Total Suspended Solid Concentration Dynamics and Distribution Based on Geospatial Models in Mojo River Estuary, Pemalang

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Abstract

Total suspended solids (TSS) concentrations and distribution provide information to determine the quality of the carrying capacity of waters as marine resources. The purpose of the research is to analyze the concentration and distribution of TSS in marine waters due to anthropogenic impacts on land. The concentration and distribution changes of TSS were analyzed using a geospatial model approach. The *in-situ* data were collected in September 2023 at 14 stations in the east monsoon and analyzed in the laboratory using the gravimetric method. The results show that TSS concentration range from 29.2–52.6 mg/L. The distribution of MPT content in the Mojo River Estuary, Pemalang has several groups of stations with convergent forms, where the high source of MPT comes from around the lagoon, namely the aquaculture and mangrove areas, then in general it is also affected by waste from anthropogenic activities of the, surrounding industries seasonal currents, which are related to wind and seasons, as well as currents due to waters from tides.

Keywords: Coastal Waters, Geospatial, Anthropogenic, Mojo Estuary, Pemalang

INTRODUCTION

Pemalang Regency is one of the regencies in Central Java Province located between 109°17'30" - 109°40'30" E and 6°52'30" - 7°20'11" S. Pemalang Regency is an area located on the North Coast of Java which has an area of 11,530 km^2. Pemalang Regency is known as a textile, weaving and convection industry area, agropolitan area, agricultural and plantation products, tourist attractions, and capture and aquaculture fisheries (Pemkab Pemalang, 2015). In accordance with its geographical location, Pemalang Regency has a coastline length of ±35 km with a sea water width of 4 miles, so Pemalang Regency has a sea area of 259.28 km^2 (Dewanti *et al.,* 2014). Mojo Village is an area located on the north coast of Java Island in Pemalang Regency which is a potential area for mangrove growth. Mojo Village has a mangove ecosystem area of 327 ha or 40.18% of the total mangrove ecosystem area in Pemalang Regency, which is 813.8 ha. The length of the coastline in Mojo Village is about 5.9 km, and the area of ponds in Mojo Village is ± 150 ha. The Mojo Village area in the north is bordered by the Java Sea, in the south it is bordered by Wonokromo Village, in the west it is bordered by the Comal River, and in the east it is bordered by Limbangan Village (Farhaby, *et al.,* 2017). The estuary of the Mojo River is a type of river that has its headwaters located at the end of the Comal River. This causes the flow of the Mojo river estuary to be filled with sand and mud material. In addition, the existence of mangrove ecosystems also affects the characteristics of the Mojo river estuary. When sea water conditions recede, the eroded solid material is carried by the river flow to the mouth of the river. This causes the presence of suspended solid material at the mouth of the Mojo river (Aini *et al*., 2016). The Mojo River estuary has the main function of draining water and transporting sedimentary material from erosion in watersheds (DAS) and their grooves. In general, the presence of materials such as sand and mud in the river flow is caused by erosion that occurs due to friction of fast and strong river flows, resulting in the erosion of land along the river flow. Some of this sedimentary material will be carried

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by flood water outside the flow channel to be deposited and most of the others will be carried to the sea or river estuaries (Shabari *et al.*, 2019).

Suspended Solids (MPT) or Total Suspended Solids (TSS) are particles floating in the water column, consisting of organic (living) and inorganic (dead) components. The organic (living) component consists of phytoplankton, bacteria, fungi, and others. While the inorganic (dead) component consists of detritus and other inorganic (dead) component particles. Suspended solids have a diameter greater than 1 µm. MPT is not toxic in waters, but if excessive MPT can increase turbidity and reduce the penetration of sunlight into the water column which ultimately affects the process of photosynthesis and inhibits fish respiration because the gills are clogged with suspended materials (Wirasatya *et al.*, 2023). The presence of suspended solids material (MPT) in waters can be sand, mud, clay, colloids, as well as organic matter such as plankton and other organisms. Hydro-oceanographic factors such as wind, rainfall, waves, currents, and tides affect MPT in coastal and estuarine areas (Ridarto *et al*., 2023).

Based on the description above, that anthropogenic activities are one of the most significant sources of pollution in the entire environmental field, especially in the Mojo River Estuary. The Mojo Pemalang River watershed passes through the city center and is influenced by anthropogenic activities dominated by urban activities. High human activities, such as industrial activities, port activities, settlements, and agricultural activities in Pemalang Regency can have an impact on the concentration of suspended solids which is increasing every year. MPT is an important factor controlling biological processes in water. Therefore, the reality that appears physically from the Mojo River Estuary, is used as a basis for knowing the condition of the waters related to the designation of the river. The aims of the research is to determine the concentration value and distribution of suspended solids material in the Mojo River Estuary during the transition season period 2, represented in September 2023.

MATERIAL AND METHODS

The Mojo River Estuary, Pemalang was selected as research location to represent the condition of Pemalang waters, which is indicated as a mangrove rehabilitated area, and as the same time by the most affected river by city activity and tourism. This condition brings the observation find out how the pollutants are distributed from the land to the sea. *In-situ* data were collected on August 23, 2023 to represent the east monsoon season at 14 stations spanning the river, the estuary, and the open sea. The research location is shown in Figure 1. The circulation pattern of the study area is governed by the impacts of surface currents driven by monsoon winds and the tidal effects and circulation masses as it flows (Pratama, 2019). The tides along the coast of Pekalongan waters are predominantly mixed tide prevailing diurnal tides (Maharlika *et al*., 2020). Tidal data obtained from the Geospatial Information Agency (BIG), 2022 iPASOET | Sea Level Monitoring (big.go.id), which is then processed using the admiralty method. The samples were collected at an elevation of 1.796 meters with LWL 1.249 meters, MSL 1.709 meters, and HWL 2.198 meters.

Water sampling and TSS quantification

Water samples were taken using a Nansen bottle sampler at the sea surface on 0.2d. The TSS concentration was measured using the gravimetric method APHA 2540.

Satellite Data Pre-Processin

The image data uses satellite acquisition data for September 2023 to describe the location according to the conditions at the time of in-situ data collection. Sentinel-2 level 1C image taken from EarthExplorer (usgs.gov) then examine the accuracy of the surface reflectance product resulting from the atmospheric correction on the image using Sen2Cor software to become sentinel-2 level 2A (Padró *et al*., 2018). This approach attempts to create a surface reflectance or Bottom of Atmospheric (BOA) value by subtracting the Top of Atmosphere (TOA) reflectance value from the multi-temporal image used, (Bioresita *et al*., 2018; Caballero *et al*., 2018). The sentinel-2 level 2A bottom of the atmospheric (BOA) satellite imagery was obtained, and the shoreline extraction was performed using ArcGIS 10.8 software. Shoreline extraction is processed by separating the land boundary from the sea boundary using the band ratio and RGB composite method. The band ratio technique produces land-water boundaries not covered by vegetation classifying into the sea area. The results of this limitation are later exported as vector data in the form of coastline data in .shp format and corrected using the on-screen digitize method on images that have been given a composite RGB color display on the three images

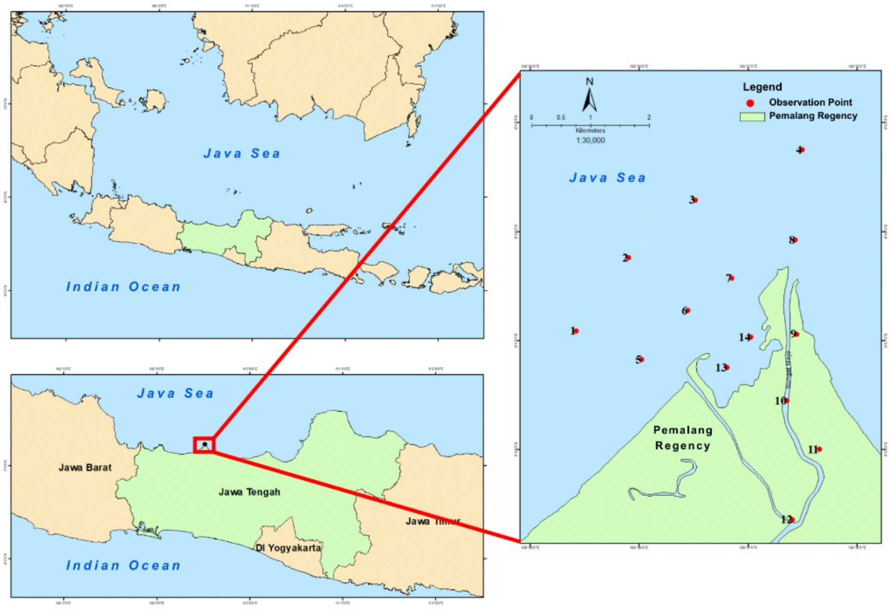

Figure 1. Map of Mojo River Estuary, Pemalang showing study area and sampling sites.

data. The coastline extraction uses the Normalized Difference Water Index algorithm to distinguish between water and land boundaries using Near-Infrared (NIR) (band 8) and green band (band 3) (McFeeters, 1996; Du *et al*., 2016; Kamaruddin *et al*., 2022; Ridarto *et al*., 2023).

Interpolation Model

A spline-based interpolation technique displayed TSS concentrations as a distribution pattern. The Spline method was used because it assumes that the interpolation value would fluctuate linearly as a function of distance from the closest sample value and will not be influenced by the location of the sample data. (Ahmad and Deeba, 2020; Kamaruddin *et al*., 2022). This distribution pattern graphically and informatively describes each parameter. (Ahmad and Deeba, 2020). The interpolation method used is spline with barriers, where this method separates the interpolation area from the boundary area, namely the land area. The land vector is used as input barrier features, which in this case uses the land of Mojo River Estuary, Pemalang. Then, in the environment setting, the extent used is the area of interest in the study area. In addition, the mask on the raster analysis is also set according to the area of interest so that the resulting interpolation follows the study area (Ridarto *et al*., 2023).

Wind Data Processing

The wind data were obtained from the European Center for Medium-Range Weather Forecast (ECMWF). The data used the u and v components which will be processed into speed and wind direction data. The data extraction results were presented in the wind rose using WRPLOT. Downloaded wind data at speeds u and v, then calculated the resultant wind speed and direction in vectors x and y. The wind data used is at one-hour intervals for an entire month, in September 2023, representing the east season each year. Wind data is used to determine the dominant characteristics of the wind's direction and speed that passes over Mojo River Estuary, Pemalang's waters (Ridarto *et al*., 2023).

2D Hydrodynamics Characteristics of Ocean Currents

Ocean currents are generated by inputting wind data, tidal data, and bathymetry data in the waters of Mojo River Estuary, Pemalang. MIKE 21 software was used with the FM flow model module to obtain sea surface current data. Current processing has several stages, such as: pre-processing the model, in the form of preparation of bathymetric and unstructured triangular mesh data; processing the model in the form of set up model parameter coefficient values in the control model section; and post-processing models in the form of numerical simulation results (Amirullah *et al*., 2014; Ridarto *et al*., 2023).

RESULTS AND DISCUSSION

TSS concentration.

TSS concentration in waters ranges from 29.2 – 52.6 mg/L. The highest TSS concentration was found in the sampling site at station 13, at the lagoon, which is related to the condition of the lagoon which tends to be stable and only gets a slight influence from tides and currents. Meanwhile, the content has occurred at station 4, which is a station that is offshore, and tends to be stable, and is more affected by climatic conditions. The TSS content at the research station showed distributed values, where each was greatly influenced by the parameters of high tides towards neap tide, currents along the coast, and climatic conditions at the time of sampling (Ridarto *et al*., 2023). Karbela *et al*. (2020), Ni'amah *et al*. (2023), and Ippah *et al*. (2024), stated that the TSS content in coastal areas will be influenced by dominant hydrodynamic factors such as tides and currents due to wind. Zhou *et al*. (2020), Zhao *et al*. (2022) and Ma *et al*. (2024) explained that the TSS content can appear dynamics according to the geomorphology and the characteristic of the sampling location, especially bathymetry, because it is related to the opportunity of organic matter waste and the process of resuspension into nutrients.

Spatial distribution of TSS

Based on the results of the research on the concentration value of suspended solids in the waters of the Mojo River Estuary, Pemalang, which was carried out when the tide was low by obtaining 14 stations. The results of the concentration of suspended solids material at the sampling station at Muara Sungai Mojo, Pemalang Regency showed a convergent pattern at several stations such as at stations 9 and 10; stations 13 and 14; and station 3 is seen in Figure 2.

Meanwhile, the relationship between the distribution pattern of suspended solids material and current, where the current is related to the wind, as well as related to the current season, shows that the direction of the current moves from southeast to northwest (Figure 2). This causes the mass of water from the upstream that flows to the estuary and towards the sea, experiencing a change in direction and the formation of station groups, and causing a convergent distribution pattern. The influence of the current caused by the wind is also suspected to be related to the sampling period (September 2023), which at that time was in the east monsoon transition. Indrayanti *et al*. (2023)

Table 1. Value of TSS by *in-situ* measurement in the waters of Mojo River Estuary, Pemalang.

Sampling sites	Longitude	Latitude	TSS Concentration (mg/L)
Station 1	109° 49' 03,706" W	6° 78' 18,251" S	39.2
Station 2	109° 49' 84,071" W	6° 77' 06,354" S	30.8
Station 3	109° 50' 86,054" W	6° 76' 18,346" S	42.8
Station 4	109° 52' 49,874" W	6° 75' 41,320" S	29.2
Station 5	109° 50' 03,731" W	6° 78' 62,133" S	34.1
Station 6	109° 50' 74,608" W	6° 77' 87,375" S	38.7
Station 7	109° 51' 42,051" W	6° 77' 37,799" S	39.6
Station 8	109° 52' 39,197" W	6° 76' 79,184" S	37.5
Station 9	109° 52' 41,116" W	6° 78' 23,316" S	45.4
Station 10	109° 52' 26,201" W	6° 79' 24,862" S	50.3
Station 11	109° 52' 76,288" W	6° 79' 99,137" S	36.6
Station 12	109° 52' 34,856" W	6° 81' 06,829" S	46.5
Station 13	109° 51' 34,930" W	6° 78' 74,501" S	52.6
Station 14	109° 51' 70,879" W	6° 78' 27,913" S	48.7

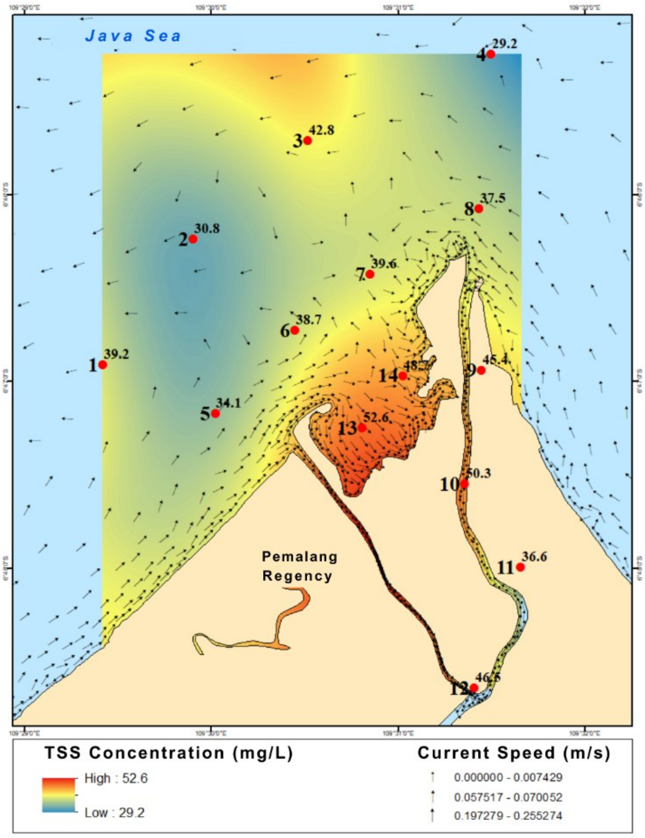

Figure 2. Spatial distribution pattern of total suspended solids at Mojo River Estuary, Pemalang.

dan Wirasatriya *et al*., (2023). stated that the distribution of TSS in a coastal area will be closely related to hydro-oceanographic phenomena and seasonal conditions at the time of sampling. Water samples were collected when the tidal was near the mean sea water level. Since the low tide conducted a greater value of TSS than the high tide, the supply of suspension is influenced by the river inputs then carried by longshore currents by the open sea (Zhao *et al*., 2022, Ridarto *et al*., 2023,).

Tidal Characteristic

Tidal data in this study was obtained from the Geospatial Information Agency of Pekalongan station, Central Java in September 2023 within 30 days which was processed using the Admiralty method to obtain the value of the tidal harmonic constant so that the tidal type at the mouth of the Mojo River was obtained. Data processing was carried out to obtain MSL (Mean Sea Level), HHWL (Highest High Water Level), and LLWL (Lowest Low Water Level) values. Based on the results of data processing, an MSL value of 1.81 meters, an HHWL value of 2.01 meters, and an LLWL value of 1.27 meters were obtained. Tidal data processing was carried out using the Admiralty method, obtaining the values of the tidal components, namely S0, M2, S2, N2, K1, O1, M4, K2, and P1 presented in Table 2. Based on the value of these tidal components, the Mojo River Estuary, Pemalang is included in the type of mixed tidal with a double daily tilt with a Formzahl number of 1,365 (Figure 3). The double daily tilt tidal type means that in one day there are two tides and two low tides, but sometimes there is also one tide and one low tide with different heights and times (Iskandar *et al*., 2020).

Wind Characteristic

The results of the Windrose analysis in September 2023 found that the dominant wind blew from the southeast to the northwest. Winds with a speed of more than 5 to 9 m/s blow from the southeast about 20.4 to 51% of the time. Meanwhile, winds with a speed of 3.60 to 5.70 m/s blow from the southeast about 5 to 11% of the time (Figure 4).

Table 2. Tidal Harmonic Components for the east monsoon transition (September 2023).

	M2	S2	N2	K1	O1	M4	MS4	K2	P1
A (m)	0.067	0.089	0.0285	0.164	0.049	0.006	0.001	0.024	0.054
g (°)	260.86	43.86	223.35	141.35	68.88	27.545	84.86	43.86	141.35

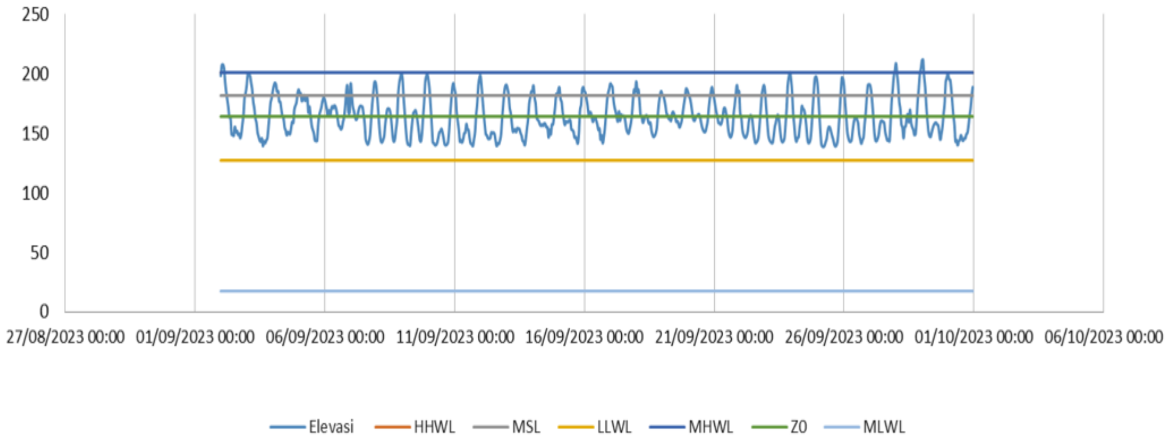

Figure 3. Tidal Chart of Pemalang Waters for September 2023

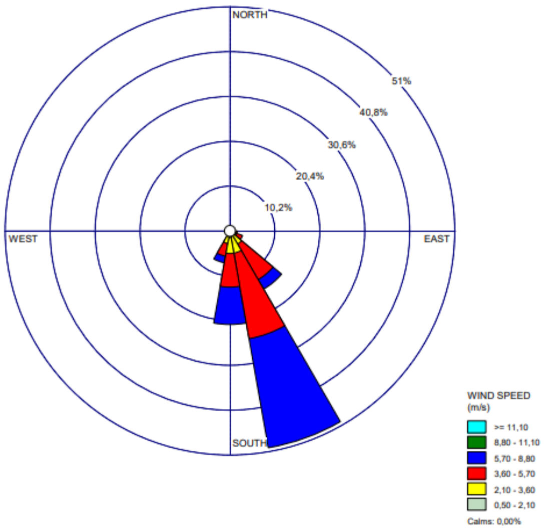

Figure 4. Wind Rose in Pemalang Waters in east monsoon transition (September 2023)

CONCLUSSION

The results of this study show that the MPT content in Mojo River Estuary, Pemalang in September 2023 has a range of 29.2 – 52.6 mg/L, where the highest concentration value is at station 13 with a concentration value of 52.6 mg/L. While the lowest value is at station 4 with a concentration value of 29.2 mg/L. 2. The distribution of MPT content in the Mojo River Estuary, Pemalang has several groups of stations with convergent forms, where the high source of MPT comes from around the lagoon, namely the aquaculture and mangrove areas, then in general it is also affected by waste from anthropogenic activities of the, surrounding industries seasonal currents, which are related to wind and seasons, as well as currents due to waters from tides.

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