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AN OVERVIEW OF SURFACE WATER QUALITY INFLUENCED BY SUSPENDED SOLID CONTENT IN THE SAYUNG WATERS, DEMAK, INDONESIA

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ABSTRACT

Abrasion which is occurred in the Sayung coast is triggered by a big role of climate change as well as the sea level rise and land subsidence. Resulting degradation ultimately affects changes in existing environmental conditions. This study aims to determine the existing water based on biological and chemical content which is affected by increasing suspended solid content in the Sayung waters. Purposive sampling technique was applied. Data were analyzed both statistically and spatially. Suspended solid value ranged between 23,1-199,6 mg/L. Distribution of suspended solid was only simulated during low tide towards high tide phase with current speed of 0-0.41 m/s. We found that dissolved oxygen value was quite high in several observation stations which indicates the fertile area with low pollution and blooming tendency. In the station where suspended solid and turbidity were high, the chlorophyll-a contents were decreased. The high concentration of suspended solid directly triggers the turbidity enhancement and declines the photosynthesis activity, which is related with marine pollution. Resulting in the primary productivity reduction in the Sayung waters.

Keywords: Hydrodynamics, Sayung waters, Suspended solid content, Water quality

INTRODUCTION

SSayung coastal area is prone to abrasion due to oceanographic and climatic factors which are destructive. As a result, level of solid particles suspension increased in the Sayung Waters (Pranoto et al., 2016). The turbulence led to enhance the turbidity, will directly inhibit the process of photosynthesis by phytoplankton and other autotroph biotas. It is crucial in terms of primary productivity reduction (Hendrarto & Nitisuparjo, 2011).

Suspended solid content is a total number of solids which is suspended and floated in water column. Suspended solid is strongly transported by water mass transport. At some point, it will settle back to the bottom when the tidal flow is weaker (Wisha & Heriati, 2016). Sayung water has a tendency of flow pattern that varies depends on the winds in the surrounding the area. The wind moves towards the coast and generates longshore current, which is the main agent of erosion (Ondara & Wisha, 2016). This situation will be affected to coastal changes (Widada *et al*., 2012). Every change in coastal area is easier to detect by employing the status of water quality which is caused by enhancing of suspended sediment and the other solid substances in waters (Wisha *et al*., 2015).

Suspended solid observation is necessary to determine the existing water quality. The high concentration of suspended solid can trigger the primary productivity reduction. Actually, the suspended solid and chlorophyll-a are the major indicator of water pollution determinant, which is represented the initial condition of the water. The identification and correlation between those parameters has been developed by employing gravimetric method and spatial analysis as well.

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Previous studies by Sidqi *et al*. (2003), Arief & Lestari. (2006), Wulandary *et al*. (2014), and Purwaningsih *et al*. (2015) defined that the concentration of suspended solid in the Sayung waters was increased every year, so the study of suspended solid content is necessary to conduct due to not only the bad impacts on the environment but also updating data on the latest condition of solid contamination in Sayung waters, Demak. This study aims to determine the existing condition of water condition viewed from biological and chemical oceanography aspects resulted by the increasing of suspended solid content in the Sayung waters.

METHODOLOGY

Data included bathymetry measured in 2016, the latest coastline from Google Eye image, current, tide, and water quality. Data of tide forecasting and topographical digital map of Indonesia are used in this study. Samples were taken from 18 observation points (Figure 1) along the coastal area. The purposive sampling technique was applied to determinate the sampling sites representing the study area (Wisha *et al*., 2016b).

Sampling was conducted during low towards high tidal condition based on tide forecasting by ERGtide. The forecasted data becomes a basis of Acoustic Doppler Current Profiler (ADCP) measurement which was deployed for 18 days before taking the water quality data. It was measured using water quality checker (WQC) multi-parameter during 1 tidal phase, i.e. on March 23, 2016 at 08:00 to 12:00 am (Figure 2).

ADCP deployment was done from 03/04/2016 at 15:00 pm until 03/22/2016 at 12.00 am with approximate measurements of 18 days, it was sufficient to represent the full cycle of spring and neap tides. The ADCP records several physical data such as tide, temperature, and current. Tide data are used as input for tide forecasting. In another case, the currents and tides data are used in the verification the hydrodynamic

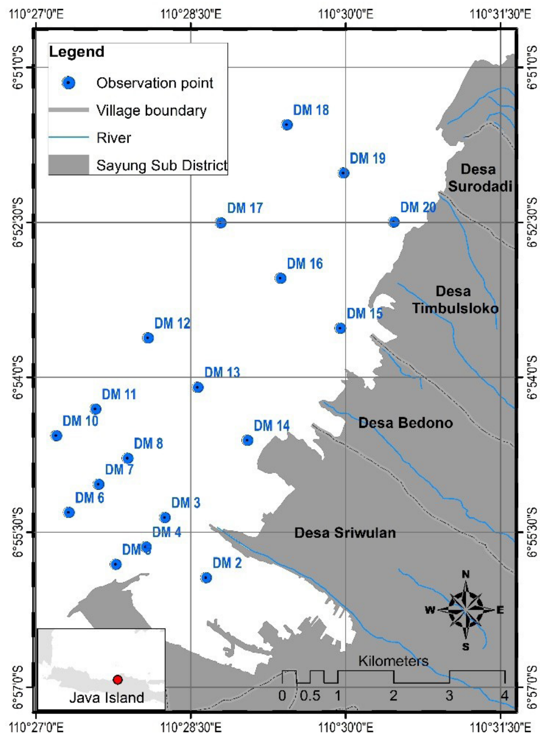

Figure 1. Research location map.

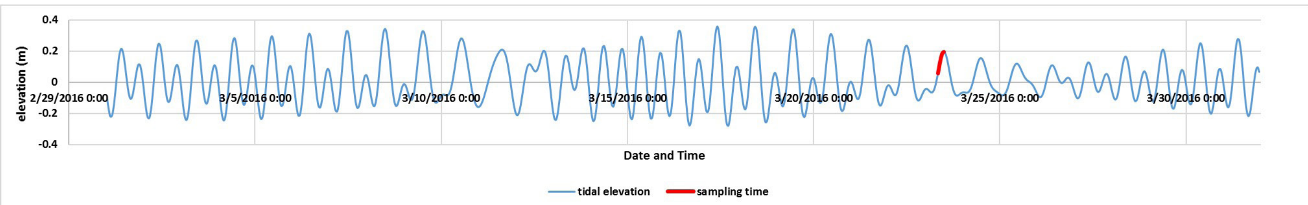

Figure 2. Tide forecasting analysis before conducting field survey.

modeling result which was simulated (Wisha *et al.*, 2016a). To evaluate the model result, it must be compared with field measurement tides data (Jin & Ji, 2004), applying Root Mean Square Error (RMSE) formula as follow:

$$RMSE = \sqrt{\frac{1}{N}\sum(xi - yi)^2} \quad \text{.............................. 1)}$$

Where:
N = The number of total data
xi = Model result
yi = Field measurement data

Flow model fm was employed to determine the distribution pattern of suspended solid and the other water quality parameters, which are transported by the water mass dynamics. Tidal currents simulation was simulated for 15 days, but the data will be displayed only when low tide towards high tide in the neap phase condition (similar with the date of in situ). To develop a hydrodynamic simulation, a flow model simulation was employed which shows the result on two-dimensional form (Warren & Bach, 1992; Mehdiabadi *et al*., 2015). The input model employed bathymetry data from Hydrography and Oceanography Center, Indonesian Navy (Pushidrosal) combined with Bathymetry measurement result and digital coastline Google Eye imagery 2016. The surface elevation was obtained by employing ERGtide in the form of time series data. Set-up of hydrodynamic model is shown in Table 1.

Suspended solid sample analysis was done using gravimetric methods SNI 06-6989.3-2004. About 100 mL of water samples were collected, gently shaken and filtered using a vacuum pump and Whatman filter paper with 0.45 µm pore size. Filters were then weighed and suspended solid concentrations were calculated using the formula as follow:

Csi= (G2-G1)x1000/V mg/L .... 2)

Where:
Csi = The suspended solids mg/L
G2 = Weight of filter paper and precipitate after heated (mg)
G1 = Weight of filter paper (mg)
V = The volume of water filtered (mL)

The suspended solid content data ware analyzed spatially by employing the inverse distance weighted (IDW) spatial analysis techniques which helps to lay out the suspended solid data to be well interpreted the process of distribution, set up for generating IDW is shown in Table 2. The IDW result was then overlaid with the hydrodynamic model data to show the distribution model of suspended solid content in the Sayung waters.

RESULTS AND DISCUSSION

Suspended solid content in the Sayung waters ranged between 23.1-199.6 mg/L, with an average in each station was 67.83 ± 25.5 mg/L. Solid concentrations were highest at station DM 2, DM 3, DM 5 and DM 15 (Figure 3). In generally, station located near the mainland has higher suspended solid concentrations than at station far away from the mainland.

The main source of solid comes from land which is transported by the river flow and triggered the turbulence of sediment resulted by waves and longshore current. Eventually, the suspended particles transported to the other areas, that condition affected by the events of resuspension from the bottom. The stirred and mixed up sediment then suspended and moved to the surface. The suspended solid concentrations that allowed by the standard of Ministry of environment and forestry (2004) for the mangrove ecosystem is 80 mg/L.

Table 1. Set-up for hydrodynamic model

Parameter	Implemented in simulation
Simulation time	Number of time step = 100 Time step interval = 30 second Start and stop simulation date = 7/03/2016 24.00 – 8/03/2016 00.50
Mesh boundary	Bathymetry = Pushidrosal bathymetry map digitation combined with field measurement 2016 Coastline = Google Eye Image digitation
Flood and Dry	Drying depth = 0.005 m Flooding depth = 0.05 m Wetting depth = 0.1 m
Boundary condition	Tide forecasting with coordinates: 1. Longitude: 110.4836; Latitude: -6.842 2. Longitude: 110.4399; Latitude: -6.895

Table 2. Set Up for Generate IDW Processing

Indicator	Implemented in IDW Processing
Projection Coordinate Syatem	Geographic (Longitude/Latitude)
	World Geographic System (WGS) 1984
Geoprocessing-Environment Setting	Processing Extend : Top = -6.851348 Bottom = -6.957948 Left = 110.452887 Right = 110.538692
ArcToolbox - Spatial Analyst Tool	IDW Set up : Output Cell Zise = 3.94639717568498E-03 Number of Points = 12 Search Radius = Variable

According to Purwaningsih *et al*. (2015), total suspended solid ranged between 49-67 mg/L which has negatively correlation to affect the deposition of heavy metals in the sediment. According to Sidqi *et al*. (2003) the suspended solid content ranged from 41.93 to 152.13 mg/L. Based on the analysis using Landsat imagery (Arief & Lestari, 2006) the value of suspended solid has range 25-50 mg/L, while Wulandari *et al*. (2014) claimed the suspended solid content ranged from 9.5 to 28.1 mg/L.

The largest intake of solid concentration derived from the river mouth. At high tidal phase condition, surface elevation is higher so the estuary will be dominated by seawater. Whereas, at low tide phase condition, surface elevation is lower than river water level, resulting in the river water domination in the estuary. It occurs in the estuarine areas and the suspended solids are transported tidally and affect the existing estuarine ecosystem (Wisha & Heriati, 2016).

Distribution of suspended solid at low tide towards high tide condition (Figure 4) shows that Sriwulan area became the center of high suspension. At station DM 3, DM 5 and DM 2 which is located in Sriwulan waters it reached 119 mg/L of suspended solid concentration. The current direction is moving towards the sea, supporting the distribution of suspended solid from the estuary to the sea water area. It is clear with the field observation that the Sriwulan water is tremendously turbid.

The other station that has a high concentration is DM 15 which is in the Timbulsloko waters area. The high concentration of suspended solid sourced from estuarine areas of Timbulsloko and trapped since moving currents from the north, east and south meet at that point. Resulting in the trapped and deposited solid in that area which causes a high rate of turbidity in the territorial Timbulsloko waters. At other stations, the suspended solid concentration is not severe high because it has been transported by the movement of tidal current with speed ranged from 0 to 0.41 m/s.

The longshore current velocity near the coast is weaker and become the drift transport in coastal areas (Wisha *et al*., 2015). The ebb flow of waters still occurred in the Sriwulan waters, with the dominant current direction moving away from the coast with

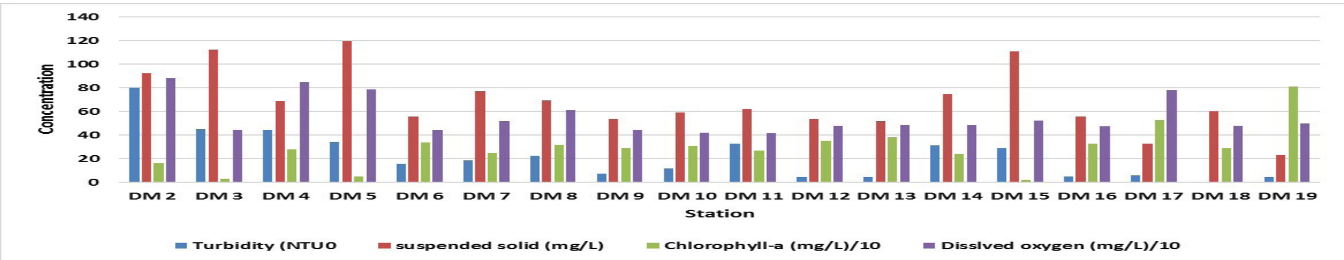

Figure 3. The comparison of suspended solid, turbidity, chlorophyll-a, and Dissolved oxygen in the area studied.

Table 3. Statistic descriptive of water quality parameters

No	Parameter	Min	Max	Mean	St Dev
1	Turbidity (NTU)	0.00	80.20	22.27	19.92
2	DO (mg/L)	4.16	8.83	5.61	1.52
3	Chlorophyll-a (mg/L)	0.20	8.10	2.92	1.82

speed ranged from 0.02 to 0.2 m/s. Currents which came from the north move along the coast and heading to the south with speed ranged from 0.02 to 0.06 m/s.

The current pattern is still in the condition of displacement from ebb to tide, which has begun to enter the coast, from west to northwest and perpendicular to the Timbulsloko waters. So that, in the region of Timbulsloko waters, occurs a turbulence on bottom particles, which is eventually suspended and floated in water column (Ondara & Wisha, 2016). Hydrodynamic model simulated on ebb to tide at the same time of sampling. The RMSE obtained is 11,25%. The comparison between model and field survey of surface elevation data is shown in Figure 5, which represents the same tidal phases but have different elevation values.

Tidal currents movement is one of the dominant factors in distribution of dissolved substances and compounds in the waters (Wisha & Heriati, 2016). Its fluctuation changed depended on tidal condition. Suspended solids distributed evenly along the Sayung coast, which is also affect the others water quality parameter at the same station and its surrounding. Water quality data is shown in Table 2.

The suspended solid is related with turbidity. In generally, when the suspended solid increases, the water becomes turbid and it inhibits the autotrophs biota by which disrupt photosynthesis activities. It will indirectly change the condition of existing ecosystem because of the disruption of producer. Proven on all station, suspended solid concentration and turbidity are proportional which are only two different stations, such as at station DM 1 and DM 2 (Figure 3). The remaining stations are slightly proportional. Based on the result, the suspended solids content has a big role in the turbidity enhancement of the water.

The high level of suspended solid indicates that bed load turbulence occurred frequently due to tidal current and other oceanographic parameters. Scour in the bottom triggered by the first breaking wave which propagates into the coast in the form of longshore current. It occurs beneath the front wave crest which triggers scour near the coast. It causes erosion in the coastal area. It supported by intake of solid materials from rivers surrounded. We know that Sayung coast tremendously threatened by erosion and tidal flood occurred in the last view years.

Turbidity values range from 0 to 80.2 NTU with an average of turbidity value was 22.26 ± 19, 91 NTU (Table 2). The highest turbidity is found in station DM 2, where an area of mangrove forests and settlements, is found in some stations near estuary such as the station DM 20 and DM 15 and DM 14 are also close to the mainland (Figure 1). Due to the high rate of water mass transport in the nearshore in the form of longshore currents and rip currents, the high turbulence occurs which results in the turbidity enhancement. Turbidity is not only harmful for fishes but also cause the water to be unproductive due to the blocking of sunlight for photosynthesis (Riyadi *et al*., 2005). Based on the previous research by Sidqi *et al.* (2003) the turbidity in Sayung waters ranged between 33-158 NTU, it indicates that the turbidity already exceeds the quality standard limits (KLH, 2004).

The high values of turbidity in some stations which are closed to the land and river estuaries caused by the activities of coastal communities that disposes the organic and inorganic substances. In addition, the type of sediment in the Sayung waters is dominantly mud and be cohesive, where the sediment size is very small, and easy to be mixed and moved by the seasons and the winds. In general, Sayung waters are relatively turbid (>1000 NTU) which has already exceeded the seawater quality standard for supporting the biota survival ability. The high of turbidity that greatly reduces the activity of photosynthesis by phytoplankton and directly inhibits the primary productivity level in the Sayung waters (Sihombing *et al*., 2015). It can be determined from the chlorophyll-a data which is shown in Table 3 and Figure 3.

DO value is very high, indicating that the region is fertile enough, but the value of dissolved oxygen which is tremendously high can be harmful to the biota. According Riyadi *et al*. (2005) the DO at water bodies of Sayung ranged from 4.71 to 5.08 mg/L. Sayung waters have a carrying capacity that is not good for marine life. According to Purwaningsih et al. (2015) the value of DO ranged from 3.2 to 3.67 mg/L. According to Suprapti (2008) the value DO in Sayung waters ranged between 6-6.5 mg/L.

Wulandari *et al*. (2014) defined that the average of dissolved oxygen content in the Sayung waters of

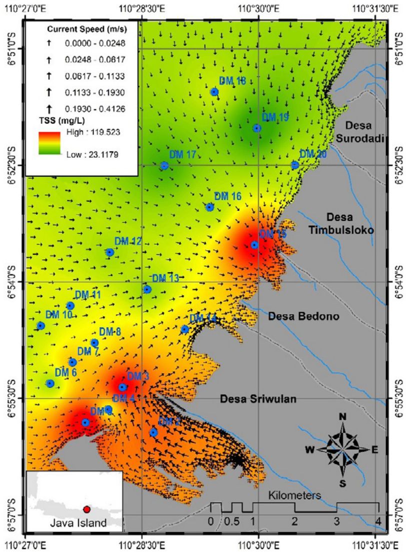

Figure 4. Suspended solid distribution in Sayung Waters.

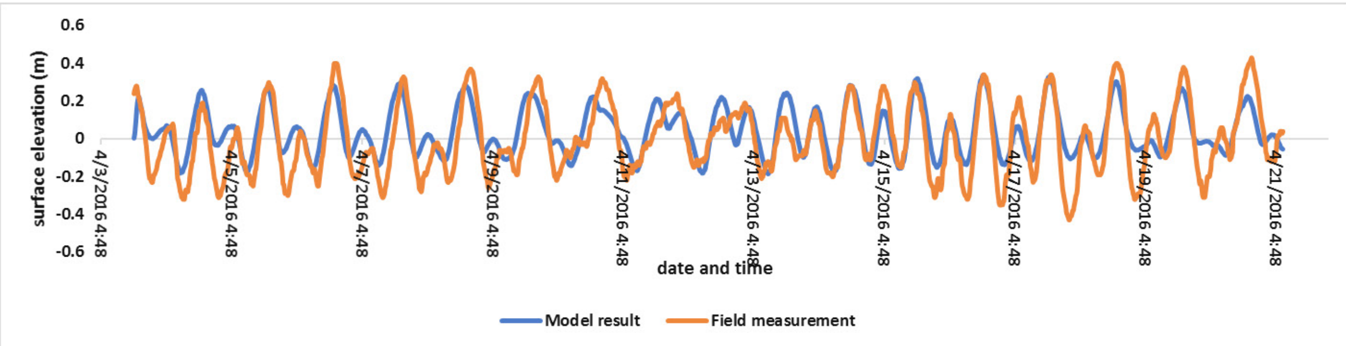

Figure 5. Model validation using surface elevation data.

5.95 mg/L, and Sihombing *et al*. (2015) also defined that the dissolved oxygen in the Sayung waters ranged between 2 and 2.57 mg/L. The minimum DO value is 2 mg/L in normal circumstances and is not contaminated by toxic compounds, which was quite reliable for phytoplankton life.

When DO content is more than 5 mg/L, it belongs to low pollution level. Whereas, the DO of 0-5 mg/L is in moderate pollution. High pollution level occurs when the dissolved oxygen content is close to zero. DO derived from the diffusion of air and phosphorylation process of photosynthesis to produce oxygen-free in the water (Salmin, 2005). Some results of the previous studies indicate that dissolved oxygen content fluctuates depending on the season and effected by the intake of suspended substances from the mainland.

Dissolve oxygen is an important parameter in the waters because closely related to the mechanism of photosynthesis by autotrophs organisms (phytoplankton). The value of DO in the Sayung waters ranged between 4.16 and 8.83 mg/L, with the average at each station of 5.6 ± 1.51 mg/L (Table 3). The highest oxygen content occurred at station 2 DM, DM 4, DM 5 and DM 17, and the other stations have lower DO values (Figure 3), these are under the standard from the Ministry of Environment (2004). The DO value which is allowed for biota and marine tourism is > 5 mg/L.

When the DO value is less than 5 mg/L, then waters are categorized in oxygen-less conditions or if continued could lead to anoxic conditions. Lack of oxygen in the water will cause mass death of fishes and other marine life (Zhou *et al*., 2008). Many factors can cause that condition, indirectly by increasing the concentrations of suspended solid and turbidity in the waters which causing a disruption of the mechanisms of photosynthesis by phytoplankton. It causes a high accumulation of nutrients due to unused nutrient by phytoplankton, and over time can cause blooming algae (Wisha *et al*., 2016b).

The chlorophyll-a concentration varied from 0.20-8.10 mg/L. The higher suspended solids and turbidity in the water, the less phytoplankton abundance will be found. The phytoplankton activity is limited due to the low intensity of lights. Resulting in low of primary productivity in the Sayung waters. Supporting of nutrient

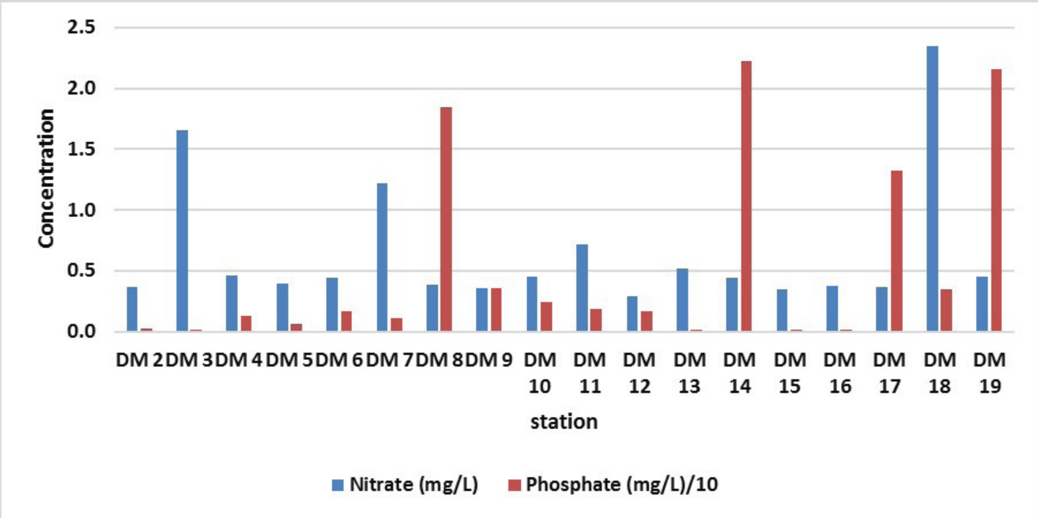

Figure 6. Nutrient concentration (N and P) in the Sayung waters.

also has a role in this condition such as phosphate and nitrate which has large influence in waters. The nutrient condition is shown in Figure 6.

The nutrient varies in each station. The high concentration of phosphate is found at the station of DM 8, DM 14, DM 17, and DM 19. Whilst, the high concentration of nitrate is found at station of DM 2, DM 7 and DM 18. Nutrients sourced from estuary and river path which contained a lot of compound of organic and inorganic materials. The nutrient unused is then deposited in the bottom of water, and will be mixed and dissolved again in the surface by upwelling mechanism. According to Chow *et al*. (2013), chlorophyll-a abundance is proportional with the strength of upwelling and vertical mixing (Biogeochemical cycle). D'Croz and O'Dea (2007) the higher concentration of chlorophyll-a in the estuary area is influenced by upwelling and the runoff process from the river.

Based on the correlation assessment between suspended solid content, DO, and chlorophyll-a concentration (Figure 7), it shows that between suspended solid and DO is not directly correlated where the adjusted R square is 0.06. It defines that the ability of independent variable (suspended solid) does not explained the dependent variable (DO). Whilst, the correlation between suspended solid and chlorophyll-a is tremendously related with adjusted R square obtained of 0.85. It defines that the suspended solid and chlorophyll-a are 85 % related.

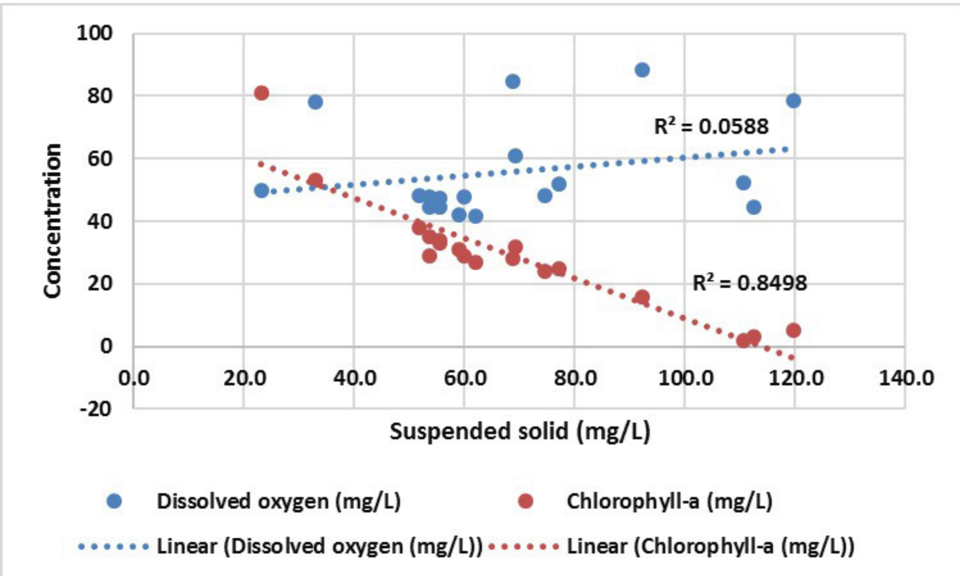

Figure 7. The correlation between suspended solid concentration, dissolved oxygen and chlorophyll-a in the Sayung waters.

Water quality condition controls the existing biota's life. Suspended solid and turbidity were so high which indicate the high level of turbulence in the Sayung waters. That condition directly causes several impacts such as decreasing primary productivity, increasing water pollution, and biogeochemical cycle problems, which inhibits biota survival ability and decreased the fishery catching. Suspended solid and turbidity explained that scour and erosion has been occurring in Sayung coast.

CONCLUSION

There is high concentration of suspended solid in the Sriwulan and Timbulsloko waters. The tidal current is the major factor transported the suspended material in the surface and water bodies. The suspended solid condition triggers the water to become turbid which directly inhibits the lights intensity to enter the water, produce an unstable photosynthesis processes and reducing the primary productivity of the Sayung waters. Suspended solid and turbidity which are severely high indicate that the erosion and turbulence mechanism still occurring in Sayung waters.

The dissolved oxygen is observed severe high in the several stations. The high DO concentration can be triggered the algal blooming. The DO condition also supports the productivity which showed by the high of chlorophyll-a concentration in the Sayung waters. The chlorophyll-a condition was controlled by the suspended solid concentration in the water and both of that two parameters are tremendously related. Water quality condition controls the existing biota's life which directly impacts to the decreasing fishery catching in the Sayung coast. It is necessary to control the pollution and preserve the coastline changes which has been occurring.

The high of DO concentration which is followed by the enhancing of chlorophyll-a identified as a blooming tendency. Authors suggest to the future research to develop a study which analyze and develop the identification of algal bloom in the turbid waters. That study is necessary to conduct and suggest controlling the disposal waste from the land source and reduces the pollution in the waters. This study can be useful as a basis for the assessment of the current environmental condition of Sayung waters for the local government by which land disposal waste of industrial and coastal activities can be potentially controlled.

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