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Dynamics of seasonal impacts on Total Suspended Solid (TSS) concentrations in coastal Semarang City using landsat 8

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ABSTRACT

Background: Semarang City, located in Central Java, faces significant water quality challenges in its coastal areas due to various activities such as industrial operations, trade, fisheries, and infrastructure development. One major concern is the concentration of Total Suspended Solids (TSS) in the coastal waters, which negatively impacts the marine ecosystem and the fisheries sector. This study aims to measure and analyze the distribution of TSS concentrations in the coastal waters of Semarang City from March to August 2018. **Methods**: Landsat 8 OLI/TIRS satellite image data, obtained from the USGS, was used for this study. The images were captured on March 18, April 3, May 17, June 6, July 24, and August 25, 2018. The data processing included radiometric correction (TOA), image cropping, land-sea masking, and the application of the Syarif Budiman algorithm to calculate TSS concentrations. TSS concentration classification followed Alabaster and Lloyd's (1982) categorization. **Findings**: TSS concentrations in the coastal waters of Semarang City varied between 36-220 mg/L. During the rainy season (March-May), concentrations ranged from 111-210 mg/L, while in the dry season (June-August), concentrations were lower, between 105-108 mg/L. Higher TSS concentrations were observed near estuaries and industrial areas, particularly in Genuk and Tugu sub-districts. **Conclusion**: TSS concentrations along the coast of Semarang City from March to August 2018 fell within class II and III of the Alabaster and Lloyd classification, indicating negative impacts on the fisheries sector. The increased TSS levels during the rainy season resulted from accumulated waste carried by water flow from human activities along the coast. Effective effluent management is essential to improve water quality and sustain the fisheries sector. **Novelty/Originality of this article**: This study provides a detailed spatial and temporal analysis of TSS distribution using satellite imagery, offering critical insights into the seasonal impacts of human activities on coastal water quality in Semarang City. The findings emphasize the need for targeted environmental management strategies to support sustainable coastal development.

KEYWORDS: total suspended solid (TSS); landsat 8 OLI/TIRS; Semarang City coast; Syarif Budiman algorithm; remote sensing.

1. Introduction

Coastal areas serve as vital transitional zones between land and ocean, rich in both biological and non-biological resources (Bengen, 2000 in Hidayah, 2018). These ecosystems are characterized by high productivity and biodiversity, which significantly contribute to their ecological and economic importance. Furthermore, coastal regions are well-positioned for growth, facilitating the development of key sectors such as transportation, industry, and tourism (Bohari, 2010 in Hidayah, 2018). As a result, these areas have the potential to

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enhance economic contributions, strengthen regional development strategies, and bolster global competitiveness. The unique attributes of coastal zones make them critical to both local economies and the broader ecosystem.

Despite their potential, coastal and marine areas are increasingly facing challenges related to the decline in the quality and quantity of their resources. Rapid population growth and intensified socio-economic activities in these regions have led to significant reductions in the ecological value of coastal environments. Human activities, such as settlement expansion, tourism development, reclamation, and agricultural practices, exert pressure on coastal ecosystems and lead to pollution (Opa, 2011 in Safitri, 2019). By 2020, Indonesia's population is projected to reach approximately 257 million, with over 60% residing in coastal areas (Bachtiar, 2002 in Suhartono, 2017). The rich diversity of coastal ecosystems and their natural resources attract various stakeholders, yet unsustainable management practices often exacerbate pollution issues in coastal waters.

Semarang City, located in the northern part of Java Island and bordered by the Java Sea, is traversed by multiple rivers, including Kali Penggaron, Kali Kedungmundu, Kali Bajak, and others. These rivers flow through densely populated areas, housing approximately 1,786,114 residents. The necessity of maintaining transportation and connectivity between settlements has resulted in the introduction of both organic and inorganic materials into the water systems. This influx of pollutants poses a significant threat to water quality, jeopardizing the health of coastal ecosystems and the availability of food resources for local communities. Consequently, addressing the challenges facing Semarang's coastal waters is crucial to sustaining the livelihoods of its residents and preserving the ecological integrity of the region.

Total Suspended Solids (TSS) serve as a crucial early indicator for assessing water quality in aquatic environments, particularly in evaluating sedimentation conditions (National Standardization Agency, 2004 in Elwafa, 2019). Increased levels of suspended materials contribute to heightened water turbidity, which adversely affects the penetration of sunlight, thereby inhibiting photosynthesis in aquatic organisms. This turbidity also impairs the visual abilities of marine life, disrupts spawning areas, and reduces the availability of food, while interfering with the absorption and decomposition of organic and inorganic materials (Dahuri, 2008). As a result, high TSS levels can significantly impact the overall health of aquatic ecosystems, demonstrating the importance of monitoring and managing these parameters.

In recent years, remote sensing technology, particularly satellite imagery, has emerged as a valuable tool for water quality research due to its multispectral capabilities and advancements in data processing and analysis (Susiati et al., 2010 in Ratnasari, 2015). This technology allows for comprehensive studies and mapping of water quality conditions in marine environments. Specifically, utilizing primary data from Landsat 8 OLI/TIRS satellite imagery can enhance the understanding of TSS levels in coastal waters. Research conducted by Tania and Sudaryatno in Subardjo has demonstrated the effectiveness of satellite imagery in predicting TSS parameters. The objective of this research is to estimate the concentration of TSS in the coastal waters of Semarang City, leveraging Landsat 8 OLI/TIRS image data collected in 2018 for accurate analysis.

2. Methods

This research employs both primary and secondary data to assess the water conditions in Semarang City. The primary data consists of Landsat 8 OLI/TIRS satellite images, which were sourced from the United States Geological Survey (USGS). These satellite images are integral for analyzing the Total Suspended Solids (TSS) parameters in the coastal waters of Semarang over specific periods. A series of images were selected based on seasonal variations and distinct recording times, including dates such as March 18, April 3, May 17, June 6, July 24, and August 25 in 2018. Additionally, secondary data were collected from relevant government agencies through their official websites, which provided essential information on rainfall across various stations in Semarang City, sourced from Central Java PUSDATARU and the Meteorology and Geophysics Agency.

To enhance the accuracy of the satellite imagery data, a Top of Atmosphere (TOA) radiometric correction was performed. This correction addresses radiometric errors inherent in the image data due to the sun's position during the imaging process. By converting the Digital Number (DN) values into reflectance, the correction enables a more precise analysis of the satellite images. This step is crucial for ensuring that the data used in assessing water quality is reliable and representative of the actual conditions in the coastal areas. The combination of primary and secondary data, along with the application of radiometric correction, establishes a solid foundation for evaluating TSS concentrations in Semarang's coastal waters.

$\rho\lambda' = M\rho Qcal + A\rho$ ....(i)

where:

$\rho\lambda'$ = TOA reflectance, without correction for sun angle

$M\rho$ = REFLECTANCE_MULT_BAND_x, where x is the Band number

$A\rho$ = REFLECTANCE_ADD_BAND_x, where x is the Band number Qcal = Digital number (DN) value

Furthermore, to eliminate the difference in Digital Number (DN) value caused by the position of the sun towards the earth. Correction with the sun angle uses the following equation.

$p\lambda = \rho\lambda'/(\cos(\theta SZ)) = \rho\lambda'/(\sin(\theta SE))$ ....(ii)

where:

$\rho\lambda$ = ToA reflectance

θSE = sun elevation

θSZ = sun zenith angle,

$\theta SZ = 90° - \theta SE$

(Candra, 2014)

Cropping is a critical process in image data analysis that involves cutting down the dataset to narrow and focus on a specific research area. This technique is employed to enhance the efficiency of data processing, ensuring that only the relevant portions of the imagery are utilized in the study. During this stage, the area of interest is carefully delineated, expanding it as needed to align with the boundaries established by the 25,000-scale Indonesian Landform Map. By doing so, researchers can concentrate on the specific geographic features and characteristics pertinent to their investigation. Ultimately, this targeted approach not only streamlines the analysis process but also improves the accuracy of the results by eliminating extraneous data that may dilute the focus of the research. The coordinates of the cut area are:

top left = 06:52:30S and 110:15:00E

bottom right = 07:00:00S and 110:30:00E

The separation process is performed using the following equation.

If $i1/i2 <= 0.5$ then 1else null....................................(iii)

Description: i1 = band 5 (NIR) i2 = band 3 (green)

(Boangmanalu et al., 2018 in Subardjo, 2020)

In this research, the determination of suspended sediment values relies on the reflectance values obtained from the red band of the Landsat 8 imagery. This approach is significant because the red band is sensitive to changes in water quality, particularly in relation to suspended sediments. As noted by Mahardika et al. (2014) in Subardjo (2020), the Syarif Budiman Algorithm is particularly effective and representative for areas experiencing varying levels of turbidity. This algorithm facilitates the accurate estimation of suspended sediment concentrations, making it a suitable tool for analyzing coastal waters. By employing this method, researchers can enhance the reliability of their assessments regarding sediment dynamics in the study area. The calculation algorithm uses the equation as below.

TSS (mg/l) = $8.1429 * Exp(23.704 * i1)$..............................(iv)

Description: i1 = band 4 (red)

(Mahardika et al., 2018 in Subardjo, 2020)

Class categories play a crucial role in categorizing Total Suspended Solid (TSS) levels into distinct groups based on their concentration ranges. This classification is informed by the assessment conducted by Alabaster and Lloyd (1982), which provides a framework for understanding the impact of various TSS concentrations on fisheries interests. By establishing specific thresholds for each class, researchers can effectively evaluate the potential implications of TSS levels on aquatic ecosystems and fish populations. The classification of TSS concentrations is outlined in Table 1, which serves as a reference for interpreting data and guiding management practices. Such categorization not only aids in monitoring water quality but also supports decision-making processes aimed at protecting aquatic habitats and ensuring sustainable fisheries.

Table 1. Classification of Total Suspended Solid (TSS) concentration levels

Class	Total Suspended Solid Concentration Level (mg/l)	Description (Effect on Fisheries Interests)
I	<25	No effect
II	25-80	Slight effect
III	81-400	Less favorable for fisheries interests
IV	>400	Not good for the fishery

Alabaster dan Lloyd (1982) dalam Mutmainah (2018)

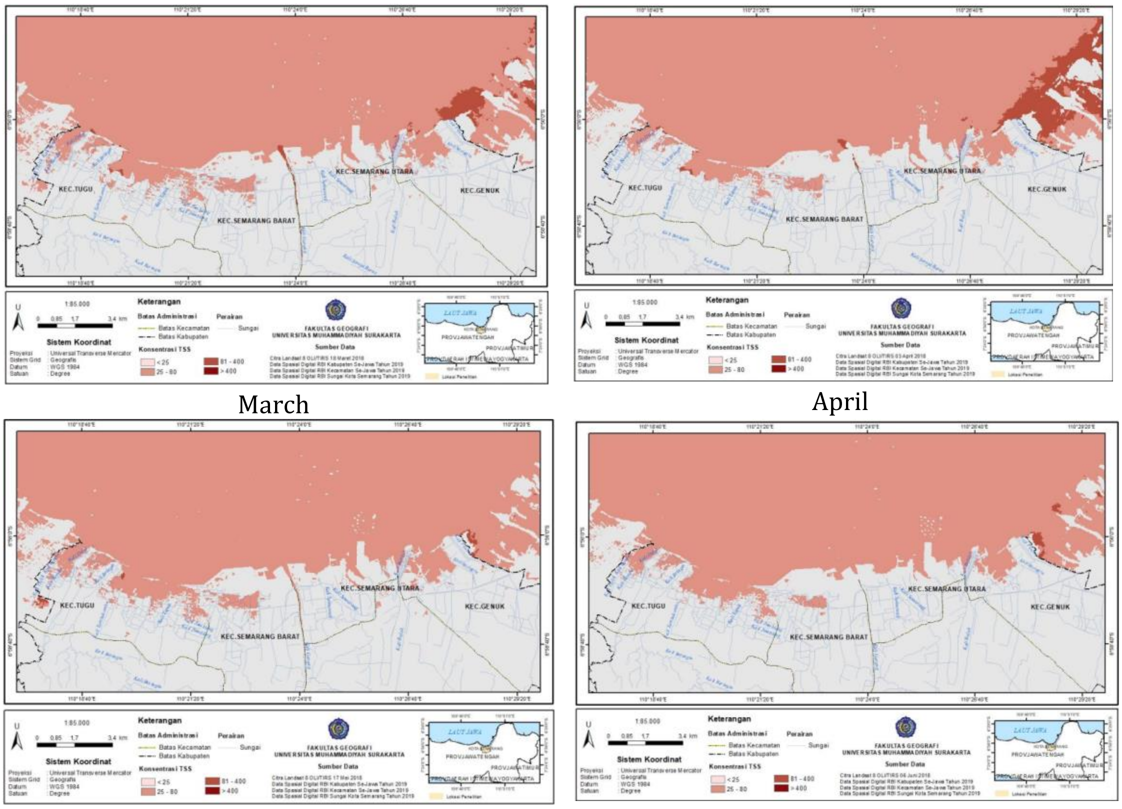
This research employed a descriptive quantitative data analysis method to assess the transformation of Total Suspended Solids (TSS) values along the coast of Semarang City in Central Java Province. The analysis involved processing Landsat 8 OLI/TIRS satellite images captured on various dates, including March 18, April 3, May 17, June 6, July 24, and August 25, 2018. Each of these time categories provided valuable data for evaluating changes in TSS levels over the specified period. The processed TSS values were subsequently visualized through the creation of maps, utilizing the Syarif Budhiman algorithm to accurately represent the spatial distribution of suspended solids. This methodological approach not only enhances the understanding of coastal water quality dynamics but also contributes to effective management strategies for maintaining the health of marine ecosystems.

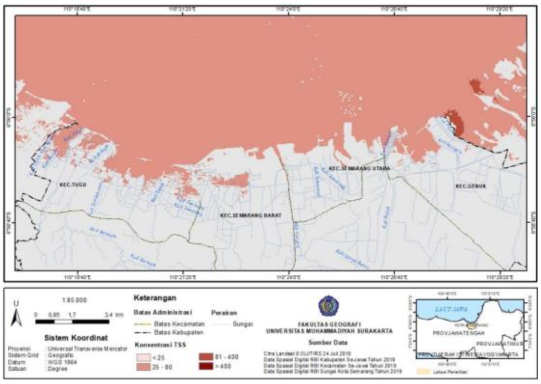
3. Results and Discussion

A study on the distribution of Total Suspended Solids (TSS) levels in the coastal area of Semarang City, Central Java Province, utilized Landsat 8 OLI/TIRS images collected on March 18, April 3, May 17, June 6, July 24, and August 25, 2018. The selection of these specific dates was carefully considered based on seasonal patterns, as indicated by information from the Meteorology and Geophysics Office. This office notes that the rainy season typically spans from December to May, while the dry season lasts from June to November each year. By aligning the image retrieval with these seasons, the study aimed to capture the dynamic changes in TSS levels that may occur due to varying weather conditions. This approach enhances the accuracy and relevance of the findings regarding coastal water quality.

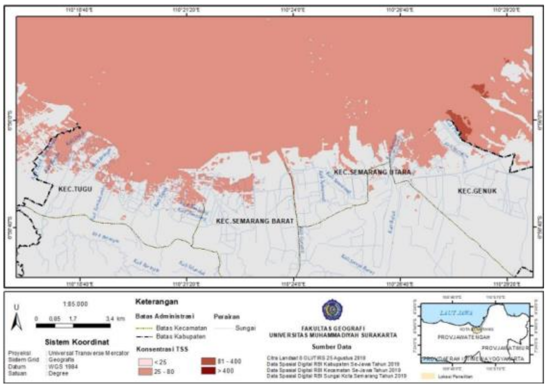
The analysis of TSS concentration and distribution in Semarang's coastal waters was conducted by processing the Landsat 8 OLI/TIRS image data, followed by visualization in the form of thematic maps. The data processing utilized Budhiman's algorithm to accurately determine the TSS levels present in the waters. To facilitate interpretation, the processed satellite images were categorized into four distinct classes based on TSS concentrations, as defined by Alabaster and Lloyd (1982). These classifications include Class I for TSS levels below 25 mg/L, Class II for levels between 25-80 mg/L, Class III for levels between 81-400 mg/L, and Class IV for levels exceeding 400 mg/L. This classification system provides a structured way to assess and communicate the varying degrees of suspended solids in the coastal environment.

Each TSS category was visually represented on the maps using specific colors to denote concentration levels, aiding in the quick identification of areas with different TSS levels. For instance, Class I, indicating TSS less than 25 mg/L, was assigned a distinct color, while Class II, representing TSS between 25 and 80 mg/L, was marked with another color. Similarly, Class III (TSS between 81 and 400 mg/L) and Class IV (TSS greater than 400 mg/L) each had their own unique color displays. Additionally, the land area of Semarang City was depicted in light gray to provide a clear contrast with the water bodies. The resulting TSS Distribution Map for Semarang City's coastal waters, covering the period from March to August 2018, is illustrated in Fig 1, showcasing the spatial variations in suspended solids across the region.





July



August

Fig 1. TSS distribution map of Semarang City coastal waters in March-August 2018.

The Schmidt and Ferguson climate classification, commonly known as the Q model, is a system that categorizes climates based on the relationship between dry and wet months. According to Lakitan (2002) as referenced by Sasminto (2014), this classification employs a letter-based system derived from the Q value, which reflects the percentage of the average number of dry months (BK) compared to the average number of wet months (BB) during the study year. This approach allows for a quantitative assessment of climate types, leading to a clearer understanding of regional climatic conditions. The Schmidt-Ferguson system identifies eight distinct climate types, as outlined by Wahid (2017), with calculations using the Q formula yielding values in the range of 0.325 to 0.493. By analyzing these values, researchers can categorize climates into specific types that correspond to various vegetation patterns and ecological characteristics.

In the case of Semarang City, the calculated Q value indicates that it falls within climate type C, which is classified as moderately wet. This classification is characterized by Q values between 0.333 and 0.600, aligning with the presence of jungle-type vegetation. Such a climate classification is significant for understanding the region's environmental conditions and their implications for agriculture, water resources, and biodiversity. The rainfall patterns, which play a crucial role in determining the climate type, further highlight the seasonal variations experienced in the area. To visualize these climatic conditions, a rainfall map of Semarang City is presented in Fig 2, illustrating the distribution and intensity of precipitation across the region throughout the year.

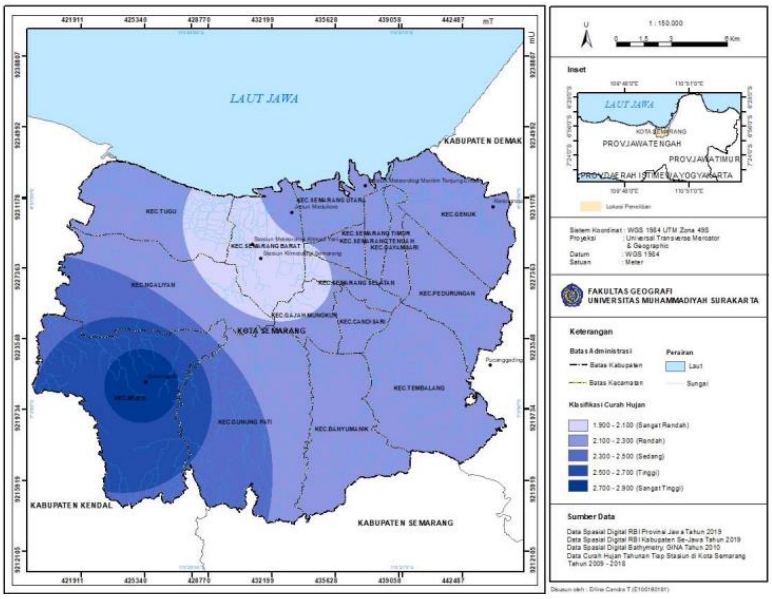


Fig 2. Rainfall map of Semarang City

Total Suspended Solid (TSS) is a critical indicator for assessing water quality, as highlighted by Hidayat (2016). It represents solid particles, both organic and inorganic, that result from natural weathering processes and industrial discharges. These suspended solids can significantly diminish water quality, impacting aquatic ecosystems and human activities. In this context, remote sensing technology, particularly satellite imagery, has proven invaluable for monitoring TSS concentrations and their distribution in aquatic environments. This research focused on the coastal waters of Semarang City, Central Java Province, utilizing Landsat 8 imagery alongside the Syarif Budhiman algorithm to estimate TSS levels effectively.

The analysis of the image data revealed that TSS concentrations in Semarang's coastal waters varied from 36 to 220 mg/L between March and August 2018. According to the classification method proposed by Alabaster and Lloyd, the observed TSS levels primarily fell within class II to III categories. High TSS concentrations pose serious risks to aquatic life, particularly fish, as they can lead to diminished oxygen availability in the water. Such conditions not only threaten the health of marine ecosystems but also have significant repercussions for the fisheries sector, which is vital for the livelihoods of the coastal fishing communities in Semarang City. The implications of TSS fluctuations underscore the need for continuous monitoring and management to safeguard both environmental and economic interests.

TSS concentrations exhibit temporal and spatial variations influenced by several factors, including domestic and industrial waste entering the marine environment via rivers and discharge pipes. Mapping the distribution of TSS in Semarang's coastal waters indicated notable differences between the dry and wet seasons. During the dry season, from June to August, TSS concentrations ranged between 105 and 108 mg/L, while the wet season, spanning March to May, saw this range increase to 111 to 210 mg/L. The heightened river discharge during the rainy season contributes to the influx of suspended materials, exacerbating water quality issues. Additionally, the sloping characteristics of Semarang's coastal areas facilitate the rapid movement of water from upstream to downstream, further influencing TSS dynamics. As emphasized by Putra (2014), rainfall plays a significant role in the fluctuations of TSS concentrations within aquatic systems. The trends in TSS concentrations along the coast of Semarang City from March to August 2018 are visually represented in Fig 3, highlighting the seasonal impacts on water quality.

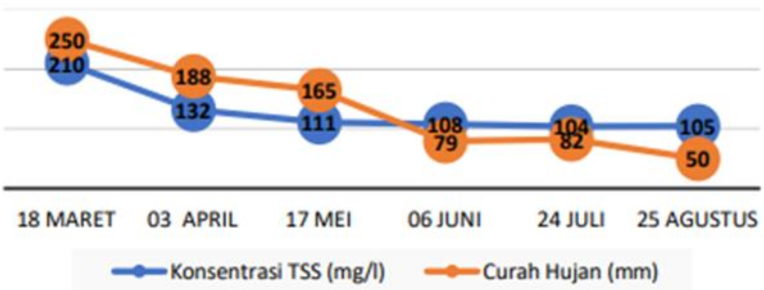


Fig 3. Total suspended solid (TSS) concentration values during March - August 2018

The shape of the distribution of Total Suspended Solid (TSS) itself is random with the dominance of concentration in certain locations. The large concentration value of a compound in the water indicates that the compound is close to the source. According to visual interpretation, the concentration of Total Suspended Solid (TSS) in the coastal waters of Semarang City tends to be higher in areas close to land and decreases as one moves away from the shoreline due to the dilution process. Semarang's coastal area serves as a meeting place for various river flows with the Java Sea, causing TSS accumulation, especially in the estuaries during the rainy season (March - May). One of the locations that experienced an increase in TSS is the estuary of Kali Garang, located between West Semarang and North Semarang sub-districts. In addition, Genuk and Tugu sub-districts also show an increase in TSS during the rainy season.

The Genuk coastal area, has TSS concentrations estimated to come from industrial activities in the vicinity, the Terboyo industrial area, and industries along the Kaligawe highway including the Small Industry Environment (LIK). The Regional Office of the Department of Industry of Central Java Province records various industries in the area, such as papermaking, cardboard packaging, printing, garment, textile, leather tanning, galvanizing, batteries, ceramics, fish and shrimp cold storage, and food and seasoning production (Wulandari, 2014). The waste generated from these industrial activities contributes to the increase in water turbidity in the area. The low degree of slope of the rivers in Genuk Sub-district (Kali Pentol, Kali Seringin, and Kali Banger) towards the sea level makes the flow of the river obstructed towards the sea and causes inundation, resulting in a buildup of suspended waste concentration downstream towards the ocean.

The existence of aquaculture waste discharges around the coast of Tugu in the form of remnants of fish feed and floating feces contributes to the presence of TSS material in the waters. Primavera (1994) in Muqsith (2014) said that in aquaculture activities the total feed given will become a pollutant load both because it is inedible and in the form of feces. As for several river flows through the Tugu Sub-district area, rivers such as Kali Tambakromo, Kali Bringin, and Kali Delik contribute significantly to the increase in Total Suspended Solid (TSS) concentration in local waters. Observations made from the rainy season to the dry season, i.e. from March to August, show that Genuk Sub-district has TSS levels that tend to be stable during this period.

4. Conclusions

Between March and August 2018, the Total Suspended Solid (TSS) concentrations observed along the coast of Semarang City, Central Java, exhibited significant variability, ranging from 36 to 220 mg/L. According to Alabaster and Lloyd's classification system, these levels fall within class II and III categories, indicating potential risks to the local fisheries sector. The rainy season is particularly concerning, as TSS concentrations tend to rise due to the influx of suspended materials from surface runoff and wastewater. Much of this waste originates from coastal activities, notably around Tanjung Mas Harbor and adjacent fisheries areas, where increased human activity contributes to pollution. The implications of these elevated TSS levels underscore the need for effective monitoring and management to protect aquatic ecosystems and the livelihoods dependent on them.

In addition to the influences of harbor and fisheries operations, several other factors exacerbate the TSS levels in Semarang's coastal waters. The ongoing expansion of residential, commercial, and industrial areas leads to increased runoff and waste discharge into nearby water bodies. Moreover, marine tourism and various infrastructure projects, such as land reclamation efforts, further complicate the situation by introducing additional pollutants. Rivers that flow into the coastal waters also contribute significantly to the TSS burden, carrying more suspended materials and pollutants into the marine environment. Collectively, these conditions pose serious threats to local aquatic ecosystems and can disrupt the livelihoods of fishermen who rely on healthy and productive waters for their income.

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