HORIZONTAL DISTRIBUTION OF NITRATE CONCENTRATION IN THE ESTUARY OF JAJAR RIVER, DEMAK REGENCY, INDONESIA

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Abstract

The Jajar River is the most popular river located in Betahwalang Village, Demak Regency, characterized by an estuary protruding a shallow depth leading to turbulence that occurs intensively both by natural phenomena and anthropogenic activities. As an extensive river heavily affected by human activities, various types of litter have degraded the water quality surrounding its estuary. By employing quantitative methods, this study mapped the horizontal distribution of nitrate concentration at nine stations representing areas close to the estuary, middle of the estuary, and far from the estuary using MIKE 21 Flow Model and ArcMap v.10.8. Later, the significant correlation between nitrate concentration and water depth was processed using SPSS v.24. The results showed that the nitrate concentration at nine stations ranged from 2.3-5.3mg/L with an average of 3.055mg/L has exceeded the threshold following the Decree of the State Minister of the Environment Number 51 of 2004 regarding Standard Quality of Seawater. Nitrate concentration and depth at all stations did not show a significant correlation ($r = -0.651$, $p>0.058$). However, when the depth was divided into two categories (<1m and 1m), a significant negative correlation was found ($r = -0.896$, $p<0.040$, and $r = -0.913$, $p<0.045$), emphasizing that the deeper the waters, the lower nitrate they contained.

Keywords: Concentration, Depth, Distribution, Jajar River, Nitrate

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DOI: 10.48047/ecb/2023.12.si5a.0368

1. INTRODUCTION

Organic and inorganic waste, the dominant waste product of human activities, contains many nitrates. For years, many individuals of Demak Regency have exploited the Jajar River by utilizing the area along the river body and estuary for living, fish auctioning, rice planting, and operating industrial activities that discharge wastes.

Studies by Dewi et al. (Dewi et al., 2019) concerning pollution biomonitoring found that the main rivers in Demak Regency have mostly been polluted by wastes generated through industries such as pulp and paper and tofu home industry, yet they also used the river as a source for drinking and agriculture. Furthermore, during the tofu production process, such as grinding, cooking (boiling), filtration, protein coagulation, and preservation, each home industry, like the tofu producers in Indonesia, generates an average of 2,610 Kg of wastewater containing high protein and nitrogen content.

The increasing population and anthropogenic activities lead to a higher waste increase through increased or decreased sediment load depending on the land use utilization. Such a situation ultimately triggers the accumulation of nutrients in the waters, specifically when the river's velocity is incapable of transporting materials along the river body. Deposited excessive nutrients can cause adverse impacts, such as a decline in dissolved oxygen, biodiversity demolition, and the excessive blossoming of phytoplankton (Hamuna et al., 2018).

Previous studies (Patty et al., 2015; Zielinski et al., 2011)expressed that nitrate is an essential nutrient for phytoplankton to grow, and their growth is also an indicator representing good water quality. However, water quality becomes poor when nitrate concentration is out of the threshold. Several studies related to nitrate distribution have been conducted in several areas such as Gangga Island, East Sulawesi (Patty, 2014), Jajar River estuary, Demak Regency (Wijayanto and Purnomo, 2015), Morosari Waters, Demak Regency (Anggraeni et al., 2015; Rigitta et al., 2015), and Karangsong Waters, Indramayu Regency (Utami et al., 2016).
However, the above studies exclusively examined the distribution of nitrate concentration toward the horizontal distribution but depth. Considering that the stirring mechanism in shallow waters such as in the estuary of Jajar River can cause intense turbulence that drives bottom sediment to be lifted and disseminates nutrients in the water column (Anggraeni et al., 2015; Rigitta et al., 2015; Utami et al., 2016), this study desires to emphasize the importance of studies related to horizontal nitrate concentration and how it relates to depth.

2. MATERIALS AND METHODS

2.1. Location and Sampling

Astronomically, the estuary of the Jajar River is at 06º 47' 02.19" - 06º 48' 22.90" South Latitude and 110º 31' 55.52" - 110º 33' 12.61" East Longitude (Figure 1). At nine stations, sample collection was carried out on September 25, 2020. With a distance of 200 m between stations, it was hoped that the distribution of nitrate concentrations gathered would be more diverse.

The stations were set based on several considerations: a) stations 1, 2, and 3 represent areas close to the estuary; b) stations 4, 5, and 6 represent the transition zone between the area near the estuary and the high seas area; c) stations 7, 8, and 9 represent the high seas area.

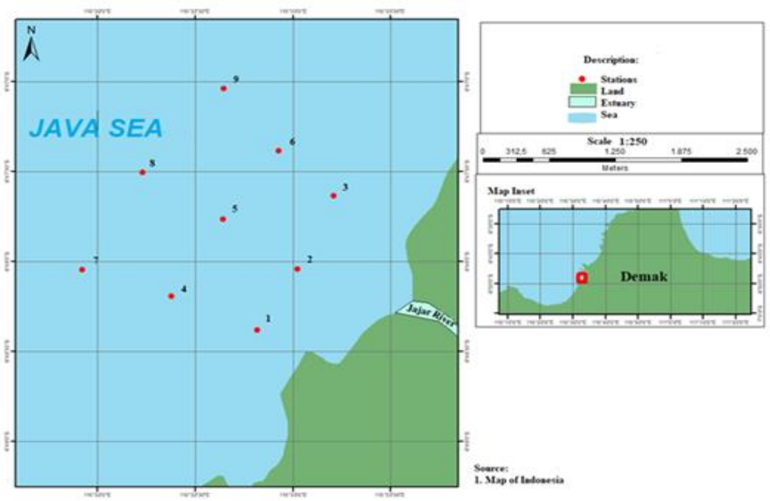

Figure 1. Map of research location in Jajar River Estuary, Demak Regency, Indonesia

2.2. Sea Currents and Bathymetry Map Data Retrieval

The pattern of sea currents was obtained by processing bathymetric data employing MIKE 21 Flow Model software. The topographic map of Indonesia was fetched through the official website of Indonesia's Geospatial Information Agency, and the bathymetric map was obtained from the website of The General Bathymetric Chart of the Oceans (GEBCO).

2.3. Sampling Method

Water sampling was collected using a bucket. Furthermore, the water sample was immediately transferred into a 500 mL sample bottle using a funnel. The water collected in the bottle was later transferred to a cool box containing ice cubes to maintain sample quality.

2.4. Nitrate Analysis

The nitrate analysis was carried out using the powder pillow procedure referring to Powder Pillows or AccuVac® Ampuls by Hach Company (Company, 2019).

2.4.1. Sample Preparation

Before starting the spectrophotometer, distilled water was poured into the sample cell as a blank solution. As much as 10 mL of water samples were poured into the sample cell. Later, a set of NitraVer 5 Nitrate Reagent Powder Pillow was added to a water sample. After all the reagents were dissolved by shaking the sample cell, they were set to stand still for five minutes until they turned yellow.

2.4.2. Measurement of Nitrate Concentration

The Hach DR 3900 Spectrophotometer was set up for nitrate measurement. The sample cell containing the blank solution was inserted into the Hach DR 3900 Spectrophotometer and set until a value of 0 (zero) showed up. After the concentration of the blank solution was measured, the cell containing the research sample was inserted into the Hach DR 3900 Spectrophotometer to measure its concentration.

2.5. Nitrate Distribution, Current Speed, and Correlation of Nitrate and Depth

2.5.1. Map of Nitrate Concentrations

Station coordinates and nitrate concentration data were inputted into a Microsoft Excel table. The nitrate concentration map was then made by importing the processed data appearing in *Xls into ArcMap 10.8 (Utami et al., 2016). This processing technique produced dot symbols and concentration values at each station.

2.5.2. Map of Sea Currents

Mapping the speed and pattern of sea currents began by entering bathymetric data into ArcMap 10.8 at the research stations. Digitization was carried out toward the research sites to generate polygon data. The data was then entered into the MIKE 21 for sea currents forecasting using the Flow FM model (Amirullah et al., 2014).

Forecasting was set from September 1 until 30, 2020, and the model results were selected for one day precisely at the date of sample collection (September 25, 2020, at 11:00). The velocity and pattern of sea currents data were then exported into Microsoft Excel and reprocessed using ArcMap 10.8 to produce a map of the sea currents distribution.

Analysis was then carried out to determine whether the current movement affected the nitrate distribution pattern at the study site.

2.5.3. Map Overlay of Nitrate Concentrations and Sea Currents

The map distribution of nitrate concentration was compared with a map of the sea currents distribution for further analysis by combining two different layers consisting of nitrate concentrations and sea currents (Emelyana et al., 2017).

2.5.4. Correlation between Nitrate Concentration and Depth

The correlation graph between nitrate concentration and depth was made using Microsoft Excel. Firstly, the correlation between nitrate concentration and depth (Wibowo et al., 2020)was carried out by statistical test using the Pearson coefficient bivariate correlation method employing the Statistical Package for Social Sciences (SPSS 24).

The first test was conducted by testing the correlation of nitrate concentration at all stations with the depth of each station. After that, the test was carried out by dividing the station's depth into two classes (depth less than 1 m and more than 1 m). The two depth categories were tested to determine the correlation of nitrate concentration with the depth classifications, resulting in a scatter plot and Pearson correlation value.

3. RESULTS AND DISCUSSIONS

The Decree of the Minister of Environment No. 51/2004 (Minister of Environment No. 51/2004, 2004) states that the nitrate concentration for standard seawater quality is 0.008 mg/L.

Considering the nitrate concentration at nine stations in this study ranges from 2.3-5.3 mg/L with an average of 3.055 mg/L, the present findings prove that the nitrate in the estuary of the Jajar River is far from a safe level, as shown in Table 1.

Table 1. Nitrate concentrations (mg/L) in the Jajar River Estuary, Demak Regency, Indonesia

Stations	Coordinates		Concentration (mg/L)
	Longitude	Latitude	
1	110º32'49.27" E	06º48'22.90" S	2.4
2	110º33'01.56" E	06º48'02.58" S	2.9
3	110º33'12.61" E	06º47'38.14" S	2.7
4	110º32'22.86" E	06º48'11.62" S	5.3
5	110º32'38.76" E	06º47'45.90" S	3.3
6	110º32'55.88" E	06º47'23.04" S	2.7
7	110º31'55.52" E	06º48'02.70" S	3.2
8	110º32'14.09" E	06º47'30.15" S	2.7
9	110º32'38.93" E	06º47'02.19" S	2.3
Average			3.055

The high nitrate concentration in the estuary of the Jajar River is a product of the lofty land use by the community along the river body for many years, such as housing, agriculture, and fish auctions. The highest nitrate concentration in this study was discovered at station 4 (5.3 mg/L). Although station 4 is not the closest to the estuary, high siltation is anticipated as the main factor that causes the nitrate concentration at this station to be the most extensive. Several studies (Muslim and Jones, 2003; Subiakto et al., 2019) found that high nitrate concentrations could have resulted from sediment containing many nitrates accumulated in a certain period. When a water body becomes shallow, the stirring mechanism by various activities on top of it causes turbulence far more intense than in areas with a deeper water column.

Since station 4 is the shallowest sampling location (0.5 m), the water column at this station is the most affected by sea currents and fishing boats. According to previous studies (Niu et al., 2016; Ulqodry et al., 2010), intense stirring in a shallow water column generally causes many bacteria to be stirred and mixed up. The reduced dissolved oxygen in a water column can be caused by the presence of enormous numbers of bacteria that decompose organic matter particles due to the moving process. In line with the previous studies, the dissolved oxygen concentration at station 4 was found to be the lowest compared to others.

The lowest nitrate concentration was found at station 9 (2.3 mg/L), located in a cluster far from the estuary. This finding is supported by previous studies (Bristow et al., 2017; Rigitta et al., 2015) stating that waste concentrations such as nitrates will decrease when they are far from the waste source due to a dilution process. The station's position far from the estuary typically contains low organic matter in its column. When the organic matter is low, the decomposition process will also be descending, which in turn causes the dissolved oxygen concentration to be high.

As a water column experiences a slower decomposition process, the waters happen to have a relatively high oxygen supply for phytoplankton to perform photosynthesis (Muslim and Jones, 2003; Zander et al., 2022). Accordingly, the present study found that station 9 (4.89 mg/L) had the highest dissolved oxygen level following its position far from the estuary.

Although river bodies in various developing countries are known to have been exploited by human activities, research by Patty (Patty, 2014) in the waters of Gangga Island, North Sulawesi, found that the average nitrate concentration was lower (0.016 mg/L) than the present findings. The low number was caused by the low level of local waste dumping and recovered by the presence of vegetation in its area. Their findings are supported by several studies (Cunningham and Saigo, 2005; Gitau and Kitur, 2016; Kao and Wu, 2001; Lekeufack et al., 2012) stating that wetlands efficiently remove various physicochemical parameters or pollutants through proper vegetation. In addition, wetlands are also effective in holding nutrients such as nitrogen and phosphorus for downstream water quality to improve (Schulz, 2006).

When the body of the Jajar River serves as a waste dumping spot, the river's estuary that accommodates all waste from human activities will experience a buildup of excessive nutrients, including nitrates. The results of the present findings are supported by previous researchers stating that nitrate is one of the waste components that can easily be carried by sea currents (Handayani et al., 2016). Besides, nitrate that enters the waters generally comes from land waste (Mustofa, 2015; Simanjuntak and Kamlasi, 2012).

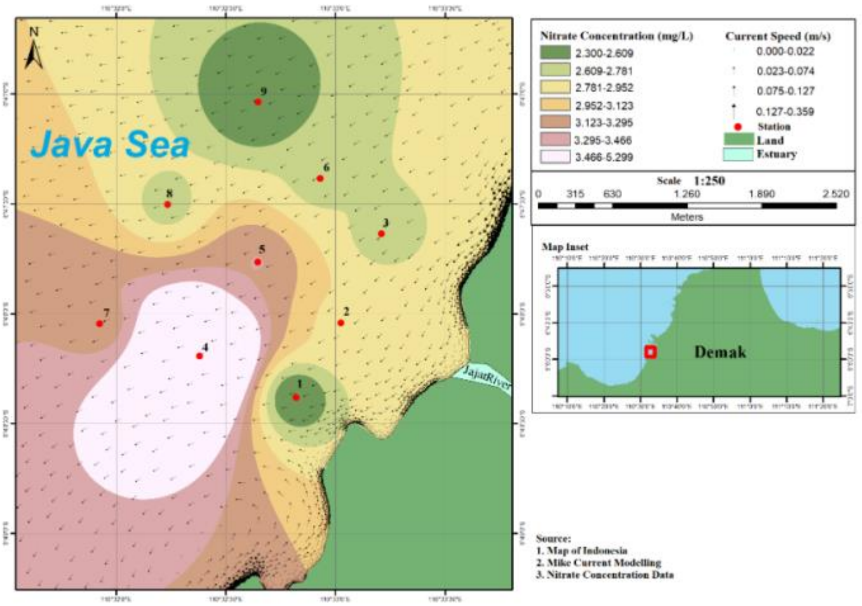

Figure 2. Sea currents and nitrate concentration distribution in the estuary of Jajar River combined

Sea waters in most archipelagic areas have a low current speed moving continuously, both horizontally and vertically (Abdul Ghani et al., 2013). Therefore, sea currents with low speeds generally only affect a small area and are also influenced by local characteristics that last for a short time. As shown in Figure 2, the present study found that the current pattern at the estuary of the Jajar River showed a tendency to move to the southwest at speeds between 0.022 - 0.359 m/s.

Because water loads and transport materials in waters are a response to current velocity and wind (Mordy et al., 2020; Razi et al., 2016), the relatively small current velocity found at the estuary of the Jajar River only has a significant impact on the surrounding area. Therefore, the distribution of high nitrate is not far from the estuary located relatively next to each other, as found at stations 4, 5, and 7.

This study found that the depth between stations was not too far apart within one cluster, as shown in Table 2 below:

Table 2. Chemical-physical parameters

Stations	Chemical-Physical Parameters			
	pH	**DO (mg/L)**	**Brightness (cm)**	**Depth (m)**
1	7.4	2.12	9.00	0.80
2	7.7	2.52	6.00	0.70
3	7.6	2.31	6.50	0.80
4	7.6	2.00	4.00	0.50
5	7.6	2.20	2.00	1.00
6	7.8	2.60	11.00	1.10
7	7.4	3.70	1.50	0.60
8	7.4	3.26	2.50	1.10
9	7.7	4.89	4.00	1.10
Average	7.58	2.84	5.17	0.86

Since depth differences affect the water's organic matter content (Muslim et al., 2017; Zander et al., 2022), the water depth at all research points is not significantly correlated with nitrate concentrations in each station due to their slight depth differences among the same clusters.

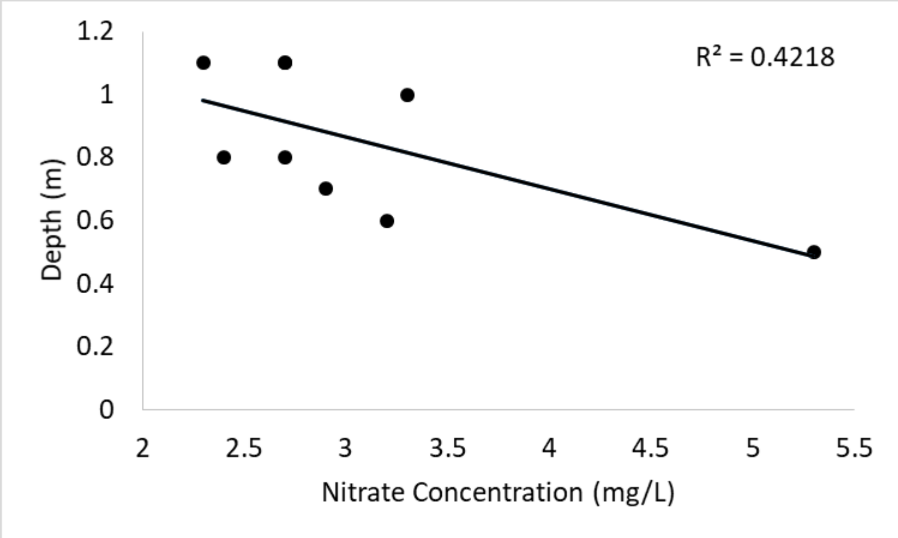

Figure 3. Correlation between nitrate concentrations and depth (all stations)

Based on Figure 3, the results of statistical tests did not show a significant connection between nitrate concentration and depth in all stations (r= -0.651, p>0.058). However, as shown in Figures 4a and 4b below, a significant negative correlation was found when the stations were grouped into two depth categories (less than 1 m and greater than 1 m).

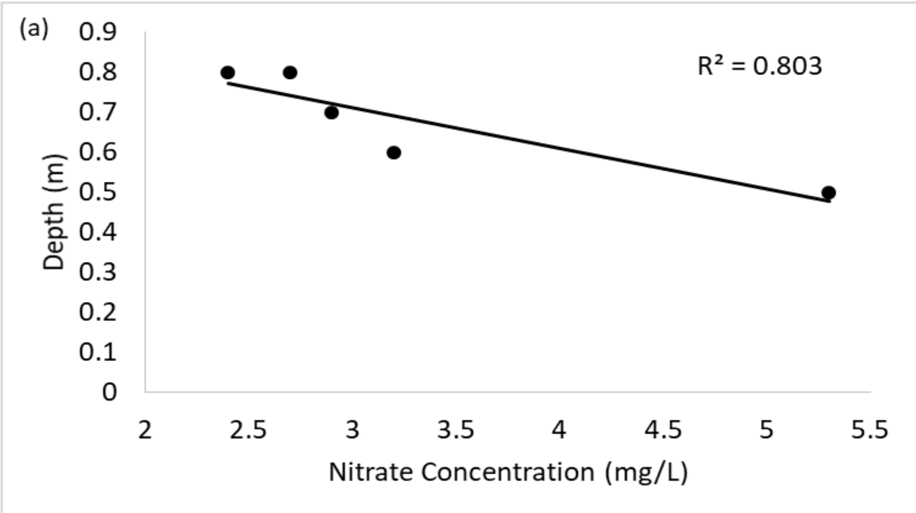

Figure 4a. Correlation between nitrate concentrations at a depth less than 1 m

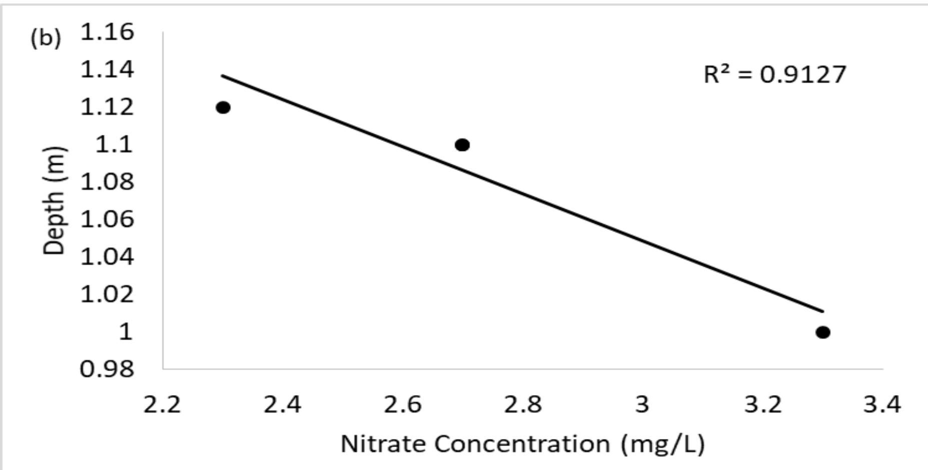

Figure 4b. Correlation between nitrate concentrations at a depth greater than 1 m

The group of stations with a depth of less than 1 m presented in Figure 4a (stations 1, 2, 3, 4, and 7) showed a significant negative correlation with r = -0.896, p<0.040, while water's depth greater than 1 m presented in Figure 4b (station 5, 6, 8, and 9) showed a significant negative correlation as well with r = -0.913, p<0.045.

In addition, based on the significance between the two depth groups, it was also found that a depth of more than 1 m has higher significance results. Thus, the deeper the water is, the lower the nitrate concentration because the deep water column will release less nitrate-containing sediment.

Groups of stations with a depth of more than 1 m are represented by stations far from the estuary where the influence of waste and activities in the estuary has been much limited (homogeneous). On the other hand, conditions at a depth of fewer than 1 m located closer to the estuary are still heavily influenced by human activities such as the traffic of fishing boats passing, fishing, and waste dumping, which causes water properties in the area to be more heterogeneous (Wibowo et al., 2020).

Generally, nitrate concentration in water is not solely influenced by depth alone but rather by the processes that transpire in sediments at the water column, such as denitrification and sediment transport (Browne et al., 2008; Tesoriero et al., 2007; Tesoriero and Puckett, 2011).

Given the importance of maintaining the quality of sea for all living entities, particular actions are needed by the local government in monitoring nitrate concentration in the waters of the Jajar River for it at least not exceed the threshold set by the Decree of the State Minister of the Environment Number 51 of 2004 regarding Standard Quality of Seawater (Minister of Environment No. 51/2004, 2004)

4. CONCLUSIONS

The concentration of nitrate in nine locations in the Jajar River, ranging from 2.3-5.3 mg/L with an average of 3.055 mg/L, has exceeded the threshold published by the Minister of the Environment Number 51 of 2004 concerning the Standard Quality of Seawater. The nitrate concentrations at all stations did not show a significant correlation (r= -0.651, p>0.058). However, there was a significant negative correlation (r = -0.896, p<0.040 and r = -0.913, p<0.045) when two categories of depth were divided (<1m and 1m), specifically for water depths more than 1 m. Therefore, this study found that the water's depth is linear to declined nitrate concentration.

5. ACKNOWLEDGMENTS

We thank Prof. Dr. Ir. Muhammad Zainuri, DEA, for the facilities provided and for making it possible for us to complete this research. We also thank Talitha Rahma D for her assistance during the field sampling and nitrate analysis in the laboratory.

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