Total Suspended Solid (TSS) Distributed by Tidal Currents during Low to High Tide Phase in the Waters of Sayung, Demak: Its Relations to Water Quality Parameters

Ulung Jantama Wisha [a]*, Koko Ondara [a]

[a] *Research Institute for Coastal Resources and Vulnerability, Ministry of Marine Affairs and Fisheries, Jalan Raya Padang-Painan KM. 16, Teluk Bungus Padang - Sumatera Barat 25245, Indonesia*

* *Penulis koresponden. Tel.: +62-751-751-458*
Alamat e-mail: ulungjantama@gmail.com

Diterima (received) 1 Desember 2016; disetujui (accepted) 25 Mei 2017; tersedia secara online (available online) 26 Mei 2017

Abstract

Sayung waters is a region highly vulnerable to catastrophic erosion along the coast, which is directly followed by an increase suspended sediments and particles from the bottom of the waters that was stirred by oceanography factors. The purpose of this study was to determine the concentration and distribution of the latest TSS condition and its effect on water quality parameters in the waters of Sayung. The sampling method is using purposive sampling, with the stations spread out along the coastal area of Sayung, the main data consist of current, tide, bathymetry, coastline and water quality, and the secondary data consist of RBI map and tide forecasting, those data is analyzed numerically and statistically. TSS value ranged between 23,1-199,6 mg.L^{-1}, the distribution of TSS is simulated in the condition of ebb to tide with current speed ranged between 0-0.41 ms^{-1}, that distribution also influenced by physical water factors such as salinity, temperature, and density and has impacts to enhancing the turbidity and indirectly decrease the photosynthesis activity and inhibit the oxygen cycle in the Sayung waters.

Keywords: *hydrodynamics; Sayung waters; total suspended solid; water quality*

Abstrak

Perairan Sayung merupakan wilayah dengan kerentanan yang tinggi dalam erosi disepanjang pantainya, yang secara langsung diikuti oleh peningkatan konsentrasi sedimen tersuspensi dan partikel-partikel dasar perairan yang teraduk oleh faktor oseanografi. Tujuan dari penelitian ini adalah untuk mengetahui konenstrasi dan distribusi dari kondisi TSS terakhir dan dampaknya terhadap parameter kualitas perairan di perairan saying. Metode pengambilan data menggunakan purposive sampling, dengan stasiun yang tersebar disepanjang pesisir Sayung, data primer terdiri dari data arus, pasang surut, batimetri, garis pantai dan kualitas air, dan data sekunder terdiri dari peta RBI dan peramalan pasang surut, data-data tersebut diolah secara numerik dan statistic. Nilai TSS berkisar antara 23,1-199,6 mg.L^{-1}, distribusi TSS disimulasikan dalam kondisi surut menuju pasang dengan kecepatan arus berkisar antara 0-0,41 m.s^{-1}, distribusi tersebut juga dipengaruhi oleh faktor fisika perairan seperti salinitas, sh da densitas dan berdmpak pada peningkatan kekeruhan perairan dan secara tidak langsung akan menghambat proses fotodintesis dan menghambat siklus oksigen di perairan Sayung.

Kata Kunci: *hidrodinamika; Perairan Sayung; total padatan tersuspensi; kualitas perairan*

1. Introduction

Sayung coastal region is highly vulnerable to the abrasion phenomena due to the mechanism of oceanographic factors that are destructive. The results of the abrasion that occurs cause the level of suspension of solid particles increases in the waters of Sayung (Pranoto et al., 2016). Increased suspense solids from the bottom of the water led to increased turbidity in the waters of Sayung, and will directly inhibit the process of photosynthesis by phytoplankton and biota autotrophs, so it is absolutely crucial in terms of reduction in primary productivity in the waters of Sayung (Aramita et al., 2015).

Total suspended solid (TSS) is the total number of solids that is suspended and floating in the water column, and the transport of TSS is strongly influenced by the mass transfer of water, and at some point, will settle back to the bottom of the water when it flows turbid weakened (Wisha and Heriati, 2016). In waters of Sayung have a tendency to flow pattern that varies according to the wind direction to be around the area, currents moving towards the coast produce currents along the coast a parameter stirring and milling in the coastal areas (Ondara and Wisha, 2016). The situation will affect to changes in the coastal region (Widada et al., 2012), changes in coastal is easier to detect using the status of water quality that is caused by the increased suspense sediment and other solid substances in waters (Wisha et al., 2015).

Several previous studies by Sidqi et al., 2015; Arief, 2010; Wulandary et al., 2014; and Purwaningsih et al., 2015 stated that the concentration of TSS in the waters of Sayung increasing every year. It is becoming an important issue to be researched because of the increase in the value of TSS can give a bad impact on the environment, and the need to update data on the latest condition of TSS in waters of Sayung, Demak. The purpose of this study was to determine the concentration and distribution of the latest TSS condition and its effect on water quality parameters in the waters of Sayung.

2. Materials and Methods

The primary data consist of bathymetry measurement results conducted by Research Institute for Coastal Resources and vulnerability in 2016, the coastline digitation of Google Earth Image year 2016, the current and tide data, the data of water quality measurements in situ, and TSS data analysis results in the laboratory, while the secondary data used is tide forecasting data and Topographic map of Indonesia 2005. The sampling stations consist of 18 stations (Figure 1) scattered along the coastal area, with reference to the purposive sampling method, that is a method to determinate the sampling sites in the area which is considered to represent the study area (Sugiyono, 2012 in Wisha et al., 2016b).

Sampling time is conducted during ebb towards tide condition, based on tide forecasting data using software ERGtide, which is based on the measurement of tides by ADCP (*Acoustic Doppler Current Profiler-Northek*). It deployed a month before taking the water quality data, sampling water quality in situ measured using *TOA DKK multi-parameter water quality checker* in one tidal conditions, i.e. on March 23, 2016 at 08:00 to 12:00 am (Figure 2).

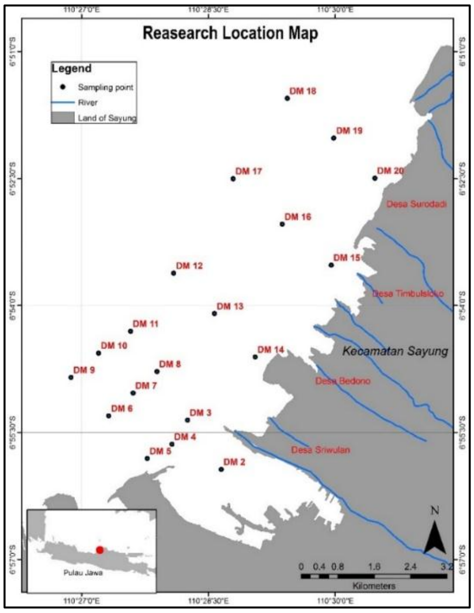

Figure 1. Research location map

ADCP deployment was conducted on 03/04/2016 at 15:00 pm until 03/22/2016 at 12.00 am with approximate measurements of 18 days, is

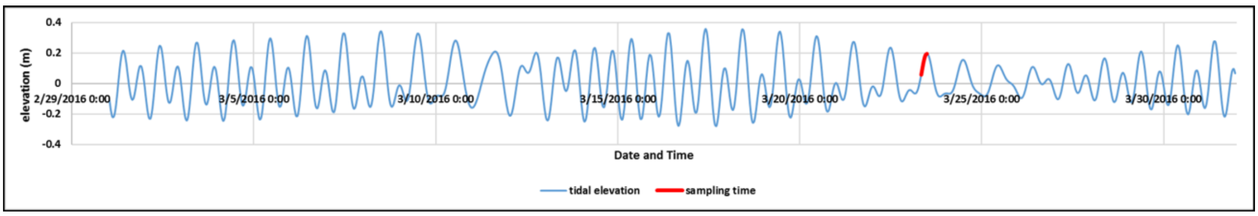

Figure 2. Tide forecasting by ERGtide software

sufficient to represent the full cycle of spring and neap tides, ADCP records the form of tide, temperature, and current. Tide data is used as input for tide forecasting, in another case, the currents and tides data are used in the verification of the results of the hydrodynamic model (Wisha et al., 2016a).

Hydrodynamic simulations conducted to determine the distribution pattern of TSS and the other water quality parameters, that are influenced by the flow pattern in the waters of Sayung, simulations were carried out for 15 days and the data is displayed on a neap tide condition (similar with the date of sampling in situ). Simulations carried out by software MIKE 21 is shown in the form of hydrodynamic two-dimensional (Zacharias and Gianni, 2008; Mehdiabadi et al., 2015).

The model input used is Indonesian Navy bathymetry data combined with field bathymetry measurement result and coastline digitized using Google Earth Image 2016, the water level with time series data is using tide forecasting results by software ERGtide, Set-up of hydrodynamic modeling can be seen in Table 1.

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 = DIHIDROS bathymetry map digitation combined with field measurement 2016
	Coastline = Google Earth 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

Sampling TSS using Nansen bottles on the station preset before, which is considered to be representative of the true distribution of TSS in the waters based on water mass movement (Wisha and Heriati, 2016). Analysis of the TSS samples using gravimetry method in accordance with ISO 06-6989.3-2004, samples of water whipped 100 mL and filtered using a vacuum pump and paper Whatman size 0.45 m. The filtrate is weighed then, and TSS concentrations calculated using the formula below:

$$Csi = \frac{(G2-G1)\times 1000}{V} \text{ mg.L}^{-1} \quad (1)$$

where:

Csi = The suspended solids mg.L^{-1}

G2 = Weight of filter paper and precipitate after heated (mg)

G1 = Weight of filter paper (mg)

V = The volume of water filtered (mL)

3. Result and Discussion

Value of Total Suspended Solid (TSS) in the Sayung waters ranged between 23.1-199.6 mg.L^{-1}, with an average of TSS in each station was 67.83 ± 25.5 mg.L^{-1}, TSS concentrations were highest at station 2 DM, DM 3, DM 5 and DM 15 (Table 2). Generally, the station near the mainland has higher TSS concentrations when compared with the station that away from the mainland, because the main source is the TSS distribution from land by the river flow, and also the erosion of sediment by waves or longshore currents and eventually the suspended particles transported to other areas, that is caused by the events of resuspension on the bottom, sediment stirred and mixed up. The TSS concentrations that is allowed by standard MNLH (2004) for the mangrove ecosystem is 80 mg.L^{-1}.

Total suspended solids often linked with turbidity, generally, when the suspension of solids increases, the water becomes turbid and it is very dangerous and threatening the autotrophs biota which would indirectly change the condition of the ecosystem and food web of existing. Proven on all station TSS concentration and turbidity is proportional, only a difference in station DM 1 and DM 2 (Figure 3), but the remaining is proportional and indicates that the TSS influence to enhancing turbidity in the water.

According Purwaningsih et al. (2015) in the Sayung waters TSS ranged between 49-67 mg.L^{-1} and TSS values correlated negatively affect the deposition of heavy metals in the sediment. According Sidqi et al. (2015) in the Sayung waters TSS ranged from 41.93 to 152.13 mg.L^{-1}, based on the analysis of TSS using Landsat imagery by Arief (2010) that the value of TSS is based on imagery ranged between 25-50 mg.L^{-1}. According Wulandari et al. (2014) in the Sayung waters, TSS values ranged from 9.5 to 28.1 mg.L^{-1}. The largest

Table 2
TSS concentration in each station

Station	DM 2	DM 3	DM 4	DM 5	DM 6	DM 7	DM 8	DM 9	DM 10	DM 11	DM 12	DM 13	DM 14	DM 15	DM 16	DM 17	DM 18	DM 19	DM 20
TSS	92.2	112.5	68.8	119.6	55.5	77.0	69.2	53.6	59.0	62.1	53.6	51.7	74.6	110.7	55.5	33.0	60.0	23.1	57.1
st dev.	0.6	0.4	0.1	0.3	0.4	0.7	0.6	0.3	0.7	0.6	0.3	0.2	0.3	0.2	0.4	0.7	0.7	0.6	0.6

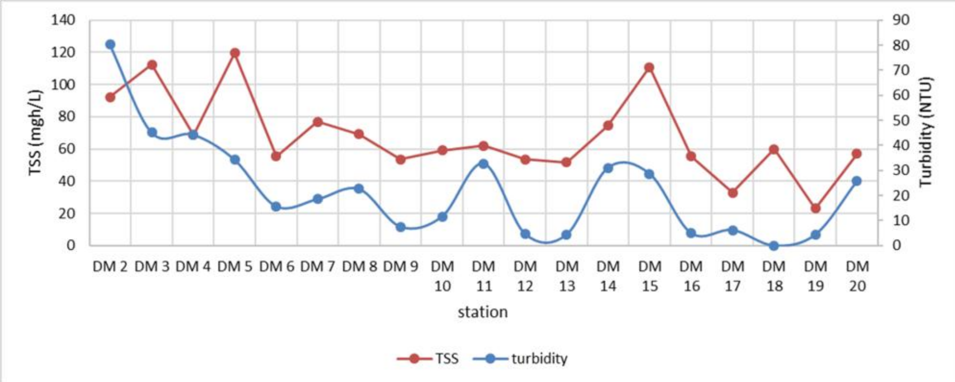

Figure 3. Comparison between TSS and turbidity concentrations in each station

intake of TSS concentration derived from the river mouth, at high tide. Sea water elevation is higher so that the estuary will be dominated by seawater, whereas at low tide which is lower than river water domination occur in estuarine areas carrying suspended solids and affect estuarine ecosystem that exists (Wisha and Heriati, 2016).

Distribution of TSS in the Sayung waters on the ebb to tide condition (Figure 4) is seen that in Sriwulan waters area became the center of the highest suspension. At the station DM 3, DM 5 and DM 2 is located in the Sriwulan waters with TSS levels up to 119 mg. L^{-1}, and it appears that the ebb flow still dominates in the region, with the direction the current is moving towards the sea. The movement supporting the distribution of TSS from the mouth of the river to the sea area, it is within their field condition that the Sriwulan waters have a high turbidity. There are one more stations that have a high concentration of that station DM 15 is located in the Timbulsloko waters area, the concentrations of the high TSS sourced from estuarine areas Timbulsloko and trapped since moving currents from the north, east and south meet at that point, so the TSS does not spread to other regions, and accumulates in that site and caused turbidity in the territorial waters of Timbulsloko, in other stations. TSS concentration is not too high because it has been transported by the movement of currents at low tide to high tide condition with a flow rate ranged from 0 to 0.41 ms^{-1}.

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 occur in the Sriwulan waters, with the dominant current direction moving away from the coast with speed ranged from 0.02 to 0.2 ms^{-1}, current that comes from the north moves along the coast and heading to the south with speed ranged from 0.02 to 0.06 ms^{-1}. The current pattern still in the condition of displacement from ebb to tide, the tide flow has begun to enter from the direction West northwest and perpendicular to the Timbulsloko waters, so that in the region of Timbulsloko waters occur the turbulence of bottom particles, which eventually suspended and floating in the water column (Ondara and Wisha, 2016). The results of hydrodynamic model only simulated on the condition ebb to tide, according to with the same time of sampling, but it can be different for other tidal conditions, error models MRSE obtained by 11,25%.

With the movement of ocean currents which is one of the dominant factors in the distribution of dissolved substances and compounds in the waters (Wisha and Heriati, 2016), causing changes in water conditions in every tidal condition change. TSS distributed evenly along the coastal waters of Sayung, it is also affecting the others water quality parameter condition in the same station and the location (Table 3). Some parameters that change is turbidity and dissolved oxygen, while the physical parameters such as temperature, salinity, and density also influence the condition of the existing TSS in the waters.

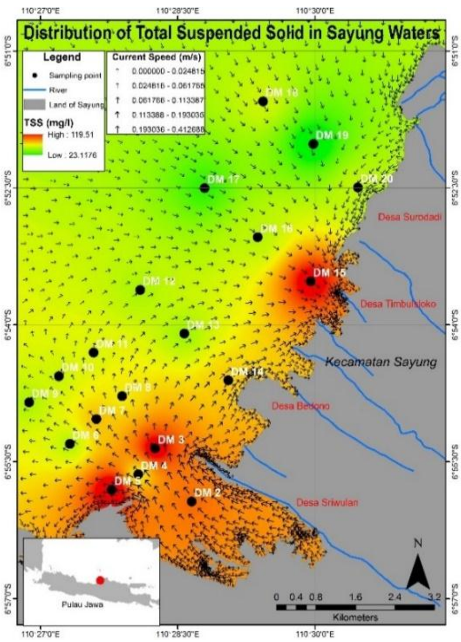

Figure 4. TSS distribution in Sayung Water

The density in the Sayung waters ranged from 1013.4 to 1018.4 kg.m^{-1}, with an average density is 1017.358 ± 1.43 kg.m^{-1} (Table 3). Density range values are not too different each station and almost evenly throughout the Sayung waters, the density value is very closely related to the conditions of temperature that is inversely proportional and the salinity/conductivity are directly proportional. The density of seawater also affects the chemical parameters especially on transport mechanism vertically, which is getting close to the bottom, settling velocity of suspended substances decreases with increasing density. When it has been settled in the bottom sediments, these substances will be difficult to suspend again, except mixed by the current in the bottom/density current that is moving currents due to differences in density and moved from high density to low density. According to Talley et al. (2011) states that the density is not too different horizontally (e.g. due to differences in surface heating) and can produce very strong ocean currents.

The value of salinity in the Sayung waters ranged from 26.6 to 31.7 %, with an average of 30.99 ± 1.13 % (Table 3), according to Wulandary et al. (2014) states that the value of the salinity in the Sayung waters reached 29 %, the value is still within the normal threshold is based on the quality standard of the Ministry of Environment (2004). The natural conditions which are always changing with the seasons, day and night, still within normal limits when changes < 5% of the average salinity. Value salinity almost uniformly in all the stations, but the lowest is at the station DM 20 which is a region of the mouth of the river estuary (Figure 5), with the input water mass of the river caused the value of the salinity or salt content in the region mixed with the salinity in the estuary, so mixing mechanism occurs in that region. It is appropriate in line with density values in station DM 20 which also has the lowest value (Figure 5). According Riyadi (2011) salinity in the ocean is influenced by various factors such as patterns of water circulation, evaporation, rainfall and river flow, and salinity in the Demak waters is almost 32, 28 %.

Table 3

Statistic descriptive of water quality parameters.

No	Parameter	Min	Max	Mean	St Dev
1	Density (Kg.m^{-1})	1013.4	1018.4	1017.358	1.431905
2	Salinity (%)	26.6	31.7	30.995	1.133566
3	Temperature (°C)	31.6	35.6	33.063	1.105145
4	Turbidity (NTU)	0.0	80.2	22.268	19.916667
5	DO (mg.L^{-1})	4.16	8.83	5.607	1.510044

The value of sea surface temperature (SST) ranged from 31.6 to 35.6 °C, with an average SST is 33.06 ± 1.105 °C (Table 1). The highest temperature values are in the station DM 14, DM 15 and DM 20 (Figure 5) which is located near the mainland and the mouth of the river, the distribution of temperature decreases in the western and the southern part of Sayung waters, as the region that is not directly influenced by the ground waste. Based on the previous studies by Purwaningsih et al. (2015) states that the range of temperatures in the Sayung waters is 30.6-31,7 °C, and according to Riyadi (2011) that the water temperature ranged between 27,44-29,82 °C and in 2008, the water temperature ranged between 29-30,5 °C (Suprapti, 2008), it indicates that the value of sea surface temperature was enhanced from the previous year.

Temperatures near the mainland and near the river mouth is higher due to the influence of the temperature of the river water. It is mixed thermodynamically, it increases the temperature in the estuary then, on the other hand due to the many industries that was dumped heat waste into the waters also has the potential to increase the temperature reaches 35 °C (classified as a high temperature for the waters).

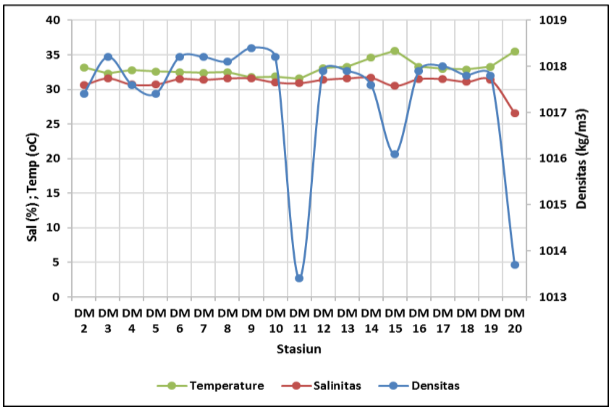

Figure 5. Salinity, density and temperature value in Sayung waters

Temperature is one of the very important physical parameters in the environment, changes in water temperature would interfere with the other physical and chemical parameters in the waters and indirectly affecting the aquatic biota. Temperatures that are too high can result in a high level of toxic in the waters, including heavy metals and nutrient deposition was inhibited (Arief, 2010).

The relationship between the parameters of temperature, salinity and density (Figure 5). It appears that at some stations there is an inverse relationship between temperature with density and salinity, and the proportional relationship is given between salinity and density. In the station DM 3, the density and salinity increases while the temperature gets down, then the DM 9 there is an increase in density and salinity were followed by a decrease in temperature, the condition also occurs in the station DM 16 and DM 17. Conditions inversely to the station DM 4, DM 5, DM 11, DM 15 and DM 20, wherein density declined rapidly followed by salinity because temperature increased in that stations. Temperature, salinity, and density are physical factors that influence the transport mechanism vertically and horizontally, but it also affects the speed of deposition of organic substances or inorganic in water (Wulandary et al., 2014). Occurred anomaly density in the station DM 11, it may be attributable to several factors, including heating locally, the influence of mangrove forests and a factor of mass transfer of water. At the station DM 15 and DM 20 has a lower density because of the influence of the river so that occur a mixing in density between sea water and river water in the estuary, so the density becomes low.

Turbidity value ranging from 0 to 80.2 NTU with an average of turbidity value was 22.26 ± 19, 91 NTU (Table 3), the highest turbidity is at station DM 2, which is an area of mangrove forests and settlements area, in some station in estuaries such as the station DM 20 and DM 15 and DM 14 are also close to the mainland (Figure 1). Because of the transport mechanism very active near the mainland like longshore currents and rip currents that cause turbulence becomes high and increases the turbidity. Turbidity is not only harmful to fish but also cause the water unproductive due to the blocking sunlight for photosynthesis (Riyadi, 2011). Based on previous research by Sidqi et al. (2015) states that the turbidity in Sayung waters ranged between 33-158 NTU, it indicates that the turbidity already exceeds the quality standard limits (MNLH, 2004).

The high value of turbidity in some stations that are close to the land and river estuaries caused by higher activity of coastal communities that dispose of substances of organic and inorganic eventually pollute the environment. In addition, the type of sediment in the Sayung waters is mud and be cohesive, where the sediment size is very small and easy to mixed by the seasons and the wind direction. In general, Sayung waters relatively turbid proven that the concentration of turbidity > 1000 NTU, and has already exceeded the water quality standard sea for survival of the organism. Turbidity is very high that greatly reduces the activity of photosynthesis by phytoplankton and directly inhibit the primary productivity level in the Sayung waters (Sihombing et al., 2015).

Dissolve Oxygen (DO) 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 from 4.16 to 8.83 mg.L^{-1}, with the average at each station of 5.6 ± 1.51 mg.L^{-1} (Table 3), the highest oxygen content is at station 2 DM, DM 4, DM 5 and DM 17, and other stations

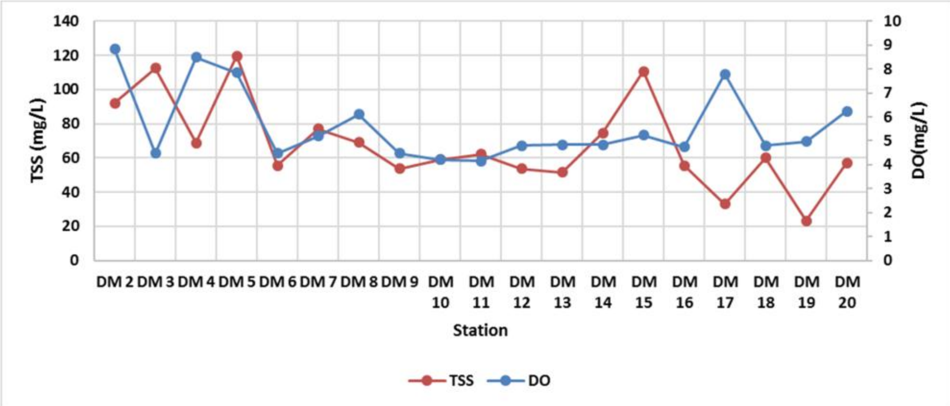

Figure 6. Comparison of TSS and DO in the Sayung waters

have lower DO values (Figure 6) and lower than the standard by the Ministry of Environment (2004), namely DO value allowed for biota and marine tourism is > 5 mg.L^{-1}, when the DO value is less than 5 mg.L^{-1}, then the waters are categorized in oxygen-less conditions or if continued could lead to anoxic conditions, a condition in which a lack of oxygen levels in the water that cause mass deaths of fish and other marine life (Tarigan et al., 2014). Many factors can cause the condition, indirectly by increasing concentrations of TSS and turbidity in the waters, causing a disruption of the mechanisms of photosynthesis by phytoplankton which causes a high accumulation of nutrients due to unused by phytoplankton, and over the time can cause a blooming algae (Wisha et al., 2016b).

TSS value is inversely proportional to the value of DO in the water, shown in Figure 6 that each station values of TSS and DO are opposite each other, at the station DM 2, DM 5, DM 7, DM 11, DM 14 and DM 15 TSS value increases and DO value decreases, so does the other stations in the time TSS value decreases then DO value increases, so that it can be said that the TSS has greatly affected to the condition of dissolve oxygen in the Sayung waters and also determine the conditions of these waters.

DO value at the station DM 2, DM 4, DM 5 and DM 17 reach a value of 7-8 mg.L^{-1}, the value is very high and it can be said the region is fertile with phytoplankton activity was good, but the value of dissolved oxygen is too high and also can be harmful to biota. According Riyadi (2011) states that the DO at Bodies water of Sayung ranged from 4.71 to 5.08 mg.L^{-1}, and the Sayung waters have a carrying capacity that is not good for marine life. According to Purwaningsih et al. (2015) the value DO at Sayung waters ranged from 3.2 to 3.67 mg.L^{-1}, according to Suprapti (2008) the value DO in Sayung waters ranged between 6-6.5 mg.L^{-1}, according to Wulandari et al. (2014) the average of dissolved oxygen content in the Sayung waters of 5.95 mg.L^{-1}, and Sihombing et al. (2015) states that the dissolved oxygen in the Sayung waters obtained by 2 to 2.57 mg.L^{-1}, the minimum DO value is 2 mg.L^{-1} in normal circumstances and not contaminated by toxic compounds, so it was quite a relief phytoplankton life. DO content is more than 5 mg.L^{-1} included the pollution level is low, whereas the DO of 0-5 mg.L^{-1} in moderate pollution. High pollution levels occur when the dissolved oxygen content is zero. DO derive from the diffusion of air and phosphorylation process of photosynthesis to produce oxygen-free in the water (Kusumaningtyas et al., 2014). Some of the results of previous studies indicate that the dissolved oxygen content fluctuates depending on the season and the effect of the intake of suspended substances from the mainland.

4. Conclusion

The TSS concentration is quite high in the Sayung waters, with the highest concentration is near the coastal area of Sayung. The distribution that occurs in ebb to tide condition is influenced by longshore current that moves from northern. The tide flow is moving towards to the coast of Sayung and ebb current that is affected by river estuary, TSS condition is directly proportional to turbidity and inversely proportional to the condition of DO in the Sayung waters, but TSS level is influenced by physical factors such as temperature, salinity and density of sea water in the region.

Acknowledgement

Acknowledgment and gratitude for Research Institute for Coastal Resources and Vulnerability on DIPA 2016 research budget in Sayung, Demak, and all those who have assisted in the completion of this scientific paper.

References

Aramita, G. I., Zainuri, M., & Ismunarti, D.H. (2015). Pengaruh Arus Terhadap Persebaran Fitoplankton di Perairan Morosari Demak. *Jurnal Oseanografi*. **4**(1), 124-131.

Arief, M. (2010). Analisis Kesesuaian Perairan Tambak Di Kabupaten Demak Ditinjau Dari Nilai Klorofil-A, Suhu Permukaan Perairan, dan Muatan Padatan Tersuspensi Menggunakan Data Citra Satelit Landsat ETM 7+. *Jurnal Penginderaan Jauh dan Pengolahan Data Citra Digital*, **3**(1), 108-118.

MNLH. (2001). *Keputusan Menteri Negara Lingkungan Hidup Nomor 4 Tahun 2001 tentang Kriteria Baku Kerusakan Terumbu Karang*. Jakarta-Indonesia: Menteri Negara Lingkungan Hidup.

Kusumaningtyas, M. A., Bramawanto, R., Daulat, A., & Pranowo, W. S. (2014). Kualitas perairan Natuna pada musim transisi. *DEPIK*, **3**(1), 10-20. doi: 10.13170/depik.3.1.1277.

Mehdiabadi, F. E., Mehdizadeh, M. M., & Rahbani, M. (2015). Simulating Wind Driven Waves in the Strait of Hormuz using MIKE21. ILMU KELAUTAN: Indonesian Journal of Marine Sciences, **20**(1), 1-8. doi: 10.14710/ik.ijms.20.1.1-8

Ondara, K., & Wisha, U. J. (2016). Simulasi Numerik Gelombang (*Spectral Waves*) dan Bencana Rob Menggunakan Flexible Mesh dan Data Elevation Model Di Perairan Kecamatan Sayung, Demak. *Jurnal Kelautan: Indonesian Journal of Marine Science and Technology*, **9**(2), 164-174. doi: 10.21107/jk.v9i2.1694

Pranoto, H. R., Atmodjo, W., & Sugianto, D.N. (2016). Studi Sedimentasi pada Bangunan Groin di Perairan Timbulsloko, Kabupaten Demak. *Jurnal Oseanografi*. **5**(1), 86-95.

Purwaningsih, F. D., Saraswati, T. R., & Soeprobowati, T. R. (2015). *Konsentrasi Logam Berat Pb, Cd, dan Cr pada Air dan Sedimen di Perairan Pesisir Sriwulan, Kecamatan Sayung, Kabupaten Demak*. Dalam Seminar Nasional Biologi II tahun 2015 bidang Pemanfaatan Sumberdaya Hayati dan Peningkatan Kualitas Lingkungan. Semarang, Indonesia.

Riyadi, A. (2011). Kajian Kualitas Perairan Laut Kota Semarang dan Kelayakannya untuk Budidaya Laut. *Jurnal Teknologi Lingkungan*, **6**(3), 497-501.

Sidqi, M., Tandjung, S. D., & Nitimulyo, K. H. (2015). Analisis Kualitas Lingkungan Perairan Berdasarkan Komunitas Meiobentos dan Kualitas Sedimen di Pantai dan Area Pertambakan, Pesisir Sriwulan Kabupaten, Demak. *Jurnal Manusia dan Lingkungan*. **10**(3), 111-119.

Sihombing, I. N., Hutabarat, S., & Sulardiono, B. (2015). Kajian Kesuburan Perairan Berdasarkan Unsur Hara (N, P) dan Fitoplankton di Sungai Tulung Demak. *Management of Aquatic Resources Journal*, **4**(4): 119-127.

Suprapti, N. H. (2008). Kandungan Chromium pada Perairan, Sedimen dan Kerang Darah (*Anadara granosa*) di Wilayah Pantai Sekitar Muara Sungai Sayung, Desa Morosari Kabupaten Demak, Jawa Tengah. *Bioma*, **10**(2), 53-56.

Talley L.D., Pickard G.L., Emery W.J., & Swift J.H., (2011). *Descriptive Physical Oceanography: An Introduction* (Sixth Edition). Boston, USA: Elsevier.

Tarigan, D.A., Yusuf, M., & Maslukah, L. (2014). Sebaran Nitrat dan Fosfat di Perairan Muara Sungai Porong Kabupaten Sidoarjo. *Jurnal Oseanografi*. **3**(3): 384-391.

Widada, S., Rochaddi, B., & Endrawati, H. (2012). Pengaruh Arus Terhadap Genangan ROB di Kecamatan Sayung Kabupaten Demak. *Buletin Oseanografi Marina*. 1(2): 31-39.

Wisha, U. J., & Heriati, A. (2016). Analisis Julat Pasang Surut (*Tidal Range*) dan pengaruhnya terhadap Sebaran Total Sedimen Tersuspensi (TSS) di Perairan Teluk Pare. *Jurnal Kelautan: Indonesian Journal of Marine Science and Technology*, **9**(1), 23-31. Doi: 10.21107/jk.v9i1.1066.

Wisha, U. J., Husrin, S., & Prasetyo, G. S. (2016a). Hydrodynamics of Bontang Seawaters: Its Effects on the Distribution of Water Quality Parameters. *Indonesian Journal of Marine Sciences/Ilmu Kelautan*, **21**(3), 123-134. doi: 10.14710/ik.ijms.21.3.123-134.

Wisha, U. J., Yusuf, M., & Maslukah, L. (2016b). Kelimpahan Fitoplankton dan Konsentrasi TSS Sebagai Indikator Penentu Kondisi Perairan Muara Sungai Porong. *Jurnal Kelautan: Indonesian Journal of Marine Science and Technology*, **9**(2), 122-129. doi: 10.21107/jk.v9i2.1298.

Wisha, U. J., Husrin, S., & Prihantono, J. (2015). Hidrodinamika Perairan Teluk Banten Pada Musim Peralihan (Agustus–September). *ILMU KELAUTAN: Indonesian Journal of Marine Sciences*, **20**(2), 101-112. doi: 10.14710/ik.ijms.20.2.101-112.

Wulandari, S. Y., Yusuf, M., & Muslim, M. (2014). Kajian Konsentrasi Dan Sebaran Parameter Kualitas Air Di Perairan Pantai Genuk, Semarang. *Buletin Oseanografi Marina*, **3**(1), 9-19.

Zacharias, I., & Gianni, A. (2008). Hydrodynamic and dispersion modeling as a tool for restoration of coastal ecosystems. Application to a re-flooded lagoon. *Environmental Modelling & Software*, **23**(6), 751-767. doi: 10.1016/j.envsoft.2007.09.007.