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MARINE WATER POLLUTION INDEX: A CASE STUDY OF LABUHAN SANGORO WATERS, SALEH BAY, SUMBAWA REGENCY

Indeks Pencemaran Perairan Laut: Studi Kasus Perairan Labuhan Sangoro, Teluk Saleh Kabupaten Sumbawa

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ABSTRACT

Saleh Bay is one of the areas in West Nusa Tenggara Province known for its significant marine resource potential, where most coastal communities rely on these resources for their livelihoods. One of the most important activities for coastal communities is seaweed cultivation. In addition to supporting the local economy, this activity has also made West Nusa Tenggara one of the largest seaweed producers in Indonesia. However, the decline in water quality has led to a decrease in seaweed production. This case has occurred in one of the waters of Saleh Bay, namely Labuhan Sangoro. This decline usually happens during certain season (rainy season) and is a result of the ice-ice disease. Water monitoring efforts are crucial as a reference for seaweed farmers regarding the water conditions they will use as a cultivation medium. This study was conducted in February 2024, coinciding with the rainy season. Seawater sampling used purposive sampling method. Sampling was carried out at six stations which were cultivation locations (sampling stations from the previous year). Measurements of seawater chemical and physical parameters were carried out in situ and in the laboratory of the Lombok Marine Aquaculture Center. The data obtained from the measurements were then descriptively analyzed using the Pollution Index method based on the Decree of the State Minister for the Environment No. 115 of 2003. The Pollution Index evaluation indicates that in February 2024, the waters of Labuhan Sangoro are still at a moderate pollution level (PI=6.1), and some stations show parameter values exceeding the quality standards.

Keywords: Labuhan Sangoro, pollution index, rainy season

ABSTRAK

Teluk Saleh merupakan salah satu kawasan di Provinsi Nusa Tenggara Barat yang telah diketahui memiliki potensi sumberdaya laut yang besar dimana sebagian besar masyarakat pesisir mengandalkan sumberdaya tersebut sebagai sumber mata pencaharian. Salah satu kegiatan masyarakat pesisir yang sangat penting yaitu budidaya rumput laut. Selain menopang perekonomian masyarakat, kegiatan tersebut juga telah menjadikan NTB sebagai salah satu produsen rumput laut terbesar di Indonesia. Namun demikian, penurunan kualitas perairan telah menyebabkan penurunan produksi rumput laut. Kasus ini terjadi di salah satu perairan Teluk Saleh, yaitu Labuhan Sangoro. Penurunan ini biasa terjadi pada musim tertentu (musim hujan) dan sebagai akibat dari serangan penyakit ice-ice. Upaya monitoring perairan sangat diperlukan sebagai acuan bagi para pembudidaya mengenai kondisi perairan yang akan mereka gunakan sebagai media budidaya. Penelitian ini dilaksakanan pada bulan Februari 2024 yang bertepatan dengan musim hujan. Sampling air dilakukan menggunakan metode *purposive sampling.* Sampling dilakukan pada 6 stasiun yaitu lokasi-lokasi budidaya (stasiun sampling pada tahun sebelumnya). Pengukuran parameter kimia dan fisika air laut dilakukan secara *in situ* dan dilakukan di laboratorium Balai Perikanan Budidaya Laut Lombok. Data yang diperoleh dari hasil pengukuran selanjutnya dianalisis secara deskriptif menggunakan metode Indeks Pencemaran berdasarkan Keputusan Menteri Negara Lingkungan Hidup No 115 tahun 2003. Evaluasi Indeks Pencemaran menunjukkan bahwa pada bulan Februari 2024, perairan Labuhan Sangoro masih berada pada level tercemar sedang (PI=6,1), dan pada beberapa stasiun ditemukan nilai parameter yang melebihi baku mutu.

Kata kunci: Labuhan Sangoro, indeks pencemaran, musim hujan

INTRODUCTION

Perairan Laut Labuhan Sangoro telah lama dimanfaatkan sebagai lokasi budidaya rumput laut. Perairan ini masuk ke dalam kawasan Teluk Saleh, Kabupaten Sumbawa, Nusa Tenggara Barat yang merupakan salah satu kawasan dengan potensi sumberdaya ekologi yang mampu mendukung teluk ini menjadi pusat kegiatan perekonomian laut (Yulius *et al*., 2017).

As one of the national seaweed suppliers which ranks 3rd in 2022, seaweed cultivation activities have great potential to support the economy of coastal communities. As is the case in the coastal area of Labuhan Sangoro, according to Kautsari & Syafikri (2017), most of the families on this coast rely on seaweed cultivation activities as their main livelihood. In addition, based on the results of direct interviews in the field, it is known that this activity has been engaged in by coastal communities for a long time so that most of them think that this seaweed cultivation activity will continue to be carried out regardless of the obstacles faced in the field (Astriana & Putra, 2024).

One of the main obstacles that cultivators in this region often face is the attack of ice-ice disease. Based on interviews conducted by Astriana & Putra (2024) with a group of seaweed cultivators in the region, it is known that this disease has caused talus damage of 20-30% of the total cultivated talus. This condition is quite economically detrimental for cultivators.

Ice-ice itself is known to be a disease in seaweed that can be triggered by changes in the aquatic environment. Some of the causative agents of ice-ice are bacteria. Some bacteria that are known to have the potential to cause ice-ice are Pseudoalteromonas gracilis (Hairuddin, 2022), the genus Pseudomonas, and Flavobacterium (Wulandari et al., 2020). Although previous studies have succeeded in identifying the cause of this ice-ice, the right solution has not been formulated to prevent the spread of ice-ice in a seaweed cultivation location.

One of the things that can currently be done to avoid losses for seaweed cultivators as a result of the emergence of ice-ice is the selection of the right cultivation location. Saleh Bay has long been known to have waters that support the development of various marine aquaculture activities, but the case of seaweed harvest failure in the Labuhan Sangoro area shows a change in the quality of the waters in this area. The existence of information regarding the value of seawater quality parameters and the results of the calculation of the pollution index can help in determining the potential of the area for the development of seaweed cultivation activities in Labuhan Sangoro.

METHODS

Place and Time

This research was carried out in February 2024 at the seaweed cultivation site which became an observation station in the previous year in the waters of Labuhan Sangoro, Saleh Bay, Sumbawa Regency, West Nusa Tenggara (Figure 1).

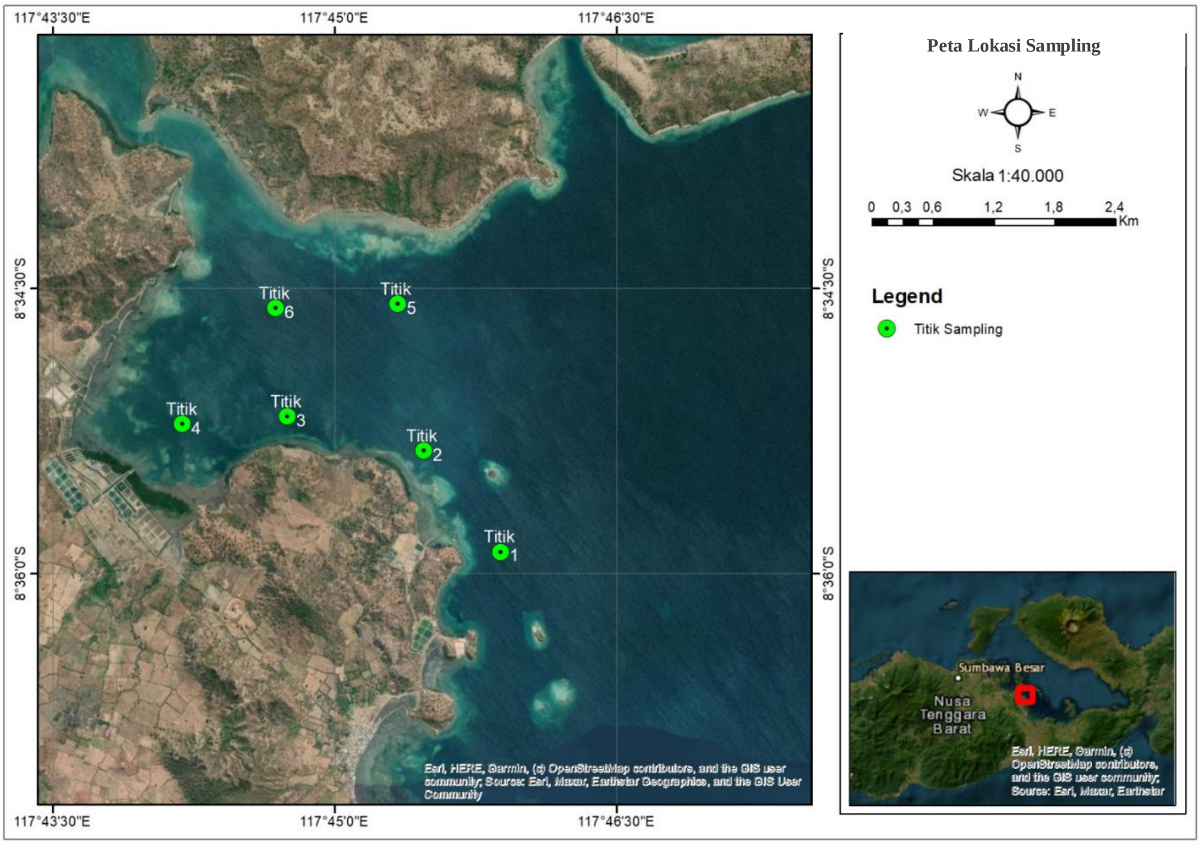

Fig 1. Sampling Location, Labuhan Sangoro, Teluk Saleh, Sumbawa Regency

Tools and Material

The equipment and materials used in this study include sample bottles (storing water samples), coolboxes (storage of water samples), secchi discs to measure the brightness level of water, spectrophotometers to measure the concentration of water quality parameters, boats, and markers.

Sampling Method

Seawater sampling was carried out using the purposive sampling method by determining 6 sampling points at the seaweed cultivation location as shown in Figure 1. Samples were taken in seaweed cultivation areas whose locations are close to shrimp pond outlets, corn fields, and locations that are relatively far from these two activities. Measurements of seawater brightness were carried out directly in the field, while measurements of other physical parameters as well as chemical parameters were analyzed at the Laboratory of the Lombok Marine Aquaculture Fisheries Center, Sekotong.

Data Analysis

The analysis of the physico-chemical parameter data obtained was carried out descriptively by, referring to seawater quality standards in accordance with PP 22 of 2021 concerning the Implementation of Environmental Protection and Management, Decree of the Minister of State for the Environment Number 51 of 2004, and other references. The water quality analysis is then carried out using the Pollution Index, based on the formula that has been stipulated in the Decree of the Minister of Environment Number 115 of 2003 attachment II concerning guidelines for determining water quality status. The formula used is as follows.

$$\mathbf{PIj} = \sqrt{\frac{(C_i/L_{ij})_M^2 + (C_i/L_{ij})_R^2}{2}}$$

The evaluation of the PI value is as follows:

0 $\leq$ PIj $\geq$ 1,0 : meet quality standards (good condition)
1,0 $\leq$ PIj $\geq$ 5,0 : lightly polluted
5,0 $\leq$ PIj $\geq$ 10 : moderately polluted
PIj > 10 : heavily polluted

RESULT

The results of the measurement of several aquatic physical and chemical parameters showed that there were variations in values at different observation stations. In detail, the results of the measurement and determination of the pollution level are presented in Table 1.

Table 1. Measurement results and determination of pollution levels

Parameters	**Stasiun**						**Scalable Ci**	**Lij**	**Average Lij**	**New Ci**	**New Ci/Lj**
	1	**2**	**3**	**4**	**5**	**6**					
Temperature **(ºC)**	29,2	29,2	28,5	28,9	29,1	28,9	28,97	28-30	29		0,033
pH	7,9	8,3	8,2	8,3	8,6	8,2	8,25	7-8,5	7,75		0,67
DO (mg/L)	1,3	2,7	3,1	3,6	3,5	3,4	2,93	5	5	2,03	0,41
TDS (mg/L)	35,5	31,7	29,2	27,6	30,9	35,1	31,67	2000	2000		0,016
Salinity (ppt)	23	15	25	17	10	18	18	33-34	33,5		8,46
Ammonia (mg/L)	0,05	0,06	0,03	0,01	0,01	0,03	0,03	0,3	0,3		0,10
Nitrite (mg/L)	0,01	0,004	0,012	0,002	0,001	0,003	0,005	0,005	0,005		1,14
Nitrat (mg/L)	0,01	0,05	0,01	0,01	0,01	0,01	0,017	0,06	0,06		0,28
PO4 (mg/L)	0,14	0,08	0,04	0,01	0,12	0,08	0,078	0,015	0,015		4,59
TOM (mg/L)	31,6	26,54	24,02	6,32	10,11	8,85	17,91	10	10		2,26
TSS (mg/L)	0,0015	0,008	0,0215	0,017	0,018	0,015	0,013	20	20		0,00067
										Ci/Lij R	1,63
										Ci/Lij M	8,46
										IPj	6,1

Note: The quality standard threshold values used refer to Poppo et al., (2008), Triyaningsih et al., (2021), KepMen LHK No. 51 of 2004, and PP 22 of 2021

DISCUSSION

Water Quality Parameters at Labuhan Sangoro Seaweed Cultivation Site

Physical Parameters: Temperature

Temperature is one of the parameters that has a significant influence on the physiological processes of seaweed, especially in terms of photosynthesis, respiration, growth and absorption of nutrients. High temperatures can cause enzyme denaturation, decreased photosynthesis efficiency and decreased chlorophyll-a production resulting in the fading of the talus color to become paler or yellowish (Kim et al., 2015; Tarmizi et al., 2022). Meanwhile, temperatures that are too low can slow down the metabolic rate, thus inhibiting the growth of seaweed. According to Olischläger et al., (2017), inappropriate temperatures can interfere with ion transport and the ability of seaweed to absorb nutrients from the environment, thus impacting seaweed growth and reproduction. The optimum temperature for seaweed growth varies depending on the species, but in general ranges from 27-300C (Indrayani et al., 2021). Based on the results of measurements at the research site, it is known that the seawater of Labuhan Sangoro has a temperature ranging from 28.5-29.2 0C. The temperature range is still within the optimal limit that supports the physiological activity of seaweed. This is supported by the research of Hurtado et al., (2013) which shows that seaweeds such as Kappaphycus and Eucheuma are able to thrive at temperatures close to 300C without showing signs of thermal stress. Thus, it can be concluded that water temperature is not a factor that causes seaweed talus loss.

Physical Parameters: Total Suspended Solid (TSS)

TSS is the number of suspended solid particles with a particle size of >2 microns (μm). High TSS can lead to a decrease in water transparency, thereby reducing the penetration of light entering the water. Suspended solids can bind to essential nutrients such as phosphorus and nitrogen, thereby reducing their availability for seaweed (Hurd et al., 2014). Based on the Ministry of Environment and Forestry No. 5 of 2014, the TSS quality standard for marine waters is 50 mg/L. TSS concentrations that exceed 50 mg/L can cause a decrease in water quality and can have a negative impact on seaweed growth. The results of the measurement of seawater samples at the study site showed that the concentration of TSS ranged from 0.0015-0.0215 mg/L. The concentration of TSS in this range was still far below the quality standard threshold so that the condition of the sea waters was still considered ideal to support the growth of seaweed. Low TSS levels indicate that water has high transparency, allowing enough light to enter the water column, thereby increasing the efficiency of photosynthesis (Hurd et al., 2014).

Physical Parameters: Total Dissoved Solid

Total Dissoled Solid (TDS) refers to the total number of solid particles dissolved in water, including salts, minerals and organic compounds with a diameter of <10-3 μm (Suniada & S, 2014). TDS in marine waters can be derived from minerals dissolved from the weathering process of rocks and plant residues, sludge and plankton. In addition, TDS can also be sourced from human activities that produce waste such as industrial activities, agriculture, livestock and others. TDS has a significant influence on marine life, including seaweed such as K. alvarezii. Optimal TDS conditions can maintain osmosis balance so that seaweed can absorb water and nutrients efficiently (Millero, 2010). The right concentration of TDS ensures the availability of ions and dissolved nutrients that are essential for seaweed growth. On the contrary, TDS levels that are too low can reduce the concentration of nutrients needed, which has an impact on inhibiting the growth and reproduction of seaweed (Hurd et al., 2014). According to the Ministry of Environment and Forestry No. 51 of 2004, the TDS quality standard for marine life is 1000 mg/L. From the results of measurements at the research site, it is known that the TDS value of Labuhan Sangoro seawater is in the range of 27.6-35.5 mg/L, where this value is not in accordance with the quality standards so it is not suitable for seaweed growth.

Physical Parameters: Salinity

Salinity has a significant influence on the osmoregulation, growth and productivity of seaweed. The K. alvarezii type of seaweed has a low tolerance to salinity changes. Salinity that is too high can cause osmotic stress, where ocean floors have difficulty absorbing water resulting in cell dehydration. In addition, high salinity can also reduce the efficiency of photosynthesis so that seaweed cannot produce energy and biomass effectively (Harrison et al., 2018; Fletcher, 2011). Meanwhile, low salinity can cause seaweed to lack ions and dissolved nutrients and experience difficulties in osmoregulation, which leads to a disturbance of ion balance in cells (Norton et al., 2020; Harrison et al., 2018). According to Ruslaini (2016), the ideal salinity for seaweed growth, especially K. alvarezii ranges from 33-35 ppt.

The results of measurements at the study site showed that the salinity of seawater was in the range of 10-25 ppt. This salinity value is not in accordance with the ideal conditions for seaweed growth. The low salinity value of seawater at the research site can occur due to the sampling time carried out during the rainy season, causing an increase in the volume of fresh water into the marine water system, thereby reducing the concentration of dissolved salts in seawater (Kumar et al., 2015).

Chemical Parameters: Degree of Acidity (pH)

Acidity (pH) is a chemical parameter of seawater whose value is influenced by the concentration of dissolved carbon dioxide, photosynthesis and biological activity in the marine environment (Hurd et al., 2014). This parameter has a very significant influence on seaweed because the pH of the water affects the availability of important ions such as carbonate (CO32-) and bicarbonate (HCO3-) which are necessary for seaweed growth (Israel et al., 2010). A high pH (>8.5) can cause an imbalance in metabolism. Meanwhile, at low pH (<7), the rate of photosynthesis is reduced so that it can inhibit the growth of seaweed and in the long term can cause talus damage (Hurd et al., 2014). Based on SNI (2011), the optimal pH that is relegated for the growth of seaweed, especially the type of K. alvarezii is 7.0 -8.5. Within this pH range, seawater conditions are considered ideal for physiological processes such as photosynthesis, nutrient absorption and seaweed biomass growth. From the measurement results, the pH of seawater in Labuhan Sangoro ranges from 7.9-8.6. Although the pH value is outside the optimal pH range for seaweed growth, this value can still be tolerated by many seaweed species through various physiological and metabolic adaptations because the event of marine biota death can occur if the pH > 9.5 (very alkaline waters) (Rinawati et al., 2016).

Chemical Parameters: Dissolved Oxygen (DO)

Dissolved oxygen (DO) is a crucial factor in seaweed growth and productivity because it supports the efficiency of photosynthesis and respiration. Optimal dissolved oxygen levels in the aquatic environment can improve the ability of seaweed to absorb nutrients. Meanwhile, hypoxia conditions can cause oxidative stress, metabolic disorders, slow down growth rates and even trigger death if it lasts for a long period of time (Nikhlani, 2021). According to Ministerial Decree No. 51 of 2004 concerning Seawater Quality Standards, the appropriate dissolved oxygen (DO) level to support the life of marine life, including seaweed is >5 mg/L and according to Nikhlani (2021), the optimal DO level to support seaweed cultivation activities is in the range of 5-7 mg/L. K. alvarezii seaweed requires DO levels ranging from

4.5-9.8 mg/L with an optimal DO of >6 mg/L (Nikhlani, 2021; Nurdiansyah, 2020). Based on the results of this study, it is known that the concentration of DO in Labuhan Sangoro, which is the cultivation site of K. alvarezii, is in the range of 1.3-3.6 mg/L. This value is outside the ideal range for the growth of K. alvarezii so that this condition can cause metabolic stress in seaweed.

Chemical Parameters: Ammonia

Ammonia (NH_3) has an important role in cell metabolism and seaweed growth. Ammonia is one of the vital sources of nitrogen for the synthesis of proteins, amino acids and nucleic acids (Hurd et al., 2014). Ammonia is produced from the decomposition of organic matter such as detritus, dead plankton, and the remains of organisms in waters (Baker et al., 2017). Ammonia also contributes to the process of photosynthesis by aiding in the formation of chlorophyll (Muller et al., 2016). Although it has an important role in the growth of seaweed, in high concentrations ammonia can be toxic. Excessive ammonia levels can lead to osmotic stress and impaired cellular function of seaweed (Norton et al., 2020). From the results of the study, it was obtained that the concentration of ammonia was in the range of 0.01-0.06 mg/L. This value is still far below the maximum limit of ammonia in the water, which is 0.3 mg/L. Low ammonia value at the research site can cause seaweed to lack a nitrogen source so that its growth is inhibited. Low ammonia levels also have the potential to affect chlorophyll production and the process of seaweed photosynthesis.

Chemical Parameters: Nitrates and Nitrites

Nitrates (NO_3^-) and nitrites (NO_2^-) play an important role in the growth of seaweed, especially as a source of nitrogen which is an essential element for the process of metabolism and protein synthesis. Although nitrates and nitrites play a role in the nitrogen cycle that supports seaweed growth, at high concentrations both compounds can disrupt the ionic balance in cells and oxygen transport in tissues, causing oxidative stress and damaging seaweed cells (Gruber & Galloway, 2008). Nitrates can be produced through the decomposition of nitrogen-containing organic matter such as plankton, followed by a nitrification process in which ammonia is converted to nitrite and then to nitrate by nitrifying bacteria (Zehr & Kudela, 2011). Nitrates can also come from runoff from agricultural activities (nitrogen fertilizers), domestic and industrial waste. Meanwhile, nitrite is an intermediate product of the nitrification process formed by the oxidation of ammonia by Nitrosomonas bacteria (Izzati, 2011). Nitrites are then further converted into nitrates by Nitrbacter bacteria (Ward, 2008). In addition, denitrifying bacteria can convert nitrate back into nitrite in anoxic conditions (lack of oxygen). Based on Government Regulation No. 22 of 2001, the quality standards of nitrate and nitrite in marine waters that do not harm marine life are <0.008 mg/L and 0.06 mg/L, respectively.

The results showed that the nitrite concentration ranged from 0.001-0.01 mg/L. Nitrite concentrations at all sampling locations were below the set quality standards. Meanwhile, the nitrate content in the Labuhan Sangoro seawater sample is in the range of 0.01-0.05 mg/L. The nitrate value has exceeded the quality standard which indicates that the waters have experienced a decline in seawater quality. However, the nitrate level <0.05 mg/L does not cause a direct toxic effect on marine life. Nurdin et al. (2020) stated that the optimal nitrate concentration for the growth of K. alvarezii seaweed is between 0.05-0.1 mg/L. Based on the range of nitrate and nitrite concentrations obtained, it can be concluded that the sea sea conditions at the research site are relatively safe to support seaweed cultivation activities.

Chemical Parameters: Phosphate

Phosphate is a source of phosphorus needed by seaweed for various metabolic processes. Phosphorus is needed for ATP synthesis, DNA and RNA formation, and chlorophyll formation. Adequate availability of phosphorus supports cell division and the development of new tissues, as well as allowing seaweed to be able to carry out photosynthesis efficiently (Norton et al., 2020; Muller et al., 2016). According to Government Regulation No. 22 of 2021, the maximum value of phosphate in marine waters ranges from 0.1-0.5 mg/L. Based on the results of measurements at the research site, seawater samples have a phosphate content in the range of 0.01-0.014 mg/L. This value is still below the quality standard which indicates that the waters at the research site are in good condition. However, the phosphate content is considered unable to support the growth of seaweed because it is below the optimal range of phosphate concentration suitable for seaweed cultivation (0.02-1.04 mg/L) (Nikhlani & Kusumaningrum, 2021).

Chemical Parameters: TOM

Total Organic Matter (TOM) is the total amount of organic matter contained in a sample, both dissolved and suspended. TOM includes a wide variety of materials, including plant remains, animals, microorganisms, and metabolic products. TOM has a complex influence on seaweed growth. In balanced conditions, TOM can act as a source of nutrients that provide nitrogen, phosphorus, and other nutrients necessary for growth. However, if the concentration is too high, it can lead to increased turbidity and a decrease in dissolved oxygen. In addition, high TOM may increase populations of heterotrophic microorganisms that may compete with seaweed for nutrients (Norton et al., 2020; Cloern, 2001). From the results of the study, it was obtained that the concentration of TOM was in the range of 6.32-31.6 mg/L. According to Pirzan & Pong-Masak (2008), a TOM concentration of more than 26mg/L indicates that the waters are fertile waters. Meanwhile, the concentration of TOM is less than 10 mg/L indicating that the waters are still in a clean condition (Sakinah, 2016). Thus, the results of the measurement of TOM concentration obtained showed that the waters where the research was conducted were in the clean-fertile category, where of the six sampling points, point 1 (TOM concentration 31.6 mg/L) and 2 (TOM concentration 26.54 mg/L) were the locations of waters that were classified as fertile waters.

Analysis of Aquatic Pollution Index at Seaweed Cultivation Locations

Based on the results of the calculation, the pollution index value at the research site was obtained which was 6.1 which indicated that the water quality in the area was in a moderately polluted condition. The water quality of Labuhan Sangoro has changed due to pollution, but it has not been included in the category of heavily polluted. However, the decline in the quality of seawater can indirectly increase the risk of seaweed diseases. Changes in environmental conditions that pass the optimal range can trigger physiological stress in seaweed which then weakens the ability of seaweed to defend itself against pathogens such as Vibrio spp bacteria which cause ice-ice disease (Hurtado et al., 2001). Several parameters with values that are not in accordance with the standards for marine life include pH, DO, TDS, salinity, ammonia, nitrate and phosphate. The decline in seawater quality is suspected to come from seawater pollution by organic waste from intensive shrimp ponds. In addition, the existence of corn fields around the research site also contributes to the decline in seawater quality, where chemical fertilizer runoff from corn fields is wasted into the water through surface water flows during rains.

CONCLUSION

The condition of the waters of Labuhan Sangoro, which is the location of seaweed cultivation activities, shows a moderately polluted status with a Pollution Index (IP) value of 6.1, indicating a significant water quality disturbance. Several water quality parameters, such as pH, DO, TDS, salinity, ammonia, nitrate and phosphate are outside the optimal range for seaweed growth, potentially increasing the risk of talus loss in seaweed and seaweed susceptibility to pathogen attack.

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