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Phosphate Content and Distribution in the Banger River Estuary and Pekalongan Coastal Waters, Central Java

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A B S T R A C T

River estuaries are complex environments because there is a strong interaction between river water and seawater. The input of river water into the sea brings a source of nutrients that can increase aquatic productivity. However, the river and estuary area in Banger River Estuary and Pekalongan Coastal Waters became one of the dumping sites for waste from various human and industrial activities. Batik waste contains textile dyes and in the form of organic matter contains phosphate elements. The problem that arises is the lack of waste treatment, as well as direct discharged into the sewer so that it can reduce water quality and disrupt biota life. The purpose of this study is to determine the content and distribution of phosphate in the Banger River Estuary, Pekalongan and its causative factors. This study uses quantitative methods based on the results of in situ sampling, which will be carried out on June 25, 2023. The analysis was carried out at the Oceanographic Chemistry Laboratory, Department of Oceanography, FPIK Undip. The results of this study show that the content of suspended solids in the Banger River Estuary, and Pekalongan City Beach Waters is in the range between 0.0001 – 0.1904 mg / L. The distribution of phosphate in the Banger River Estuary, and the Coastal Waters of Pekalongan City tends to follow the coastline pattern, although there are a group of stations that form a convergent pattern in estuarine waters. The distribution occurs as an influence of various Oceanographic parameters such as ebb to tides, currents and seasons, as well as the mixing of water masses, and depth.

Keywords: Phosphate, Distribution, Banger River Estuary, Pekalongan

1. Introduction

Pekalongan is an area on the north coast of Java which is the center of the batik industry in Indonesia. River estuaries are complex environments because there is a strong interaction between river water and sea water. The input of river water to the sea brings a source of nutrients that can increase water productivity. River estuaries are very productive areas and ecologically function as spawning grounds, rearing grounds and nursery grounds for marine biota. However, the river and estuary areas in Pekalongan have become a dumping ground for waste from various human and industrial activities. The batik industry produces a lot of waste, especially liquid waste. One of the rivers in Pekalongan that is polluted by batik waste in the form of organic waste is the Banger River. The problem that arises is the lack of waste processing, and it is directly thrown into the sewer. Waste that is thrown into rivers without going through a waste management process can reduce water quality and disrupt biota life (Zainuri *et al*., 2022).

The results of observations of Banger River waste are dominated by the textile industry. Maslukah *et al*., (2020) stated that waste which is the impact of anthropogenic activities is the burden of input of chemical elements into waters. One of the inputs of chemical elements that can cause a decrease in water quality is phosphate ions or P ions (PO_4^{2-}). The results of observations by Zainuri *et al*. (2022) and Ridarto *et al*., (2023) at the mouths of various rivers in Pekalongan showed waste range values ranging between 40.3-85.4 mg/L in 2021 and 64.7-140.5 mg/L in 2021. 2022. This shows that the waste content is quite high in the waters, where the presence of this waste is closely related to organic waste, nitrates and phosphates. Excessive phosphate content can cause eutrophication. The phosphate content in estuaries has a dynamic amount and is influenced by currents and tides.

The results of observations by Zainuri *et al*., (2020)., Zainuri *et al*., (2022) show that the chance of tidal occurrence as a result of high tides per year can reach 1.68 hectares. This condition causes waste that is carried into estuaries and coastal waters to again inundate land areas around the Pekalongan coast. This is in accordance with the occurrence of tidal/sea level rise which occurred in the period May-June 2020 and December 2019 - February 2020 (BPPS Pekalongan, 2022). These tidal floods cause waste to re-accumulate in waters, rivers or settle on land. This was stated by Maslukah *et al*., (2020) that the presence of waste in estuaries will become chemical elements in dissolved and suspended form which undergo a process of interacting with each other. It was further added that suspended particles have the ability to adsorb dissolved elements, and are followed by a destabilization process to form larger aggregates and ultimately settle to the bottom of the water due to gravitational forces. The destabilization process causes the concentration of dissolved chemical elements to decrease and increases their concentration in the sediment (Maslukah *et al*., 2017). However, the resuspension process can be a source of elements in the water column (Prartono & Hasena, 2009). The aim of this research is to determine the content and distribution of phosphate in the Bange River Estuary and Coastal Waters, Central Java and the factors that influence it as an effort to monitor and mitigate tidal rise/sea level rise disasters.

2. Material and Method

Materials

This research uses primary data in the form of secondary data. The primary data used is water samples containing phosphate, which are taken in situ and analyzed in the laboratory to determine the phosphate content. Meanwhile, secondary data used are landform maps and bathymetric data for Pekalongan waters obtained from the Geospatial Information Agency (BIG) in Tanahair.indonesia.go.id, tidal data for Pekalongan waters obtained from the Geospatial Information Agency (BIG) in ina-sealevelmonitoring.big.go.id, and Pekalongan water wind data obtained from marine.copernicus.eu. This secondary data is used as a base map for distribution maps and modeling input.

Method

The method used in this research is a quantitative method (Sugiyono, 2009). Phosphate data obtained through field sampling produces values that require numerical calculations.

Location Determination Method

Determination of sampling locations was carried out using a purposive sampling method where the selected locations were considered to represent the entire research area. This research was conducted at the Banger River Estuary with geographical boundaries of 6°49"50 - 6°51"20 Latitude and 109°40"0 - 109°42"0 Longitude on June 25 2023 at 06.30-13.00 WIB with 28 stations.

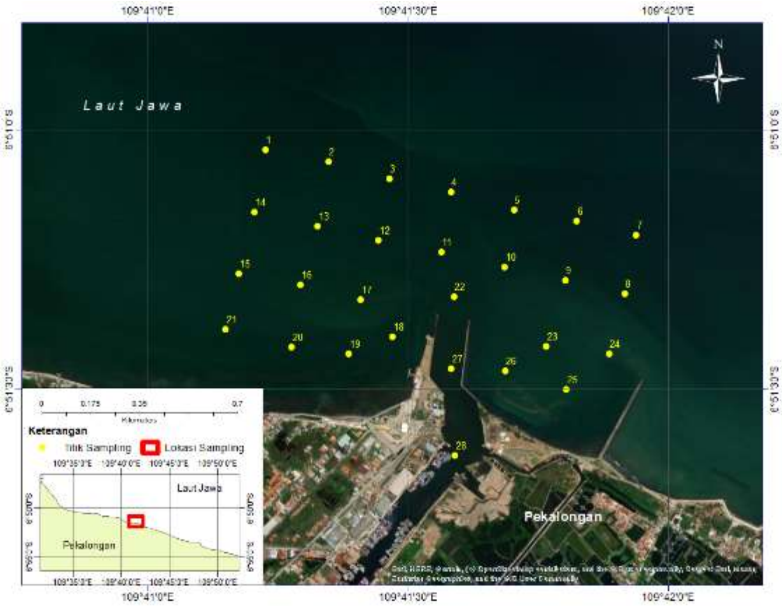

Figure 1. Area of Interest

Seawater Sampling Method

Sampling was carried out at low tide to high tide. Sea water samples were taken using a Nansen bottle. The water samples obtained are immediately placed into a sample bottle and stored in a coolbox filled with ice cubes.

Phosphate Analysis Method

Phosphate analysis begins with making a standard phosphate solution, namely dissolving KH_2PO_4 to become a standard phosphate solution with contents of 1 µM, 3 µM, 5 µM, and 10 µM. Then the standard solution is stored in a dark bottle. Next, the phosphate reagent is made by dissolving 0.34 grams of potassium antimonyl tartrate in 250 ml of aquabidest, 7.5 grams of ammonium molybdate in 250 aquabidest, 46.6 ml of sulfuric acid in 300 ml of aquabidest, and 5.4 grams of ascorbic acid in 100 ml. aquabidest. All solutions were homogenized and stored in dark glass bottles. The reagent mix was made by mixing ammonium molybdate, sulfuric acid, ascorbic acid, and potassium antimonyl tartrate successively in a ratio of 10:25:10:5. Then, for every 10 ml of seawater sample, 1 ml of reagent mix was added. The spectrophotometric procedure was carried out using a wavelength of 885 nm because ammonium phosphomolybdate can absorb light at this wavelength. The phosphate content value is obtained through a linear equation. The absorbance of ammonium phosphomolybdate is directly proportional to the phosphate content. This method refers to Strickland and Parson (1972).

Wind Processing Method

Wind data is extracted using Ocean Data View (ODV) and then processed in Microsoft Excel to obtain wind speed and direction values. Next, the data is displayed using WRPLOT View in Windrose form.

Ocean Current Processing Method

The current data was processed by entering tidal current data and bathymetric data into MIKE 21. The current data used came from the period 15 June to 15 July 2023. The hydrodynamic model of tidal currents was created using the FlowModel FM module. The results of processing using MIKE 21 are the speed and direction of tidal currents which are presented in map form.

Phosphate Distribution Processing Method

The research location map was created using Google Earth and then digitized and registered using ArcGIS. Phosphate content values are presented in a table using Microsoft Excel to be entered in ArcGIS. Next, the spline interpolation method is used to interpolate the data. This method is carried out by connecting points at each station, which are then visualized with color levels. Next, to determine the effect of current on phosphate content, the distribution map and current direction were overlaid with the phosphate distribution map.

Results and Discussion

Phosphate Concentration in Banger Estuary

Based on in situ measurements, the content in the Banger River Estuary is between 0.0001 – 0.1904 mg/l (table 1). Stations 4, 11, 12, 17, and 27 are stations that have high phosphate content. This is due to its location near the estuary, making it the first place to receive phosphate runoff from the river. The high phosphate content in estuaries is by research results by Maslukah *et al*., (2021) that phosphate carried by river flows can reach 90% of the initial content and end up in the estuary. Station 20, which is located in shallow water, also has high phosphate content. This is related to sediment resuspension, namely the process of releasing particles from sediment again (Handoyo *et al*., 2020). Phosphate deposits can be degraded back from sediment to water. Phosphate compounds that accumulate in sediment undergo a decomposition process using biotic processes, namely with the help of bacteria or through abiotic processes that produce dissolved phosphate so that it can return to the water column through diffusion and cause the phosphate content to become high. The lowest phosphate content is at stations located offshore and in the eastern area of the estuary. The low phosphate content in offshore waters is caused by microbiota metabolic processes. Phosphate contained in water will decompose into ionic compounds in the form of H_2PO^{4-}, HPO_4^{2-}, and PO_4^{3-}, which are then absorbed by phytoplankton and enter the food chain (Zainuddin and Nofianti, 2022). Meanwhile, in the area east of the estuary, the low phosphate content is caused by a lack of phosphate input from the river. Waters that have a phosphate content above 0.1 mg/L have experienced eutrophication (Misbach *et al*. 2021, Zainuri *et al*. 2022). Based on this, the phosphate values at stations 3, 6, 11, 12, 20, and 27 at the mouth of the Banger River are above the eutrophication threshold.

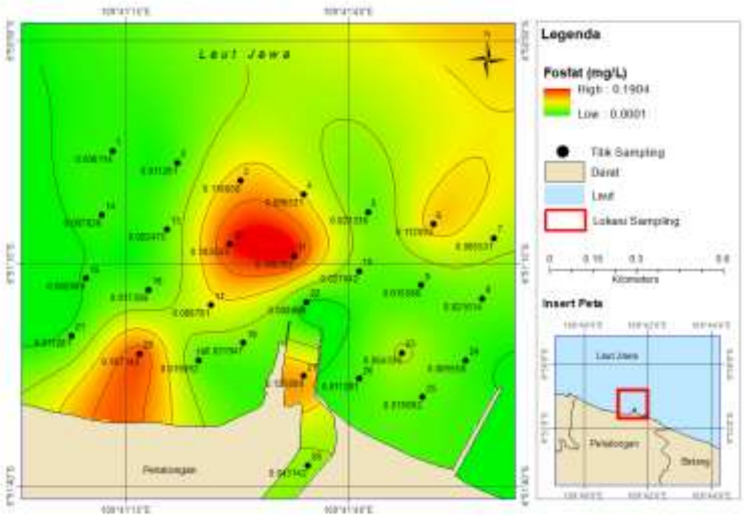

Figure 2. Phosphate Distribution in Banger Estuary

Table 1. Phosphate Concentrations in Banger Estuary, Pekalongan

Longitude	Latitude	Station	Phosphate Concentration (mg/L)
109 ° 41 ' 15.5 " T	6 ° 50 ' 54.5 " S	1	0.0061
109 ° 41 ' 20.8 " T	6 ° 51 ' 3.7 " S	2	0.0113
109 ° 41 ' 27.9 " T	6 ° 51 ' 5.7 " S	3	0.1181
109 ° 41 ' 35 " T	6 ° 51 ' 7.2 " S	4	0.0965
109 ° 41 ' 42.3 " T	6 ° 51 ' 9.2 " S	5	0.0233

109 ° 41 ' 49.5 " T	6 ° 51 ' 10.6 " S	6	0.1129
109 ° 41 ' 56.4 " T	6 ° 51 ' 12.1 " S	7	0.0655
109 ° 41 ' 55.1 " T	6 ° 51 ' 18.9 " S	8	0.0216
109 ° 41 ' 48.2 " T	6 ° 51 ' 17.4 " S	9	0.0156
109 ° 41 ' 41.2 " T	6 ° 51 ' 15.8 " S	10	0.0276
109 ° 41 ' 33.9 " T	6 ° 51 ' 14.1 " S	11	0.1904
109 ° 41 ' 26.6 " T	6 ° 51 ' 12.8 " S	12	0.1835
109 ° 41 ' 19.6 " T	6 ° 51 ' 11.1 " S	13	0.0225
109 ° 41 ' 12.3 " T	6 ° 51 ' 9.5 " S	14	0.0078
109 ° 41 ' 10.5 " T	6 ° 51 ' 16.7 " S	15	0.0027
109 ° 41 ' 17.6 " T	6 ° 51 ' 17.9 " S	16	0.0173
109 ° 41 ' 24.5 " T	6 ° 51 ' 19.6 " S	17	0.0888
109 ° 41 ' 28.2 " T	6 ° 51 ' 23.9 " S	18	0.0319
109 ° 41 ' 23.2 " T	6 ° 51 ' 25.9 " S	19	0.0199
109 ° 41 ' 16.6 " T	6 ° 51 ' 25.1 " S	20	0.1671
109 ° 41 ' 8.9 " T	6 ° 51 ' 23.1 " S	21	0.0113
109 ° 41 ' 35.3 " T	6 ° 51 ' 19.3 " S	22	0.0001
109 ° 41 ' 46 " T	6 ° 51 ' 25 " S	23	0.0543
109 ° 41 ' 53.2 " T	6 ° 51 ' 25.9 " S	24	0.0096
109 ° 41 ' 48.3 " T	6 ° 51 ' 30 " S	25	0.0199
109 ° 41 ' 41.2 " T	6 ° 51 ' 27.9 " S	26	0.0113
109 ° 41 ' 35 " T	6 ° 51 ' 27.6 " S	27	0.1258
109 ° 41 ' 35.4 " T	6 ° 51 ' 37.7 " S	28	0.0431

Phosphate Distribution Patterns in Banger Estuary

The distribution pattern of phosphate in the Banger River Estuary is influenced by wind, currents, tides, as well as dissolved oxygen and salinity. Wind processing shows that the wind blows from east to west, following the observation season, namely the east monsoon (Figure 3). Wind direction causes the current to move in the same direction as the wind so that the distribution of phosphate also tends to move in the same direction as the current movement. Phosphate input from the estuary is pushed by currents so that it accumulates in the waters in front of the estuary leaning slightly to the west. Next, the current moves in a circle towards the coastline. This change in flow direction is thought to be because in the western part, there is the Sengkarang River which also produces river run-off. The run-off of the Sengkarang River has a greater speed than the current originating from coastal waters. This causes the current from the Banger River to reverse towards the coastline. This rotation of currents causes mixing which can increase the phosphate content in these waters. This can be seen at station 20 which has a high phosphate content which is marked in red (Figure 4). Meanwhile, the waters at station 6 receive water input from the Loji River which moves in the same direction as the breakwater at Slamaran Beach so that phosphate content accumulates in the waters in front of the breakwater and continues to be pushed by the current so that its position tends to the east. This is following Putra *et al.* (2022) who stated that the existence of a breakwater at Slamaran Beach affects sediment transport where sediment from the mouth of the Loji River moving towards the west will be blocked by the breakwater in the middle of Slamaran Beach. Sediment is a medium that can store phosphate and if diffusion occurs, phosphate can leach back into the water column (Maslukah *et al*., 2019). Thus, the distribution of phosphate is also influenced by the coastline pattern even though there is a group of stations that form a convergent pattern in estuarine waters.

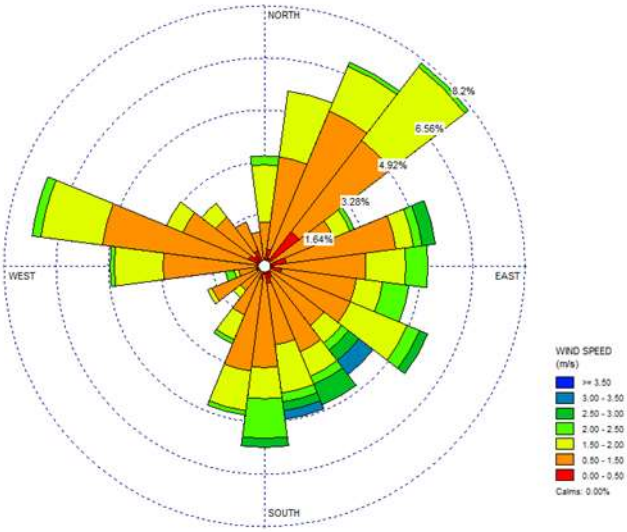

Figure 3. Windrose in Banger Estuary

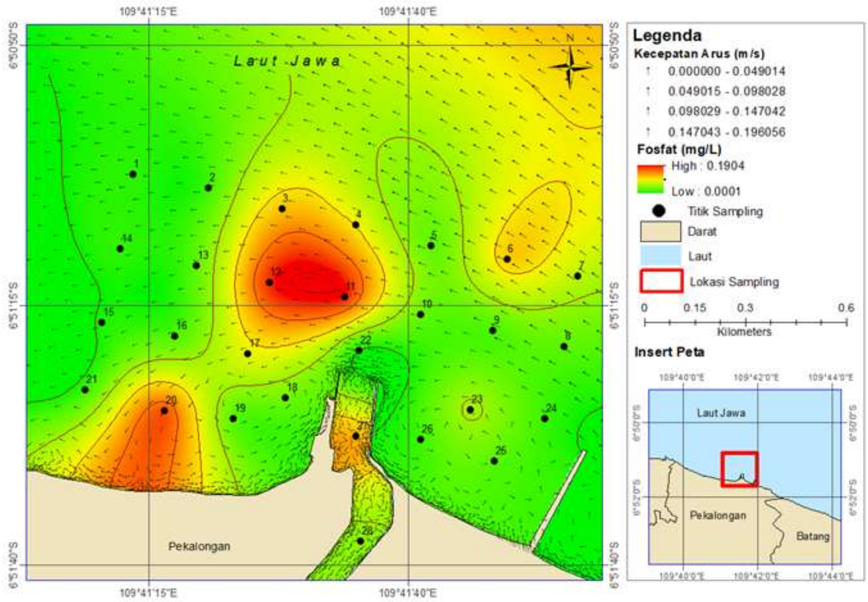

Figure 4. Overlay map of Phosphate Distribution and Current Direction in Banger Estuary

The type of tide in the study area is a single daily mixed tide, where there is only one tide a day with different heights. These tides affect the phosphate content in the waters. At the time of sampling, the tides were at high tide to low tide. Phosphate content tends to be higher at high tide. By Damayanti *et al*. (2022), states that the phosphate concentration at high tide has a higher value than at low tide. These tides are related to the process of concentration of chemical elements in the waters.

4. Summary

The phosphate content in the Banger River Estuary and Pekalongan City Coastal Waters is in the range of 0.0001 – 0.1904 mg/L, with values tending to be high at stations near the coastline and decreasing offshore. This is related to the supply of nutrients from various human activities, both from upstream to the estuary, as well as activities in coastal waters. The distribution of phosphate tends to follow the coastline pattern, although there are a group of stations that form a convergent pattern in estuarine waters. This distribution occurs as an influence of various oceanographic parameters such as tidal to ebb conditions, currents and seasons, mixing of water masses, and depth which contribute to the influence on the content and distribution of phosphate in the Banger River Estuary and the Coastal Waters of Pekalongan City.

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