



Water Quality and Pollution Level in Plawangan Barat, Segara Anakan, Cilacap Based on Pollution Index Approach

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ABSTRACT

Segara Anakan is a lagoon located in Cilacap, Central Java. It is characterized as a fragile ecosystem that is very susceptible to the impacts of alterations and land development. This region is susceptible to habitat degradation caused by human activity, resulting in alterations in water quality and pollution. The objective of this study was to provide a comprehensive description of water quality by analysing its physical and chemical properties. Additionally, the study intended to assess the level of water pollution by employing the Nemerow Sumitomo Pollution Index (PI) approach. The water quality sampling was conducted in the western region of Segara Anakan, namely Plawangan Barat. The obtained data were compared to the established standard quality for marine organisms, as outlined in the PP RI No. 22/2021. The classification of the water pollution level was determined according to Minister of Environment Decree No. 115/2003. The findings of this study indicate that the parameters of temperature, salinity, pH, dissolved oxygen (DO), and biological oxygen demand (BOD) in the water remain suitable for marine life throughout all study stations. However, it was observed that the levels of Total Suspended Solid (TSS), phosphate, and nitrate did not match the established safety thresholds. The pollution index indicated that the water quality in West Plawangan shows varying pollution levels, ranging from light to moderate pollution. Based on the findings obtained, it can be concluded that the Segara Anakan lagoon exhibits a diminished level of suitability for the life of marine organisms

Keywords: Water Quality, Pollution Index, Nemerow Sumitomo, Plawangan Barat, Marine Pollution.

ABSTRAK

Segara Anakan merupakan sebuah laguna di perairan Cilacap, Jawa Tengah, dan merupakan ekosistem sensitif yang mudah terpengaruh oleh perubahan dan perkembangan lahan. Daerah ini merupakan kawasan yang rentan terhadap kerusakan habitat akibat aktivitas antropogenik yang dapat menyebabkan perubahan kualitas air. Penelitian ini bertujuan untuk mendeskripsikan kualitas air berdasarkan parameter fisika dan kimia serta menentukan indeks pencemaran air dengan pendekatan Indeks Polusi (PI) Nemerow Sumitomo. Pengambilan sampel kualitas air dilakukan di Segara Anakan bagian barat, yaitu Plawangan Barat. Hasil pengukuran kemudian dibandingkan dengan baku mutu air laut untuk organisme laut berdasarkan PP RI No. 22 Tahun 2021. Penetapan tingkat pencemaran air diklasifikasikan berdasarkan Keputusan Menteri Lingkungan Hidup No. 115 Tahun 2003. Kajian ini menunjukkan bahwa suhu, salinitas, derajat keasaman (pH), oksigen terlarut (DO), dan kebutuhan oksigen biologis (BOD) perairan masih sesuai untuk organisme laut di semua stasiun penelitian, sedangkan *Total Suspended Solid* (TSS), fosfat, dan nitrat tidak memenuhi tingkat keamanan. Indeks pencemaran menunjukkan bahwa kualitas air di Plawangan Barat menunjukkan tingkat pencemaran yang bervariasi, mulai dari pencemaran ringan hingga sedang. Berdasarkan hasil yang diperoleh, dapat disimpulkan bahwa Laguna Segara Anakan menunjukkan penurunan kesesuaian terhadap kehidupan organisme laut.

Kata kunci: Kualitas Air, Indeks Polusi, Nemerow Sumitomo, Plawangan Barat, Pencemaran Laut

1. Introduction

The Segara Anakan Lagoon is situated along the southern coastline of Central Java, in proximity to the Indian Ocean and Nusakambangan island. The Segara Anakan area is located within the geographic coordinates of 07°35' – 07°44' Latitude and 108°45' – 109°00' Longitude (Sarmili and Faturachman, 2016). Segara Anakan Lagoon is an ecologically sensitive area with unique ecosystems, including mangroves and diverse aquatic life. This region possesses a distinctiveness due to its representation of harmonious and well-balanced land ecosystems, estuaries, and marine ecosystems, serving as a habitat for diverse fauna and flora (Saputra, 2007). Segara Anakan area's distinctiveness and strategic significance are reinforced by the inclusion of the area as one of the National Strategic Areas, as stipulated by the PP RI Number 26/2008 on National Spatial Planning.

The Segara Anakan Lagoon is geographically separated and linked by two distinct canals, specifically referred to as the east canal (Plawangan Timur) and the west canal (Plawangan Barat) (Hidayati et al., 2014; Piranti et al., 2020). Plawangan Barat is influenced by various river catchments, including Citanduy, Cibereum, Sawitali, Tirangkesik, Ujung Gagak, Ujung Alang, Klaces, and Masi Kecela (Siregar et al., 2007; Irwansyah, 2010; Hartono et al., 2013; Syakti et al., 2013). Plawangan Barat is characterized by a significant level of activity, as seen by the escalating rates of land conversion for purposes such as fishing, agriculture, and settlement (Azis et al., 2021). The intense activity within the Plawangan Barat environment can induce alterations in the physical and chemical attributes of the surrounding waters. Additionally, the heightened human activity within this region can give rise to anthropogenic stress, thereby exerting a suppressive impact on aquatic ecosystems (Irwan et al., 2017; Piranti et al., 2020; Reid et al., 2020; Nurito et al., 2020). According to Kasari and Effendi (2017), the presence of contaminants in the environment can lead to a decline in water quality and the occurrence of water pollution. Piranti et al. (2020) stated that the presence of substandard water quality can exert detrimental effects on the marine organisms inhabiting these aquatic environments. Meshesha et al. (2020) also reported that a reduction in water quality may have implications for the viability of aquatic ecosystems.

The lagoon supports many plant species. The lagoon also supports various fish and shellfish species important for local fisheries. Changes in water quality can impact these populations, potentially affecting the livelihoods of fishing communities (Nair and Nayak, 2023). Water quality in the lagoon can also directly affect human health, especially for the communities living in the surrounding areas. Contaminated or poor-quality water can lead to waterborne diseases and health issues (Shetaia et al., 2020). Hence, monitoring water quality holds significant importance for the conservation of ecosystems, the well-being of local communities, sustainable economic activities, and addressing environmental and climate change challenges.

This study aims to determine the physical and chemical properties of the waters in Plawangan Barat Segara Anakan Cilacap, with a focus on evaluating the suitability for marine organisms. Additionally, the study intends to quantify the extent of water pollution using the Nemerow Sumitomo Index. The findings can be utilised to formulate a comprehensive approach for the management of water quality in Plawangan Barat Segara Anakan Cilacap. The provision of essential data and valuable insights enables individuals to make well-informed decisions and successfully implement management and conservation strategies.

2. Material and methods

2.1. Study Area and Sample Collection

This study was conducted on August, 2020, in the Plawangan Barat waters, Segara Anakan Cilacap. Nine sampling sites were chosen in the western region of Segara Anakan, specifically in Plawangan Barat (see Figure 1). In order to ensure consistency and accuracy, a total of three surface water samples were obtained at a depth of 10-15 cm using 1-L plastic containers. These containers were carefully prepared by rinsing them with trioxonitrate (v) and afterwards soaking them overnight with distilled water. This precautionary measure was taken to prevent any unforeseen alteration in the inherent properties of the water samples. Subsequently, the samples were carefully transferred into a designated container equipped with ice packs and subsequently conveyed to the Productivity and Water Quality Laboratory, Fisheries and Marine Sciences Faculty, Jenderal Soedirman University. The samples were diligently maintained at a temperature of approximately 4 °C until the commencement of the studies.

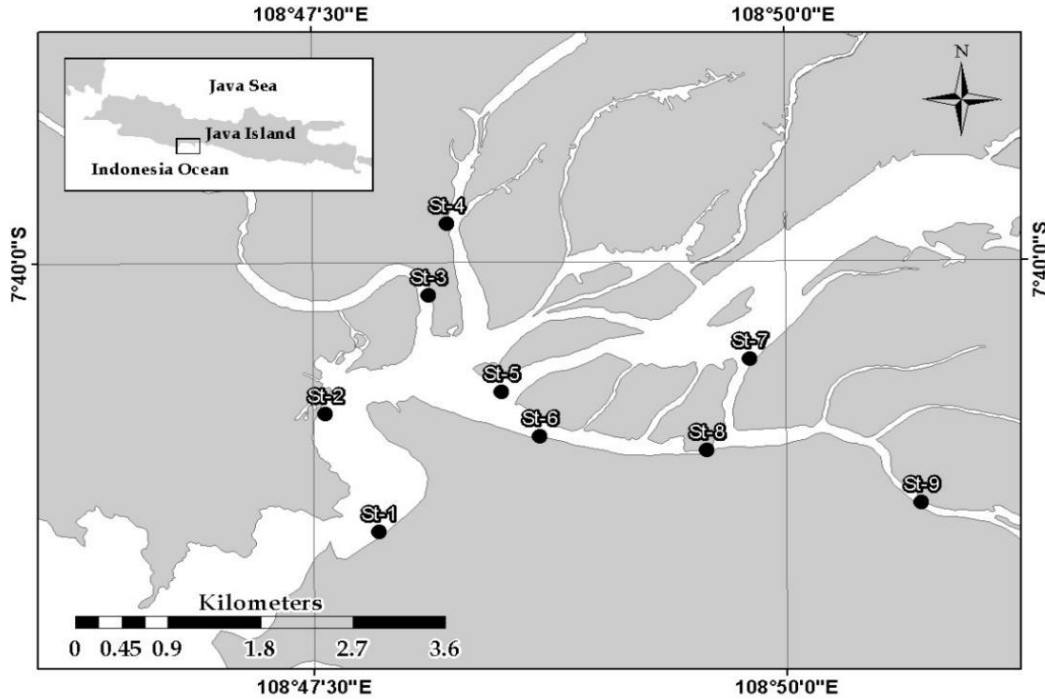


Figure 1. Sampling Points in the Plawangan Barat, Segara Anakan Cilacap (St-1: Macan, Plawangan Barat; St-2: Sawitali Estuary; St-3: Citanduy River; St-4: Cibereum River; ST-5: Lorogan, Tirangkesik Estuary; St-6: Ujung Gaqak; ST-7: Ujung Alang; St-8: Klaces; ST-9: Masi Kecela)

2.2. Waters Quality Analysis

The parameters assessed in this investigation encompassed the physical and chemical characteristics of the water samples. Physical parameters encompass several factors like as temperature, salinity, and total suspended solids (TSS), whereas chemical parameters encompass metrics such as Potential Hydrogen (pH), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), nitrate, and phosphate. The collection of seawater samples adheres to

the prescribed methodology outlined in the Indonesian National Standard (SNI) method No. 6964.8.2015. The measurement techniques and standardized analysis procedures were outlined in Table 1.

2.3. Data Analysis

Water Quality Assessment

The assessment of water quality status was conducted by comparing the measured data values against the prescribed water quality requirements, sea water quality standards for

Table 1. Standard and analytical methods of physical and chemical parameters for water quality

Parameters	Unit	Quality Standard	Analytical Methods
Physical			
Temperature	°C	28-32	APHA 2550 B 2012
Salinity	‰	s/d 34	IK-S1 (Salt meter)
TSS	mg/L	80	APHA 2540 D 2012
Chemical			
pH		7 - 8,5	APHA 4500 H+ B 2012
DO	mg/L	>5	IK-S2 (DO meter)
BOD ₅	mg/L	20	Winkler (APHA, 2017)
Nitrate (NO ₃ -N)	mg/L	0.06	Kjeldahl (SNI No.02.2811-2005)
Phosphate (PO ₄ -P)	mg/L	0.015	SNI 06-6989.31-2005

marine organisms based on PP RI No. 22/2021, indicated in Table 1.

Waters Pollution Level

The level of pollution was determined using the Pollution Index (Nemerow and Sumitomo, 1970) as described in the State Minister of Environment Decree No. 115/2003 concerning the determination of water quality status attachment II, as follow:

$$PI_j = \frac{\sqrt{\left(\frac{C_i}{L_{ij}}\right)^{2_m} + \left(\frac{C_i}{L_{ij}}\right)^{2_R}}}{2}$$

L_{ij} : Concentration of water quality parameters in water quality standards (j)

C_i : Concentration of survey water quality parameters

PI_j : Pollution index for designation (j)

$(C_i/L_{ij})_M$: Maximum C_i/L_{ij} value

$(C_i/L_{ij})_R$: Average C_i/L_{ij} value

The criteria for the level of water pollution based on the Pollution Index value are presented in Table 2.

3. Results and Discussions

3.1. Physical and Chemical Quality of Water in Plawangan Barat

Temperature

The survival of aquatic creatures is significantly influenced by temperature, making it a crucial physical component (Daroni & Arisandi, 2020). The findings indicate that the temperature in Plawangan Barat adheres to the acceptable quality requirement and is conducive to the sustenance of marine organisms. The station with the highest recorded temperature is IV, located at the Cibeureum river, with a measurement of 29.87°C (**Figure 2**). The sampling was conducted at noon midday (12.05 WIB), which corresponds to the peak solar heat period. Rizki et al. (2016) assert that the primary heat source in bodies of water is solar radiation. The radiant energy emitted by the sun permeates the atmosphere and then reaches the water's surface, where it is absorbed, leading to a rise in temperature. In the meanwhile, it is worth noting that elevated temperatures can induce physiological strain on aquatic creatures. The rise in temperature is also

Table 2. Category of Pollution Level Based on Pollution Index Value

No	Plj Value	Category
1.	$0 \leq PI_j \leq 1.0$	Meets quality standards (good condition)
2.	$1.0 < PI_j \leq 5.0$	Mildly polluted
3.	$5.0 < PI_j \leq 10$	Moderately polluted
4.	$PI_j > 10$	Severely polluted

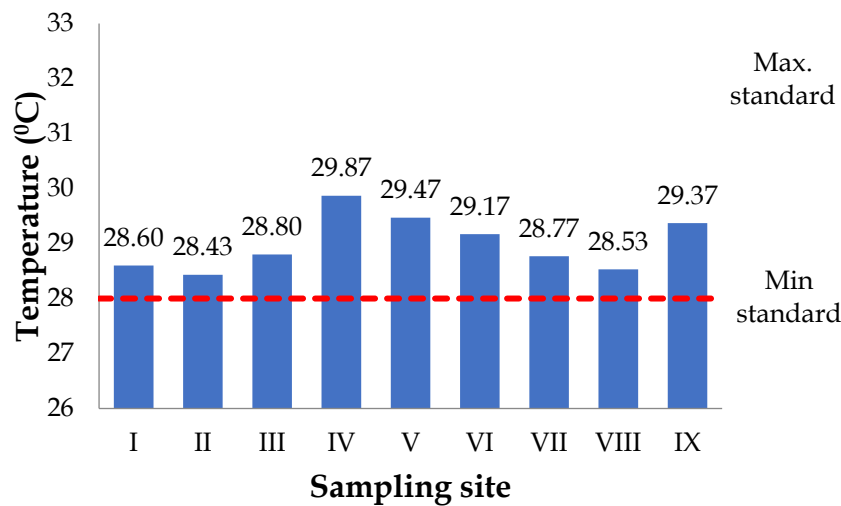


Figure 2. Temperature in Plawangan Barat

associated with heightened metabolic activity and respiration rates among species, resulting in an elevation of oxygen consumption. Consequently, this leads to a reduction in the quantities of dissolved oxygen within aquatic environments. According to Sudirman and Sameidi (2014) and Mainassy (2017), when exposed to extremely low temperatures, aquatic species experience a reduction in metabolic activity and a decrease in fish mobility.

Salinity

Salinity is a crucial water quality characteristic that exerts a direct impact on marine organisms in aquatic environments (Telesh and Khlebovich, 2010; Yurisma et al., 2013). The salinity values observed at Plawangan Barat fall within the acceptable range outlined by the designated quality criteria, which is a maximum of 34 ‰. Consequently, these salinity levels are deemed suitable for sustaining marine organisms. The Citanduy river recorded the lowest reading, which is 15.33 ‰ (Figure 3).

This phenomenon can be attributed to freshwater inflow from rivers that ultimately flow into the estuary (Suharto et al., 2019). Estuaries are transitional zones where freshwater from rivers or streams meets and mixes with seawater from the ocean. The varying proportions of freshwater and seawater in the estuary can lead to lower salinity levels. Tides are an additional component that exerts influence over the fluctuating levels of salinity in estuarine regions. Tides play a significant role in estuarine dynamics (Geyer and MacCready, 2014; Wells, 1995).

When the tide is high, seawater may dominate the estuary, leading to higher salinity. During low tide, freshwater from rivers and streams can flow into the estuary, reducing salinity levels.

The station exhibiting the greatest value was identified as station II within the Sawitali estuary, displaying a salinity level of 28.33 ‰. The geographical location of this region is close to the Indonesian Sea, resulting in a heightened impact of seawater influx (Saraswati et al., 2017; Patty et al., 2020). According to Dionne (1963), Estuaries can be categorised into distinct sectors based on salinity levels. These sectors include: (1) the lower estuary, which maintains a direct link to the sea and exhibits high salinity, (2) the middle estuary, characterised by the mixing of fresh and salt water resulting in intermediate salinity levels, and (3) the upper estuary, where tidal influences are observed but salinity levels are negligible. The intricate interplay between river discharge, tidal forces, and morphological characteristics gives rise to discernible patterns in the distribution of salinity (Couceiro and Schettini, 2021).

Total Suspended Solid (TSS)

The impact of total suspended solids (TSS) on the biota of aquatic ecosystems is a significant concern. Based on the findings, it can be observed that the majority of TSS values surpass the established quality standard threshold of 80 mg/L (Figure 4), rendering them unsuitable for marine organisms.

The elevated total suspended solids (TSS) can lead to a reduction in sunlight penetration within aquatic environments, hence impacting the

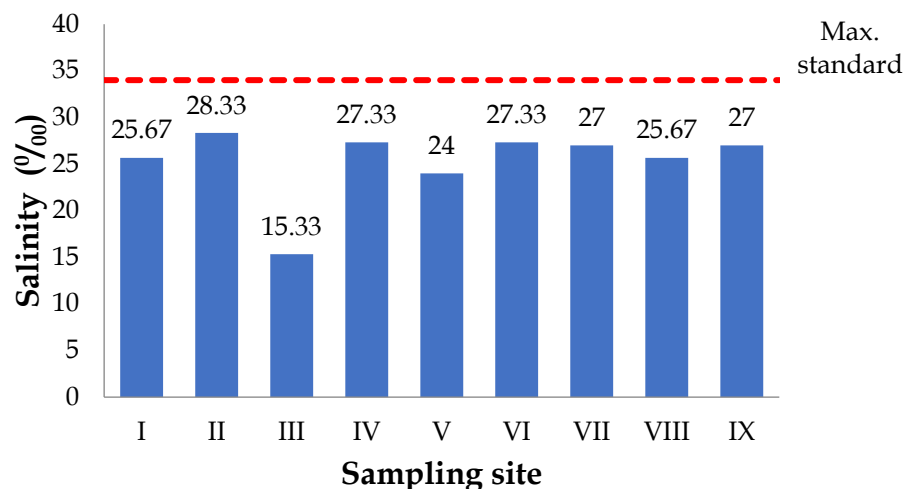


Figure 3. Salinity Values in Plawangan Barat

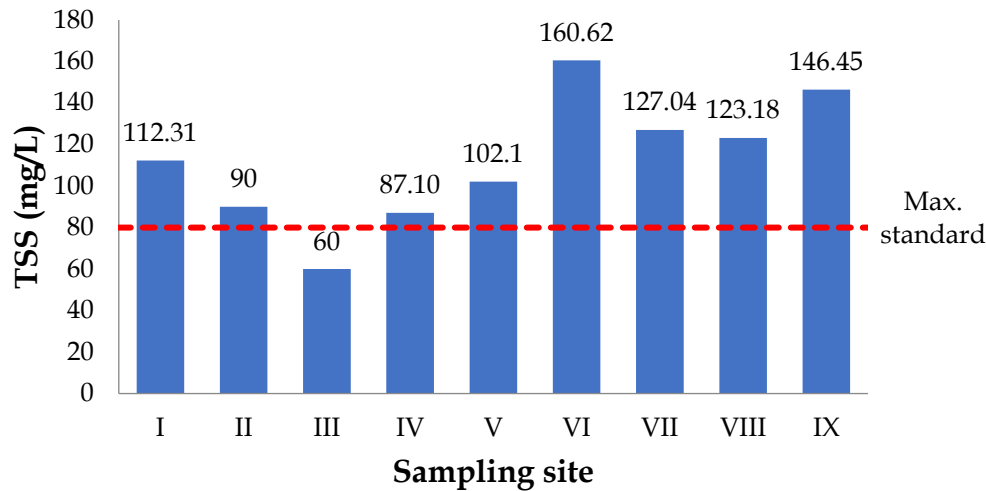


Figure 4. TSS values in Plawangan Barat

photosynthetic process and diminishing the dissolved oxygen levels in the water (Romdoni, 2019; Hermawan & Wardhani, 2021). Prolonged oxygen deprivation will result in the development of anaerobic conditions within the aquatic environment, ultimately resulting in the demise of aerobic creatures. In addition, it should be noted that elevated concentrations of these particles have a direct impact on aquatic organisms, particularly fish, as they can become trapped and filtered via their gills (Rinawati et al., 2016). In aquatic environments, elevated total suspended solids (TSS) levels are indicative of a higher concentration of organic matter. This phenomenon is observed in Plawangan Barat as a result of the introduction of residential trash into the water. At station III, the Citanduy river exhibits optimal water conditions. The fall in total suspended solids (TSS) levels can be attributed to the dilution of a significant volume of freshwater, resulting in a reduction of organic matter within the water column (Erwin, 2014).

pH

The pH value indicates the good or bad condition of the water quality (Azizah, 2017; and Daroni and Arisandi, 2020). The decrease in pH value also reduces water quality, which will affect the life of aquatic organisms (Susana, 2009; and Siburian et al., 2017). The results showed that the pH value in Plawangan Barat ranged from 7.12 to 8.05 (Figure 5). This indicates that the pH at all stations is still within the optimal range and suitable for marine life. According to Susana (2009) and Simanjuntak (2012), the factors that affect the high and low pH values include salinity, water mass, and organic matter content in water.

Salinity can influence pH, but the relationship is not always straightforward. Several factors can affect how salinity influences pH in estuaries, i.e. buffering capacity and dilution effect. The buffering capacity of water refers to its ability to resist changes in pH when an acid or base is added. Seawater, which is relatively high in salinity, has a strong buffering capacity, meaning it can resist significant changes in pH. Therefore, in estuaries where seawater dominates during high tide, the buffering capacity from the seawater can help stabilize pH levels. Related to the dilution effect and water mass, during periods of high freshwater input, such as after heavy rainfall, the influx of low-salinity freshwater can dilute the estuarine water. This dilution can lead to a decrease in pH because freshwater tends to be slightly acidic. During such events, the lower salinity levels in estuarine waters can make pH more variable (Chakraborty et al., 2011; Guo, 2019).

Organic matter content can also significantly impact the pH of water, and its effects are often related to the process of organic matter decomposition. When organic matter, such as dead plants, leaves, or organic debris, enters water bodies, it undergoes decomposition by microorganisms. During decomposition, organic matter is broken down into simpler compounds. This process consumes oxygen and releases various chemical substances, including carbon dioxide (CO_2). CO_2 dissolves in water and reacts with water to form carbonic acid (H_2CO_3). Carbonic acid can further dissociate into bicarbonate ions (HCO_3^-) and hydrogen ions (H^+). The increase in hydrogen ions in the water can

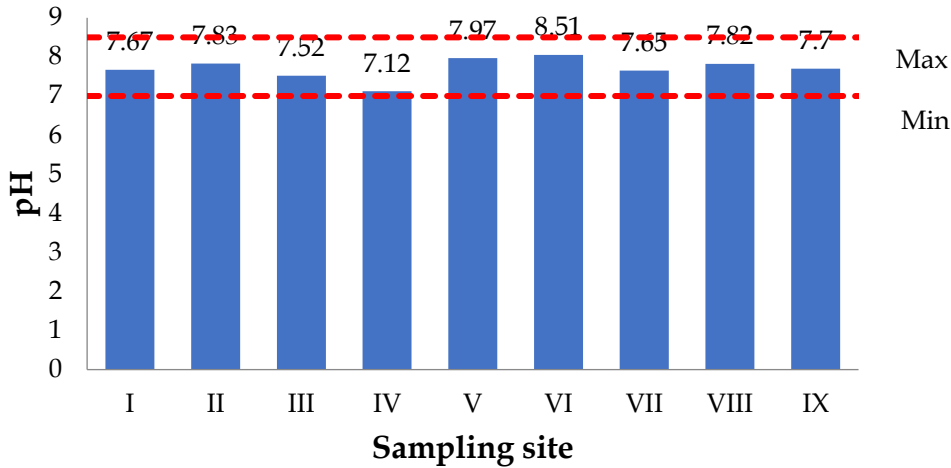


Figure 5. pH values in Plawangan Barat

lower the pH, making it more acidic (Cai et al., 1998; Wurts and Durborow, 1992).

Dissolved Oxygen (DO)

Dissolved oxygen is a component needed by all organisms, whether living on land or in water (Kasari and Effendi, 2017). The results showed that DO in Plawangan Barat was still within the optimal limit according to the quality standard for marine life, which was more than 5 mg/L (Figure 6).

Dissolved oxygen is an essential constituent required by all species, regardless of their habitat, be it terrestrial or aquatic (Kasari & Effendi, 2017). The findings indicated that dissolved oxygen (DO) levels in Plawangan Barat were found to be within the acceptable range as per the established

quality guideline for marine organisms, which stipulates a minimum threshold of 5 mg/L (Figure 6). Aquatic species rely on dissolved oxygen for the purpose of respiration, as well as for the degradation of organic matter into inorganic compounds facilitated by microorganisms. Additionally, it serves as a fundamental element in fulfilling the metabolic requirements of aquatic species (Edward and Pulumahuny in 2003). The observed elevation in dissolved oxygen (DO) levels at station III of the Citanduy river is likely attributable to the efficient occurrence of photosynthesis within the water. The observed low value at station I in the Macan area, specifically in Plawangan Barat, is likely attributed to the influx of organic waste originating from the nearby estuaries. The fluctuation of dissolved

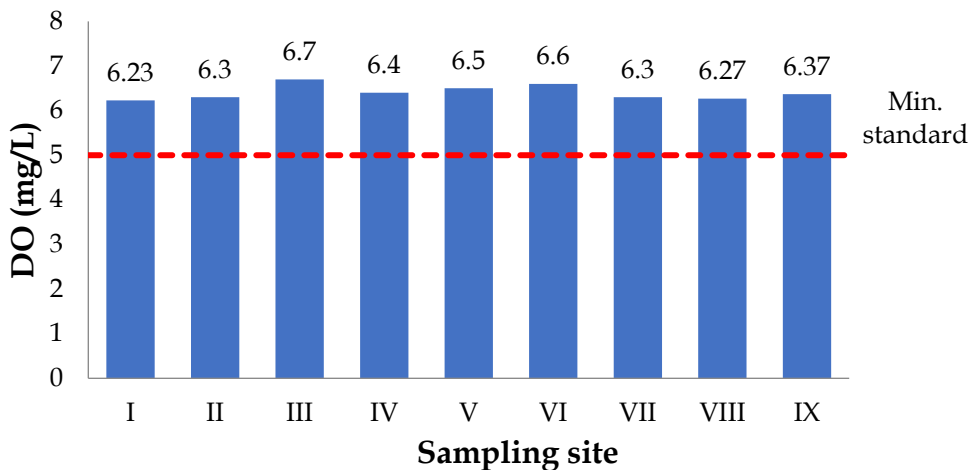


Figure 6. DO Concentration in Plawangan Barat

oxygen (DO) values can manifest on a daily and seasonal basis due to various factors, including photosynthetic activity, water mass mixing, organism respiration, and the introduction of polluting waste (Mainassy, 2017; Saraswati et al., 2017).

Biochemical Oxygen Demand (BOD)

The measurement of Biochemical Oxygen Demand (BOD) in water serves as an indicator of pollution, with higher levels indicating a larger concentration of organic matter (Daroni and Arisandi, 2020). According to the findings, the BOD value observed in Plawangan Barat exhibited a notable level of quality and remained suitable for sustaining marine organisms (Figure 7).

The station V of Tirang Kesik estuary exhibited the highest Biochemical Oxygen Demand (BOD) value, measuring 10.23 mg/L. The occurrence of this situation can be attributed to the proximity of the station to neighbouring estuaries, namely Citanduy, Cibereum, and Ujung Gagak rivers. These rivers are known to have a significant amount of organic debris, which is a result of the intense human activity in their vicinity (Saraswati et al., 2017). Despite being greater in comparison to other stations, the result remains below the designated quality guideline of 20 mg/L, which is considered safe for marine life. The fluctuations in the biochemical oxygen demand (BOD) are intricately linked to the dissolved oxygen (DO) levels in aquatic environments. In the interim, the elevated

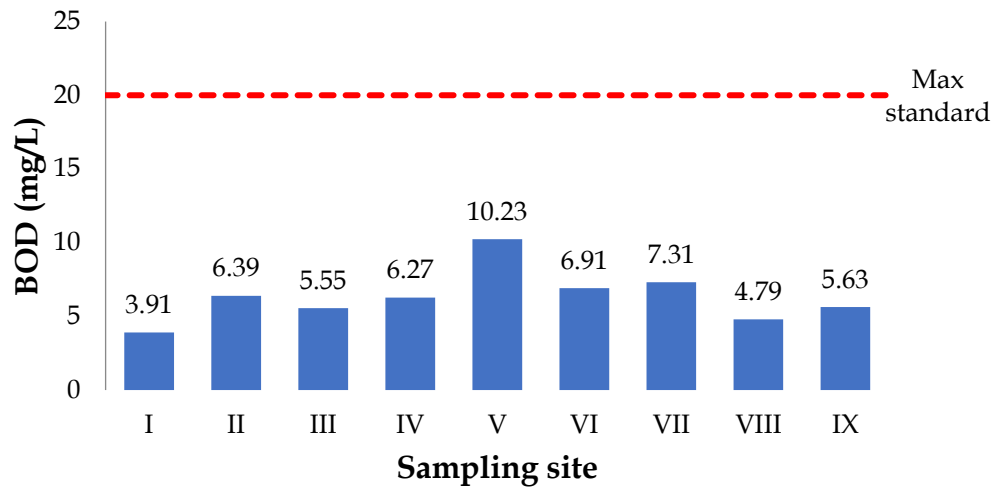


Figure 7. BOD Value in Plawangan Barat

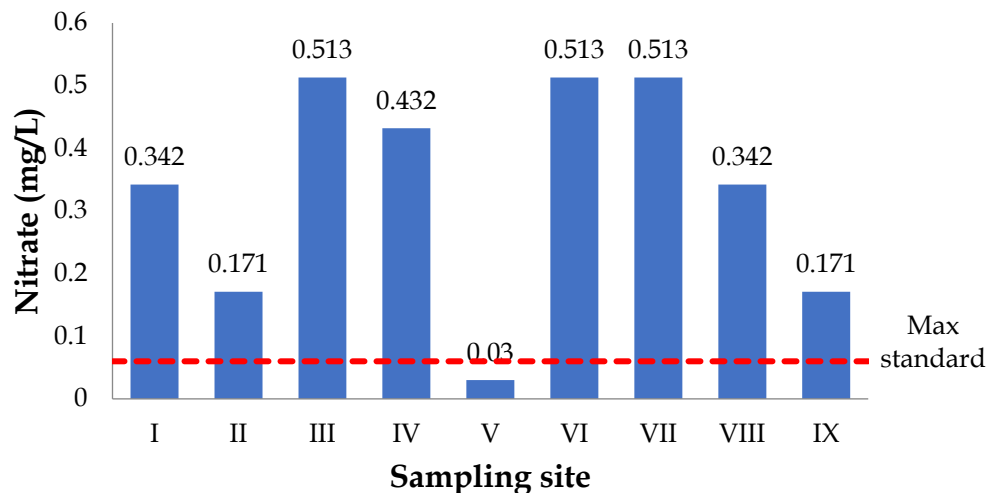


Figure 8. Nitrate Concentration in Plawangan Barat

biochemical oxygen demand (BOD) level may result in a heightened requirement for oxygen. The reason for this phenomenon is the essential requirement of bacteria to facilitate the decomposition of organic substances present in water, resulting in a subsequent decline in the concentration of dissolved oxygen (Siregar et al., 2007).

Nitrate (NO₃-N)

Nitrate is one of the most influential parameters for marine life (Salim et al., 2017). The results showed that the overall condition of the water in Plawangan Barat was not suitable for marine life because the levels had exceeded the specified quality standard (Figure 8). The elevated levels observed can be attributed to the introduction of organic material resulting from various land-related activities, including erosion and the deposition of domestic and agricultural waste, such as residual fertilisers (Irwan et al., 2017; Suharto et al., 2019).

The presence of nitrate in water is a crucial factor for facilitating protein synthesis in aquatic organisms. However, when nitrate levels reach elevated quantities, it can lead to the excessive proliferation of algae, hence causing uncontrolled development. The reduction of dissolved oxygen levels in water can result in the mortality of aquatic creatures, since they are unable to

withstand low oxygen circumstances (Siregar et al., 2007; Irwan et al., 2017).

Phosphate (PO₄-P)

Phosphate is an important nutrient for the growth and development of aquatic organisms, especially phytoplankton (Simanjuntak, 2012). The findings indicate that the phosphate concentration in the waters of Plawangan Barat has over the acceptable quality threshold (Figure 9), rendering it unsuitable for marine organisms. The Cibeureum river, specifically station IV, exhibited the highest recorded phosphate level of 0.949 mg/L. The presence of a significant quantity of organic materials, particularly derived from residential trash transported by downstream river currents, is the primary cause of this phenomenon (Hermawan & Wardhani, 2021). Furthermore, an excessive amount of phosphate has the potential to induce eutrophication, a phenomenon characterised by the rapid growth of phytoplankton. This proliferation of phytoplankton can result in the formation of a dense layer on the water's surface, impeding the entrance of sunlight. Consequently, this limited sunlight availability can lead to oxygen depletion, ultimately resulting in the demise of marine organisms (Siregar et al., 2007).

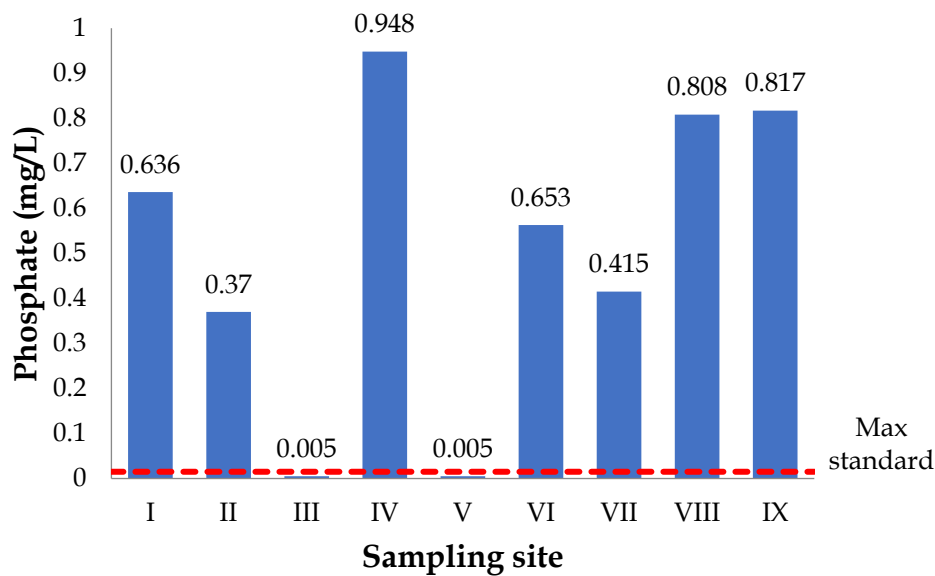


Figure 9. Phosphate Concentration in Plawangan Barat

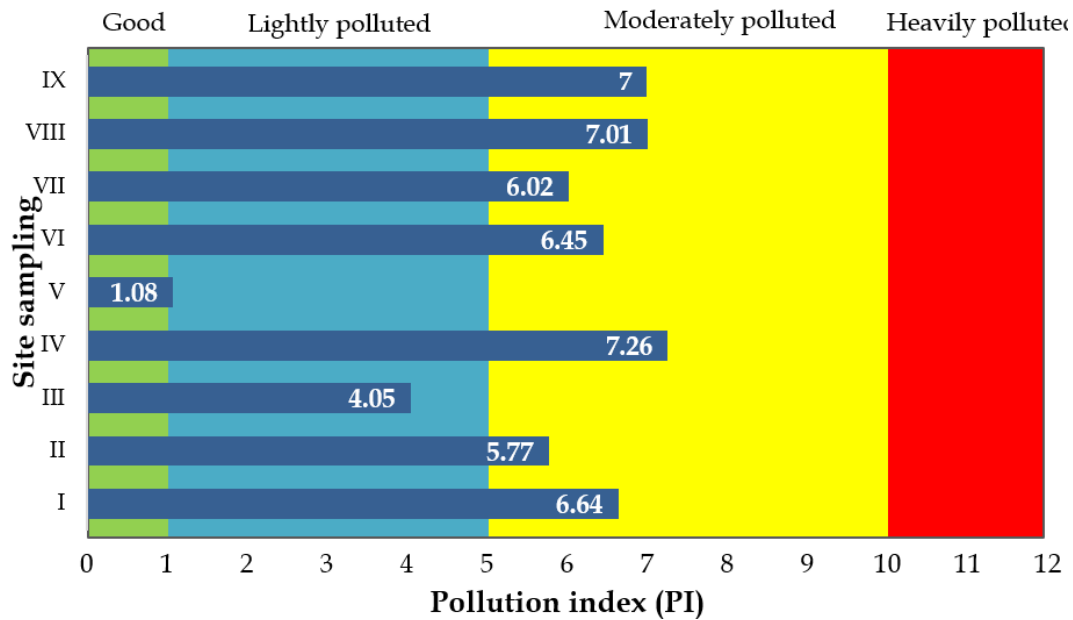


Figure 10. Pollution Index (PI) Value in Plawangan Barat

3.2. Water Pollution Level in Plawangan Barat

The level of water pollution can be estimated from the value of its Pollution Index (PI). The PI is a straightforward and accessible assessment approach used to evaluate water pollution levels. Researchers have utilised many studies on the application of the pollution index to estimate pollution levels in rivers and estuaries (Suriadikusumah et al., 2021; Ujjania and Dubey, 2015; Wei et al., 2009). The aforementioned approach has successfully generated a metric to assess the extent of contamination in relation to the established water quality standard. The aforementioned criterion is utilised to assess the quantities of organisms, chemicals, energy, or constituents present in water, in addition to the pollutants. Based on the results, the waters in Plawangan Barat are classified as lightly to moderately polluted, with a PI value of 1.08–6.88 (Figure 10).

Figure 10 shows that stations III and V are in a lightly polluted state, while stations I, II, IV, VI, VII, VIII, and IX are in a moderately polluted condition. The highest level of pollution is at station IV in the Cibereum stream with an index value of 7.26. This condition can be caused by the accumulation of organic matter carried from the Cibereum River Basin and then enters the waters of Plawangan Barat. Previous research in Segara Anakan Cilacap by Kasari and Effendi (2017), showed that the level of pollution in these waters is already in the category of lightly polluted which

is thought to be influenced by anthropogenic activities in the waters, especially domestic activities, which can reduce the quality of the waters and increase the level of pollution. Hermawan and Wardhani (2021) reported that the Cibereum watershed is a densely populated area, making the domestic sector the main source of pollution in the river.

Based on the analysis of eight observed characteristics, it is evident that the physical and chemical condition of the waters in Plawangan Barat Segara Anakan Cilacap is relatively favourable. Nevertheless, it is evident that three specific parameters, namely TSS, phosphate, and nitrate, have surpassed the established quality limits for marine life in the Segara Anakan waters. Consequently, it can be inferred that the presence of these three parameters contributes to the mild to moderate pollution status observed in the aforementioned waters. This phenomenon is also observed in the coastal regions of Makassar city (Suharto et al., 2019) and in Manado Bay (Patty et al., 2019). According to the author, the criteria that have surpassed the established quality threshold include nitrate and phosphate. These elevated levels are believed to result from the substantial influx of home and industrial waste from the surrounding environment. Hence, it is imperative to address this issue due to the significant role that phosphate and nitrate serve as markers of aquatic productivity. However, elevated concentrations of these compounds can lead to the phenomenon of eutrophication, as highlighted by Hamuna et al. (2018). The

presence of TSS (Total Suspended Solids) in aquatic environments poses a significant threat to the respiratory processes of marine organisms, hence jeopardising their survival (Rinawati et al., 2016; Hamuna et al., 2018).

Table 1 displays the value of the condition factor of Indian mackerel in the Bali Strait waters. Indian mackerel condition factor values ranged from 0.86 to 1.15. The highest value was found in August and the lowest value was found in June. Based on the stage of gonadal maturity, the condition factor value of Indian mackerel increases with increasing gonadal maturity of Indian mackerel (Table 2).

From 167 individuals, the number of male Indian mackerel (121 individual) was more than the number of female Indian mackerel (46 individual) for each of gonadal maturity stage (Figure 5). The sex ratio of Indian mackerel was 2.63:1.00. The size at first maturity for male and female mackerel was 19.34 cm and 19.76 cm (Figure 6).

4. Conclusions

Based on the assessment of various factors including temperature, salinity, pH, dissolved oxygen (DO), and biological oxygen demand (BOD5), it can be concluded that the water quality conditions in Plawangan Barat Segara Anakan Cilacap remain conducive for marine life. In light of the TSS, phosphate, and nitrate levels, it may be concluded that the water is no longer deemed appropriate due to the surpassing of quality standards in terms of these parameters. The Pollution Index value suggests that the water quality in Plawangan Barat, Segara Anakan, Cilacap, falls within the range of mild to moderate pollution. The primary focus that necessitates attention from both the Cilacap district government and the local population pertains to the strategies for safeguarding and overseeing water quality. This can be achieved through the reinforcement of policies or by enhancing public consciousness.

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