 5.93 $mg.L^{-1}$ while the current velocity is 0.60 $m.s^{-1}$. Station 2 with current velocity 0.43 $m.s^{-1}$, has oil and grease concentration of 6,13 $mg.L^{-1}$. Station 3 with an average oil and grease concentration of 22.4 $mg.L^{-1}$, the mean current velocity is 0.18 $m.s^{-1}$. Meanwhile the station 4, the average oil concentration is 10.7 $mg.L^{-1}$ and the current velocity is 0.49 $m.s^{-1}$. It means that the current condition increases the presence of oil in the waters decrease in addition caused by the source of pollutants may occur along with the current velocity that affects the distribution of oil and grease.

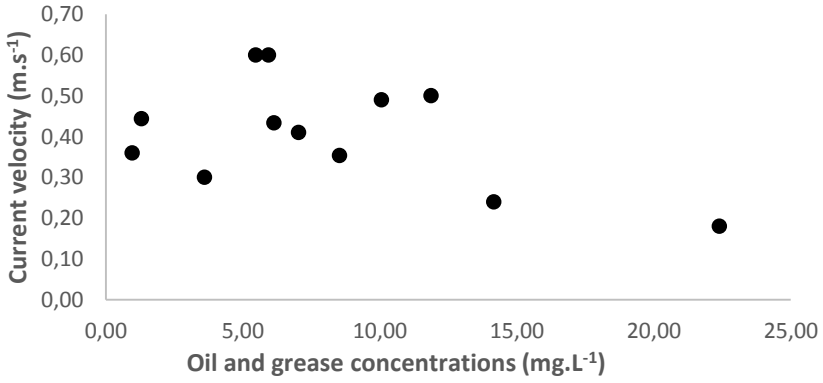


Figure 5. Current velocity to oil and grease movement in Donan Estuary, Cilacap

The change in current velocity is inversely proportional to the oil and grease concentration value of each station. Generally, as the velocity increased, the oil and grease would drift faster and contaminate area would be larger (Peishi et al., 2011). In this research, the difference in proximity to the source is suspected to be the cause of this condition.

2.4. Wind effect to oil and grease movement

Wind data on June showed, dominant from the southeast with an average speed of 8.98 knots. The direction of wind roses (figure 6), the results of data processing in Windrose, was divided into 2 directions of the wind direction of 8 wind direction of which comes from the Southeast (South East) and East (East). The dominance of the wind moves from the southeast by 54% and from the east by 44% with various classes of wind speeds starting from 1 -17 knots.

Wind speed on June based on the data was divided into 4 successive classes namely low speed ranges from 1-4 knots, medium speed ranges from 4 to 7 knots, high speed ranges from 7 to 11 knots and high speed ranges from 11-17 knots. The highest frequency about 60.1% is obtained from the 7-11 knot class with the direction of the winds coming from the southeast. Meanwhile, the lowest frequency is in grades 1-4 knots with a percentage of about 2.2%. It showed that the dominant direction of the wind is from the southeast. This is in accordance with Kurniawan et.al. (2011) research which states that during of June, the wind in the Territory of Indonesia entering the Southeast season, where this month the Australian Monsoon blows from the Southeast across the Indonesian territory to the West.

The influence of the wind gave its own impact on the distribution of oil and grease. The oil layer generally moves in the same direction as the wind movement (Wang et al., 2005; Husseien et al., 2009; Wardhana, 2004). Therefore, the spread of oil layers located at the sea surface was also affected by the surface wind. If the wind speed is blowing larger than 20 $km.h^{-1}$ which of course occurs in the open sea, the dispersion of the oil layer is determined by the local wind conditions. This does not apply if wind speeds are less than 10 $km.h^{-1}$ where the wind does not play an important role in the oil dispersal process (Fingas, 2000). Meanwhile, based on the observation of the research location, the wind blew at an average speed of about 8.9 knots, which means the wind speed is smaller than 20 $km.h^{-1}$ so that the wind has little effect on the distribution of oil and grease.

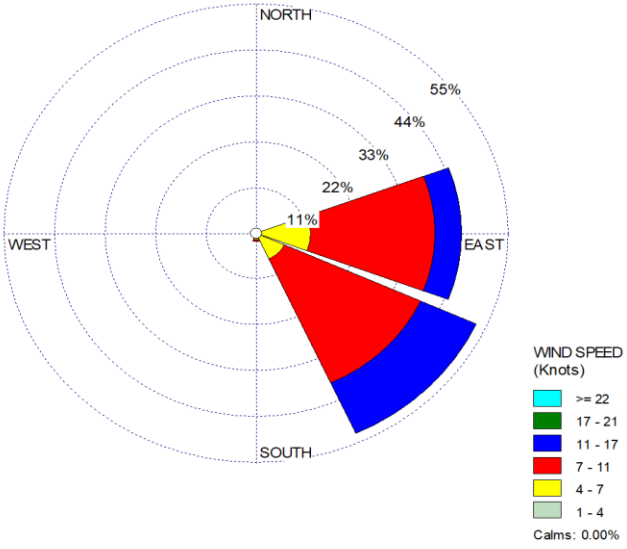


Figure 6. Windrose on June 2017

2.5. Total suspended solid and temperature effect to oil and grease

Oil and Grease analyzed at each station have different concentrations. Oil and grease distribution was influenced by current, tidal, wind. In addition, the presence of oil and grease related to the presence of TSS and water temperatures. TSS and temperature values in each station have different values. The Temperature distribution when sampling oil and grease presented in Figure 7.

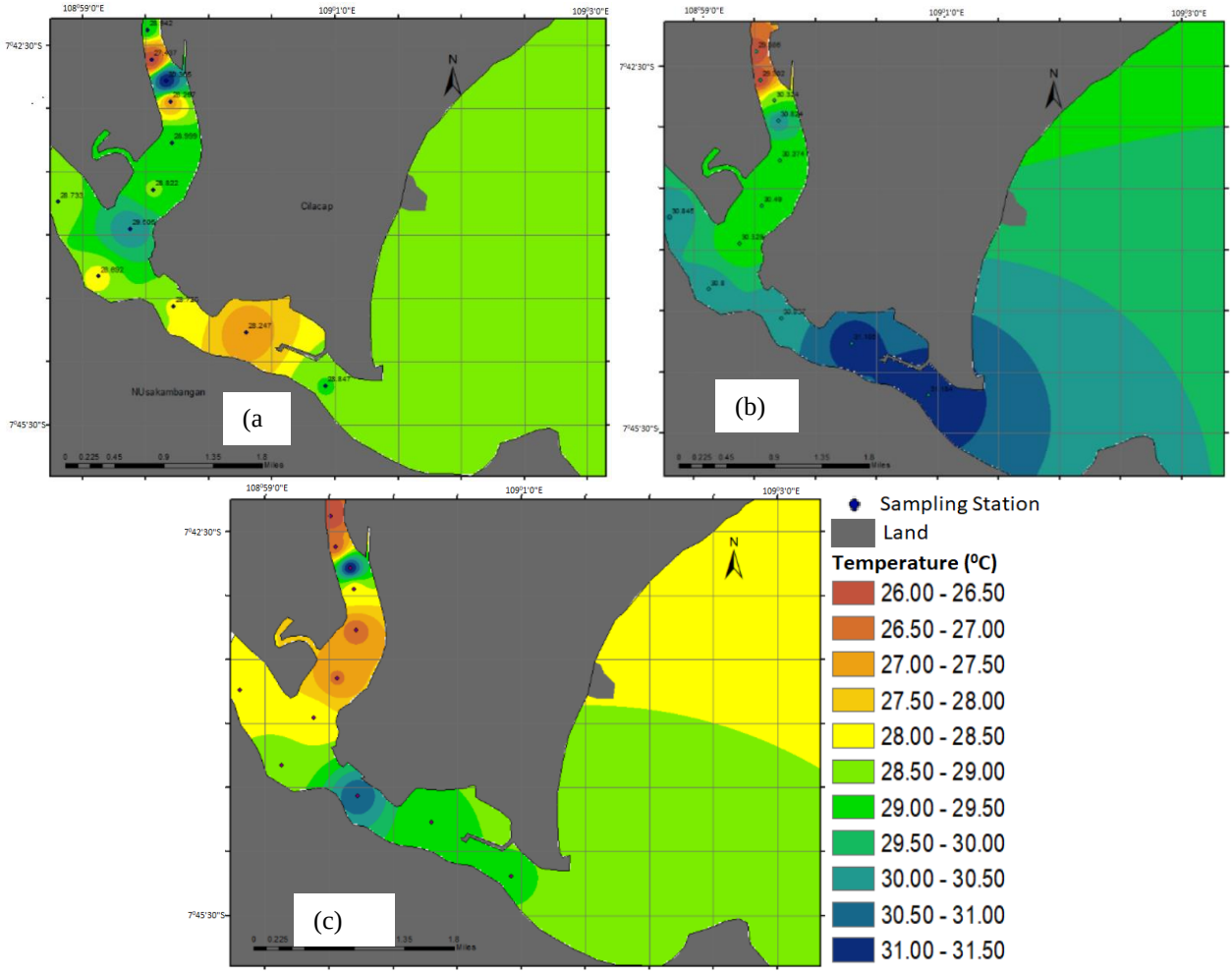


Figure 7. Distribution of Temperature at Donan Estuary, Cilacap (a) June 8th, 2017 (b) June 15th, 2017 (c) June 20th , 2017.

Water temperatures have a range of 26°C - 32°C with the highest average temperature at station 3. This is possibly influenced by high-temperature oil waste so that the waters at station 3 tend to be warmer than other stations. According to Kinne (1964), water temperatures in the estuary area typically show greater annual and diurnal fluctuations than the ocean, especially if the estuary is shallow and the water coming (at rising) into the estuary waters is in contact with the area with the substrate exposed. The value of water temperature affects the oil and grease is in the process of weathering oil at evaporation stage. Some oil and grease fractions tend to evaporate at high temperatures. Light oils such as gasoline can evaporate up to 90% of the total volume for two days, while light oils evaporate up to 40%, heavy crude oil (residue) evaporates alkane and aromatic compounds for 1-10 days (Khan, 2006).

Meanwhile, TSS which is a factor affecting the existence of oil and grease have different

values on each station. TSS at the site has a range of 156 - 312 mg.L^{-1}. This TSS condition has been depicted in each station shown in Figure 8. Pamungkas et al. (2014), stated that the water content of TSS of Muara Sungai Donan has an average of 258,6 mg.L^{-1}. High TSS levels in a waters make the waters turbid and cause difficult light into the water column. Besides, TSS has a role in the process of oil clump.

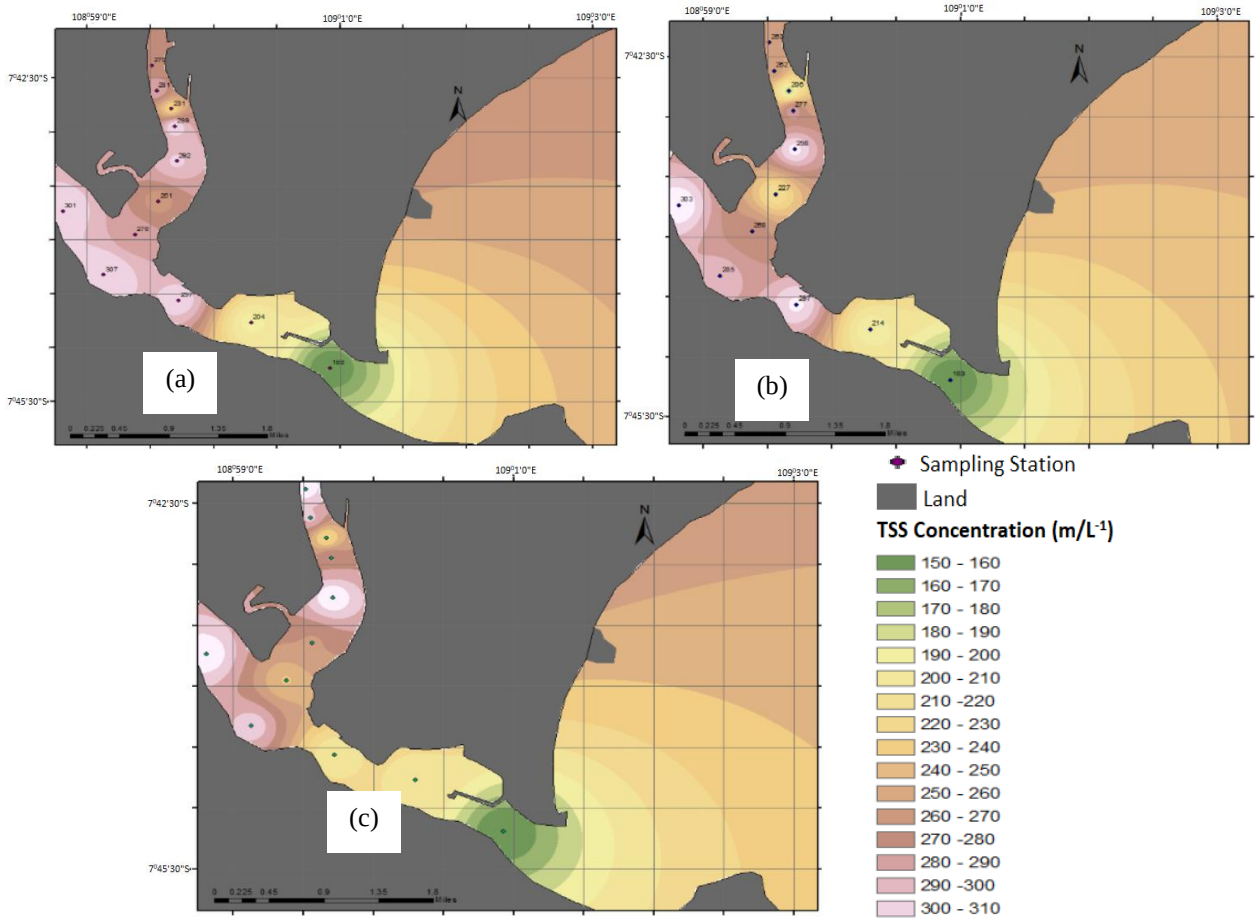


Figure 8. TSS Pattern in Donan Estuary, Cilacap (a) June 8th, 2017 (b) June 15th, 2017 (c) June 20th, 2017.

Based on the average TSS pattern has a high value at stations 8, 9 and 10. While at station 6 there is a buildup of sediment so that at station 6 it tends not to form a significant distribution pattern. The value of TSS decreases at stations 11 and 12. Tarigan and Edward (2003) research mentions that at the mouth of the river the value of TSS was likely to be larger, it's caused by sedimentation and organic waste carrying river currents containing solids that cause water turbidity. The TSS value of the research results includes exceeding the standard quality threshold that has been stipulated in Government Regulation no. 82 The year 2001 namely the value of suspended solids of <50 mg.L^{-1}.

The pattern of TSS distribution and temperature at each observation station has a relationship to the presence of oil and grease. Based on the pattern of TSS distribution and oil and grease, stations with high TSS values tend to have higher concentrations of oil and grease and decreased TSS values followed by a decrease in the value of oil and grease, because of the old suspension material deposited in the water. In addition, variations in the depth of the study sites

have an important impact on the presence of TSS.

3. Conclusion

Based on the research results it can be concluded that different oil and grease concentrations in each station are influenced by the different activities of the source of the pollutants.. In addition, the increase in oil and grease concentrations at each station was followed by a decrease in the current velocity of each station. While the high concentration of oil and grease in each linear station with a high value of TSS. While temperature as supporting data research influence to evaporation process some fraction of oil and grease in waters. The other hand, the wind has little effect on the distribution of oil and grease.

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