Determination of Chlorophyll-a and Its Distribution in the Waters of the Mangrove Forest Rehabilitation Area in Mojo Estuaria, Pemalang

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Abstract

Pemalang Regency has a mangrove area of around 2,839.44 but has been damaged reaching 453.38 Ha or about 16% of the existing area. This causes ecological functions in resisting abrasion, erosion, sedimentation, and carbon capture to decrease. Government efforts to restore the function of mangroves on the North Coast of Central Java carried out by rehabilitation require input from a water productivity approach. This study aims to determine the content and distribution of chlorophyll-a found in Pemalang Waters, Central Java. This was done by *in situ* observations in Pemalang Waters to see the fertility level of the waters, by purposive sampling at 20 sampling sites, on April 30, 2024. The results obtained will be interpolated with ex situ data, including the Indonesian Earth Map (RBI), tidal data obtained from the SRGI website, flow data obtained from the Batnas website, and wind data obtained from the BMKG website. The next geospatial approach is ODV 4, Ms.Excel, and WR Plot application mapping; current analysis will be performed using ArcGIS 10.8 and Mike 21 applications; while the tidal analysis is carried out by the Admiralty method. The results of research conducted in Mojo Waters, Pemalang showed that the range of chlorophyll-a values was in the range of 1,858 - 41,287 mg / m^3. The results were analyzed in sampling areas including rivers, estuaries, lagoons, eastern drift currents, western drift currents, waters still affected by estuaries, and the high seas. The distribution of chlorophyll values in these waters is the impact of nutrient supply from land because it is closely related to human activities, freshwater and seawater resuspension, drift currents, breaking waves, tidal currents. This causes the distribution pattern to occur from northeast to southwest.

Keywords: Chlorophyll-A, Distribution, Aquatic Fertility, Geospatial, Mangrove Mojo, Pemalang

INTRODUCTION

Mangrove ecosystems are one of the three coastal ecosystems that have an important ecological role in supporting the life and sustainability of fishery resources. Mangrove ecosystems (mangroves) are ecosystems located in coastal areas that are affected by the tides of sea water so that they are always waterlogged (Latifah *et al*., 2018). Syamsu *et al.* (2018), stated that mangroves as brackish forests or mangrove forests are trees that grow in brackish areas on alluvial soils in areas were seawater and freshwater meet around river estuaries. The function of mangrove ecosystems in tropical regions has an important role for the productivity of coastal ecosystems. The high nutrient content in mangrove forest areas is one of the reasons for supporting this function and role. These nutrients will support the productivity of the waters in the region (Karubaba, 2001). Primary productivity is related to the biological conditions of the ocean, especially the variability of the rainy season, which can trigger changes in ocean productivity parameters including changes in chlorophyll-a indicators. Aquatic productivity is supported by the presence of nutrients and chlorophyll-a in the waters. Chlorophyll-a plays an important role in the carbon cycle where the carbon cycle is a description of the mechanism by which carbon flows between the environment of living things, inorganic matter and the atmosphere (Kunarso *et al*., 2018).

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The destruction of mangrove forests in Indonesia is mostly caused by human actions, both in the form of conservation of mangrove areas into other means of use such as settlements, industry, recreation, and so on. Pemalang Regency as one of the districts in Central Java Province which has a coastal area with a length of about 35 km and has a mangrove area of about 2,839.44 Ha. The area of mangroves that have been damaged reaches 453.38 hectares or about 16% of the existing area. The remaining mangrove forests are only in certain parts that are only able to withstand abrasion directly from the coast. The government's efforts to restore the function of mangroves on the North Coast of Central Java have been carried out intensively since 1998 by rehabilitating the area by planting mangrove seedlings with the aim of improving coastal conditions so that they can recover and be able to function optimally, especially in carrying out their function as a natural defense system. One of the successes of mangrove rehabilitation can be seen on the North Coast of Pemalang which has a positive impact on the coastal ecosystem and the surrounding community, especially on the density, height, and diameter of tree plant stems, as well as the return of biota that constitutes the ecosystem is a benchmark for this success.

One of the successes of mangrove rehabilitation can be seen on the North Coast of Pemalang which has a positive impact on the coastal ecosystem and the surrounding community, especially on the density, height, and diameter of tree plant stems, as well as the return of biota that constitutes the ecosystem is a benchmark for this success. The purpose of the research is to determine the concentration value and distribution of chlorophyll-a in the Mojo River Estuary in April, 2024.

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 April 30, 2024 to represent the east monsoon season at 20 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 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 10200-H). The image data uses satellite acquisition data for April 2024 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 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).

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).

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 April 2024, 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).

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

Station points that represent chlorophyll-a values in the river area include stations 11 – 14. This river is called the Comal River where on the right and left sides there are ponds owned by residents. The value obtained at each of these stations was 3.08715 mg/m^3; 3.2809 mg/m^3; 3.7019 mg/m^3; and 3.92475 mg/m^3. Station points that represent chlorophyll-a values in the river estuary area include stations 4 – 5. The values obtained at each of these stations were 5.6379 mg/m^3 and 2.8175 mg/m^3 respectively. The chlorophyll-a content at stations 4 and 5 when viewed on the research map is assumed to get nutrient supply from river and lagoon areas as well as the influence of tidal currents of seawater. The content values at stations 4 and 5 have quite striking differences. This striking difference in values can be caused by the characteristics of the sampling location at the station where station 4 which has a higher value is located closer to the lagoon near the mangrove area while station 5 is located closer to the downstream area or the mouth of the Comal River. Station points representing chlorophyll-a values in the lagoon area include stations 9 – 10. The values obtained at each of these stations were 41,287 mg/m^3 and 10.80965 mg/m^3 respectively. Stations 9 and 10 have a large value when compared to the results of the overall chlorophyll-a content value at the research site. In this lagoon there is a mangrove area, therefore it can be concluded that the station has a high value for chlorophyll-a content because it gets a supply of nutrients from mangroves. However, when compared overall, station 9 has a very large value spike so that it is assumed that there is an anomaly at the station that when sampling occurs, turbulence occurs which results in damage to the sample. The station points representing the value of chlorophyll-a in the eastern drift current area include stations 6 – 8. The value obtained at each of these stations consecutively was 1,858 mg/m3; 2.0565 mg/m^3; and 1.9412 mg/m^3. The value of chlorophyll-a content at this station is quite small when compared to other station points. This area is the place where the waves break and visually the waters in this area have quite murky water. The turbidity of the waters in this area indicates that there is a stir which makes it difficult for sunlight to enter the water body. The chlorophyll-a cycle is highly dependent on the intensity of the sun shining on the place, so the low chlorophyll-a content in this area is assumed to be caused by the lack of sunlight entering the water body so that the continuous photosynthesis process is not optimal. Station points that represent chlorophyll-a values in the western drift current area include stations 1–3. The value obtained at each of these stations is 3.1796 mg/m^3; 3.07525 mg/m^3; and 6.1125 mg/m^3. As figure it from the research map, the location of stations 1-3 is quite close to the lagoon which has a mangrove area. The chlorophyll-a content obtained at the station can be assumed to also get a nutrient supply from the lagoon where previously discussed the station in the lagoon area has the highest chlorophyll-a content value than stations in other areas due to the supply from the mangrove area. Station points that represent chlorophyll-a values in water areas with the influence of phenomena that occur around the coast include stations 15 – 17. The value obtained at each of these stations was 2.73525 mg/m^3; 3.30065 mg/m^3; 3.66725 mg/m^3. In simple terms, the beach can be interpreted as a connecting area between the land and the sea. The beach is a dynamic coastal area, meaning that the beach space (shape and location) changes rapidly in response to natural processes and human activities. Sampling is carried out at low tide. This causes the nutrient elements contained in sediments in coastal areas to accumulate in water bodies and supply chlorophyll-a concentrations for the photosynthesis process. Station points that represent chlorophyll-a values in the high seas area with the influence of phenomena that occur around the

Table 1. Value of Chlorophyll-a (mg/m^3) by *in-situ* measurement in the waters of Mojo River Estuary, Pemalang.

Sampling sites	Longitude	Latitude	Chlorophyll-a concentration (mg/m^3)
Station 1	109°30'0.11"E	6°47'18.23"S	3.1796
Station 2	109°30'17.42"E	6°46'53.99"S	3.07525
Station 3	109°30'38.27"E	6°46'36.35"S	6.1125
Station 4	109°31'0.21"E	6°46'21.31"S	5.6379
Station 5	109°31'26.01"E	6°46'11.80"S	2.8175
Station 6	109°31'57.53"E	6°46'15.48"S	1.858
Station 7	109°32'18.39"E	6°46'42.33"S	2.0565
Station 8	109°32'24.21"E	6°47'6.11"S	1.9412
Station 9	109°30'48.47"E	6°47'13.17"S	41.287*
Station 10	109°31'3.77"E	6°47'0.74"S	10.80965
Station 11	109°31'26.63"E	6°46'56.14"S	3.08715
Station 12	109°31'19.83"E	6°47'40.29"S	3.2809
Station 13	109°31'38.83"E	6°47'57.17"S	3.7019
Station 14	109°31'24.93"E	6°48'37.98"S	3.92475
Station 15	109°30'53.50"E	6°45'41.95"S	2.73525
Station 16	109°31'27.49"E	6°45'36.43"S	3.30065
Station 17	109°32'1.17"E	6°45'41.64"S	3.66725
Station 18	109°30'50.42"E	6°45'3.91"S	2.84145
Station 19	109°31'26.85"E	6°45'2.06"S	3.0931
Station 20	109°32'5.19"E	6°45'5.74"S	5.74215

*) The data is anomalous, and is not included in further processing

coast include stations 18 – 20. The value obtained at each of these stations consecutively is 2.84145 mg/m³; 3.0931 mg/m³; and 5.74215 mg/m³. Data collection is carried out at high tide where seawater will go towards land, the water carries nutrients from the open sea and when high tide the nutrient supply tends to be small because it is caused by the movement of water from the high seas to land. Solar intensity A fairly high solar intensity will cause the temperature to increase, while the nutrient content becomes more limited. This condition was stated by Maslukah *et al.* (2019)., Misbach *et al*. (2021)., Purwanto *et al.* (2021), Maslukah *et al*. (2021.), Maslukah *et al*. (2022.), and Suryoputro *et al.* (2023). who stated that the chlorophyll-a content at each station will have a fairly wide value and have an impact on aquatic fertility, as a result of the influence of ecosystem conditions, as well as hydro-oceanographic factors, such as tides, coastal currents, organic matter resuspension, and nutrient supply from mangrove forest areas.

Observations in Mojo Waters, Pemalang at 20 station points determined using purposive sampling, obtained chlorophyll-a values that were quite varied. The chlorophyll-a values obtained showed a divergent or diffuse pattern at 20 observation station points. The sampling area includes rivers, estuaries, lagoons, eastern drift current, western drift current, waters still affected by estuaries, and the open sea (Figure 2). The highest concentration of chlorophyll-A was at Station 9 at 41,287 mg/m³ which was in the lagoon close to mangroves and the lowest was at Station 6 at 1,858 mg/m³ which was in around of the rupture wave.

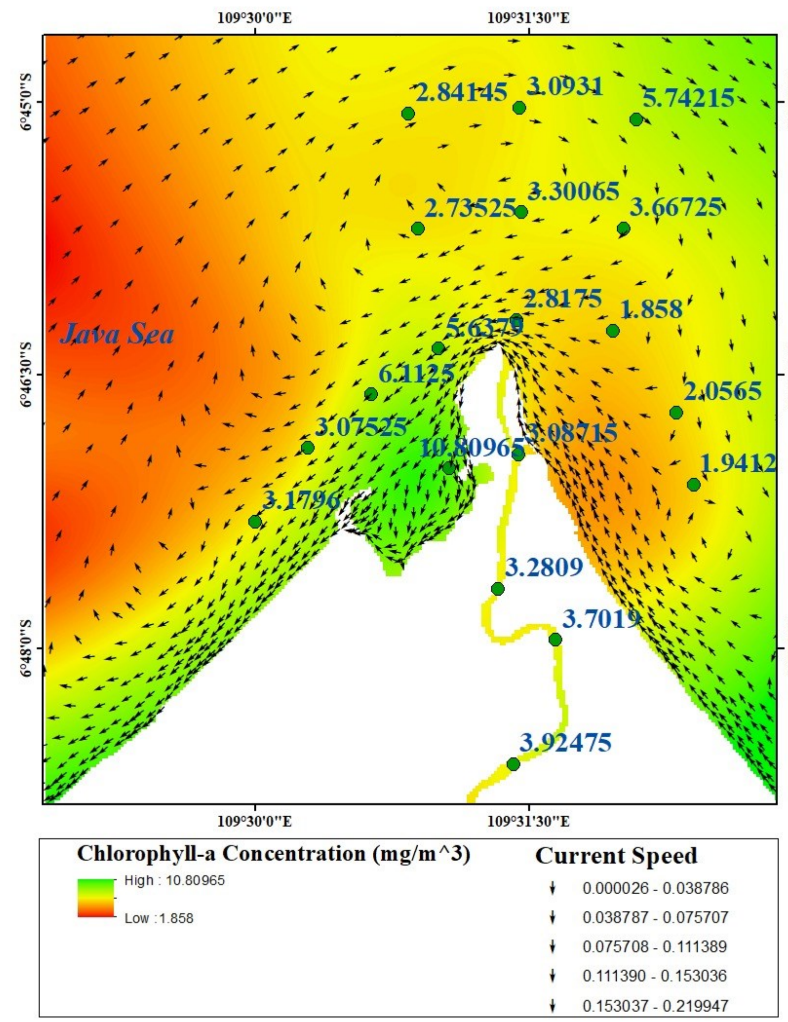

Figure 1. Spatial distribution pattern of Chlorophyll-a at Mojo River Estuary, Pemalang

The results show that the research area is included in the oligotrophic waters in around of the burst wave (stations 6-8); meso-oligotrophic in the offshore sea areas of stations (15-19) and rivers (stations 5, 11-14, 1-2); mesotrophic in the high seas area (station 20), lagoon (10, 3-4); and Eutrophic in the Mangrove area (Station 9). The classification is based on the trophic status of waters according to Parslow *et al.* (2008), namely the chlorophyll content in the range of 0 – 2 mg/l classified as oligotrophic, 2 – 5 mg/l classified as mesotrophic, 5 – 20 mg/l classified as mesotrophic, 20 – 50 mg/l classified as eutrophic and >50 mg/l classified as hyper-eutrophic Based on the results of the distribution map, the distribution of chlorophyll-a can be said to be a divergent or diffused distribution. Factors that affect the distribution are hydro-oceanographic parameters such as currents moving from northeast to southwest and tides that carry dissolved particles in the waters (Maslukah *et al*., 2019; Purwanto *et al*., 2021.; Ningrum *et al.,* 2022; Suryoputro *et al*., 2023).

Tidal data in this study was related to the seawater sampling for chlorophyll-a processing were taken on April 30, 2024 or during the transition season 1 and at 08.00 – 11.30 WIB when the tide is as seen in figures3 and 4. The tidal elevation is obtained from the website of the Indonesian Geospatial Reference System (SRGI) provided by the Geospatial Information Agency (SRGI). The downloaded elevation data is then filtered to get the hourly tidal elevation. Furthermore, the tidal chart below is obtained by processing the elevation value with the Admiralty method. The formzhal number obtained is 0.793771982, so the tidal type is a mixture inclined to double daily.

Wind data is represented by wind roses or windroses in figure 4.4 below which shows wind speed in Pemalang in April 2024. The maximum wind speed and direction are obtained from the official BMKG website which is then processed numerically with the help of Ms.Exel before being input into the WR Plot software. The direction of wind movement is dominated from the northeast to the southwest. Wind speed is dominated in the speed range of 3.60 – 5.70 m/s. (Figure 4).

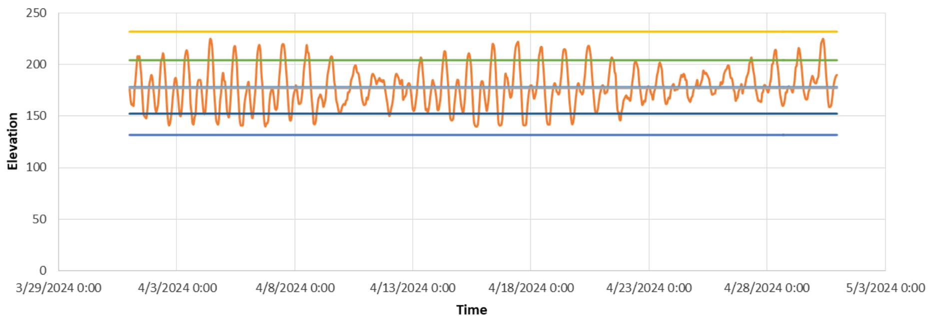

Figure 2. Tidal Chart of Pemalang Waters for April 2024

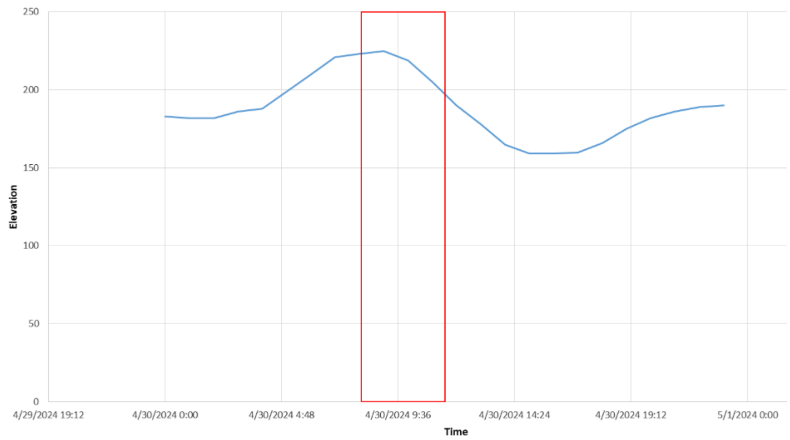

Figure 3. Tidal Chart of Pemalang Waters on April 30, 2024

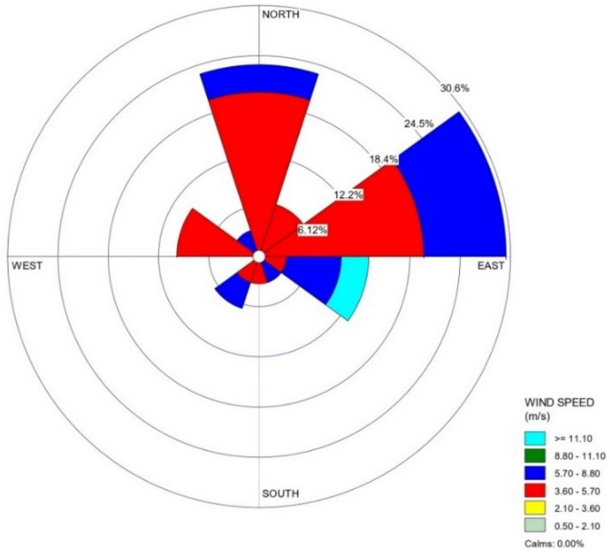

Figure 4. Wind Rose in Pemalang Waters (April 2024)

CONCLUSSION

The value of chlorophyll-a in Mojo Waters, Pemalang is in the range of 1,858 - 41,287 mg/m^3. Factors that affect the distribution of chlorophyll-a content values in the waters of Mojo, Pemalang including rivers, estuaries, lagoons, eastern drift currents, western drift currents, waters, which still affected by estuaries, and the high seas. The distribution of chlorophyll values in these waters is the impact of nutrient supply from land because it is closely related to human activities, freshwater and seawater resuspension, drift currents, breaking waves, tidal currents. This causes the distribution pattern to occur from northeast to southwest.

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