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The Influence of Heavy Metal Content of Iron (Fe) on the Porong River Flow in Seagrass Plant

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ABSTRACT: The Porong River is greatly influenced by human activities such as industry, agriculture, fish ponds, and fishing boat transportation. One of the industrial activities that is a source of waste in the Porong River basin is PT. Lapindo Brantas which caused a mudflow in 2004. Several metal contents were found in the Lapindo mud, one of which is iron (Fe). The function of Fe is to play a role in the formation of chlorophyll. Determination of seaweed plant sampling points is carried out based on a random method. Water sampling is carried out using a mechanism using a 250 ml bottle for each repetition, there are 4 repetitions for each point and will be deposited in a 1liter bottle. Water samples are taken from the lower part of the water surface at the specified points. As for water samples, they are stored in a safe place without being exposed to too much shaking. The concentration of heavy metal iron (Fe) contained in the water is then absorbed by seaweed plants and will be tested for biconcentration factor (BCF). Therefore, it is necessary to conduct an analysis of the heavy metal content of iron (Fe) in the seaweed cultivation area of Kedungpandan Village, Jabon District, Sidoarjo Regency to find out how much heavy metal iron (Fe) there is.

KEYWORDS: Seaweed, Ferrous metal (Fe), Environment, Water, and Pond

I. INTRODUCTION

Rivers are one of the aquatic ecosystems influenced by many factors, both from natural activities and human activities. Rivers play a significant role in the lives of communities. The benefits of rivers for humans include sources of household water, industrial water sources, irrigation, fisheries, agriculture, recreation, transportation, and many other uses that rivers (River Basin Areas) can provide for life.

The Porong River is a continuation of the Brantas River Basin that originates in Mojokerto City (Bendungan Lengkong Baru) flowing eastward and emptying into the Java Sea. The Porong River borders Sidoarjo Regency and Pasuruan Regency. The name Porong is taken from the name of a sub-district in Sidoarjo Regency that is traversed by the river flow. The Porong River has two tributaries, namely Sedat and Kali Kambing.

The Porong River is greatly influenced by human activities such as industry, agriculture, fish farming, and transportation of fishing boats. The presence of these human activities can increase the input of waste into the waters of the Porong River. One industrial activity that is a source of waste in the Porong River basin is PT. Lapindo Brantas, which caused a mud eruption in 2004. The Lapindo mud disaster brought several new problems, one of which is soil and water pollution due to the metal content absorbed by soil sediments, and to this day, the affected area continues to expand.

Many efforts have been made to address the mud eruption, one of which is the disposal of mud or channeling mud into the Porong River, which can cause more widespread environmental pollution. According to Mauliana & Suprayitno (2017), several metal contents were found in the Lapindo mud, one of which is iron (Fe). Based on the information search that has been conducted, the water used by seaweed farmers in Dasa Kedungpandan, Jabon District, Sidoarjo Regency uses water flow originating from the Porong River, which is used or becomes the disposal of Lapindo mud. Therefore, it is necessary to take action Analysis of Heavy Metal Content of Iron (Fe) in Seaweed Cultivation Land in Kedungpandan Village, Jabon District, Sidoarjo Regency to Determine How Much Heavy Metal Iron (Fe) is Present.

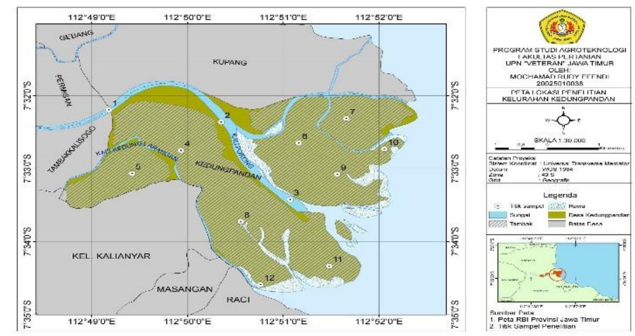
According to Gelyaman (2018), iron metal will be available for plants at a pH range of 4.6 to 7.4 and will become unavailable at a pH greater than 8.5. Anitra *et al*. (2016) explain that at a pH between 6 and 7, Fe metal easily associates with the resistant fraction, making it readily available for plants. Fatma *et al*. (2013) state that iron (Fe) is absorbed in the form of ferric ions ($Fe3+$) or ferrous ions ($Fe2+$). Fe can be absorbed in the form of chelates (metal bonds with organic materials) and is stated to be one of the essential nutrients for plants. The function of Fe is to play a role in chlorophyll formation. Therefore, optimal availability of Fe is needed by plants. If Fe in the nutrient solution is insufficient, then chlorophyll formation will not be perfect (Fatma *et al*., 2013).

In addition, Ferreira et al. (2022) add that although the content of this metal, especially iron, is abundant in the earth's crust, only a small amount of iron is needed by plants. Thus, if in excess, it can cause toxicity and has the potential to be a contaminant. The seaweed cultivated in Kedungpandan Village, Jabon District, Sidoarjo Regency is of the Gracilaria sp. type. The cultivation and care of Gracilaria sp. seaweed are very easy because the care of Gracilaria sp. seaweed is very simple even though the environmental conditions of the waters differ between brackish water and sea water, such as in ponds. Gracilaria sp. seaweed can adapt to environmental conditions that are different from its original environment. This seaweed can survive in salinity between 15 g/l and 50 g/l (Aslan, 1998).

Generally, seaweed cultivation in Kedungpandan Village is done manually, both in planting and harvesting methods. Seaweed harvesting is done daily, and the harvested results are immediately dried; drying is done next to the pond (the boundary road between one pond and another). The dried seaweed will be stored in a warehouse and will be taken every week. The Lapindo mud, which contains various heavy metals, has caused the aquatic ecosystem and aquaculture in the Sidoarjo area to be polluted (Purnomo, 2014). Based on the statement above, there is a need for analysis of the heavy metal content of iron (Fe) in the Porong river flow in seaweed cultivation areas.

II. METHODOLOGY

Sample collection was conducted in the seaweed cultivation area of Kedungpandan Village, Jabon District, Sidoarjo Regency. More precisely, the land is located on the eastern side of the Lapindo mud, which is the former overflow of Lapindo mud. The determination of the sampling points for seaweed plants was carried out based on a random method, which is a sampling technique that is random in order to determine the influence of heavy metal content of iron on seaweed plants (the effect of heavy metals on chlorophyll formation).



Sediment samples were taken at each sampling location using a pipe. The sediment samples taken are sediments located in the river and ponds where seaweed samples have been taken. Sediment samples were collected at a depth of approximately 30 cm. The samples were placed in plastic, and then the samples were put into a cool box for analysis using the AAS (Atomic Absorption Spectrophotometer) method.

Water samples were taken using a mechanism with a 250 ml bottle for each replicate, with 4 replicates at each point, and will be composited into a 1-liter bottle. Water samples were taken from the surface of the water that was downwind at the predetermined points. Furthermore, the water samples were stored in a safe place without being too shaken.

The concentration of heavy metal iron (Fe) present in the water is then absorbed by the seaweed plants. Due to this translocation, it is necessary to measure the heavy metal content (Fe) in the seaweed cultivation area. The measurement aims to determine the heavy metal content of Fe required seaweed plants for chlorophyll formation and whether it is still within safe limits on seaweed cultivation land in Kedungpandan Village, Jabon District, Sidoarjo Regency by Calculating BCF Value**.**

Bio Concentration Factor or bioconcentration factor is the ratio of the concentration of substances in the tissues of aquatic organisms to the concentration in water or sediment (Widawati *et al*., 2020). The category of BCF values is divided into three: low accumulation (BCF<100), medium accumulation (100≤BCF≤1000), and high accumulation (BCF>1000) (Baker, 1981). BCF is calculated using the formula based on Baker (1981) as follows:

$$\mathrm{BCF} = \frac{\mathrm{Corg}}{\mathrm{C}}$$

Description:
BCF: Bio Concentration Factor or bioconcentration factor
Corg: Concentration of heavy metals in organisms
C: Concentration of heavy metals in water or sediment

The BCF value in the study is expected to be >1, because a BCF value of 1-10 indicates that the plant is classified as a high accumulator, 0.1-1.0 indicates that the plant is classified as a medium accumulator, and <0.1 indicates that the plant is classified as a non-accumulator (Chandra *et al*., 2018).

III. RESULTS AND DISCUSSION

Parameter	Unit	Quality Standards	Everage pond water								
			T4	T5	T6	T7	T8	T9	T 10	T 11	T 12
Physics											
Temprature	°C	28-32	31.1	31.6	31.5	31.1	30.6	31.4	30.9	30.8	30.9
Brightness	cm	30-45	37.5	30	32	39	32.5	34	28	44	31.5
Depth	cm	0.3-300	0.51	0.84	0.73	0.78	0.72	0.65	0.91	1.05	1.24
Chemistry											
pH	-	7.5-8.5	8.77	8.91	8.66	8.78	8.63	8.83	8.62	8.35	8.26
Salinitas	ppt	25-31	26.13	26.13	0.73	26.05	25.95	27.38	28.40	28.78	28.38
Fe	mg/L	0.003	0.24	0.10	0.27	0.16	0.24	0.27	0.44	0.20	0.26

Meeting the quality standards set by Kepmen No. 75 of 2016 and Government Regulation No. 20 of 2021.

Parameter	Unit	Quality Standards	Everage Water		Source
			T1	T2	T3
Physics					
Temprature	°C	28-32	31.2	31.4	31.6
Brightness	cm	30-45	30	31.2	35
Depth	cm	0.3-300	1.31	1.40	1.51
Chemistry					
pH	-	7.5-8.5	7.3	7.5	7.4
Salinitas	ppt	25-31	23.62	24.42	24.45
Fe	mg/L	0.003	0.29	0.27	0.27

Meeting the quality standards set by Kepmen No. 75 of 2016 and Government Regulation No. 20 of 2021.

A. Karakteristik Fisika

Temperature

Temperature is only observed in the field and not analyzed in the laboratory. Measurement of water temperature can only be observed in the field because if taken home, the water temperature will change and be less accurate. Observations of water temperature are conducted directly in the field using a thermometer at each predetermined point.

Based on the results of temperature measurements of the Porong River waters in Kedungpandan Village, Jabon District, Sidoarjo Regency, which have been conducted, are still in the range of 28-32 °C as stipulated by the Ministry of Marine Affairs and Fisheries Regulation No. 75 of 2016. Based on the results obtained, there are different values based on location for the highest average temperature value, which is at point T5, at 31.6 °C, and the lowest value, which is 31.2 °C, at point T4. Meanwhile, the temperature at the main points (T1, T2, and T3) has values that are not too different, namely 31.2 °C, 31.4 °C, and 31.6 °C. According to Masykur *et al*. (2018), water temperature affects the life of the biota within it. Because of the temperature in the waters local still below the quality standard limit, means the temperature of the river water can still support life in the waters. The water temperature is influenced by the intensity of sunlight that reaches the water, the measurement location is an open location so that sunlight directly reaches the water surface. This can be a cause of the high temperature of the river water. The more intense sunlight that hits the water body, the higher the temperature of the river water will be (Djoharam *et al*., 2018).

Brightness

The brightness of the seaweed cultivation pond can determine the intensity of sunlight that enters the pond waters. Based on the results of the brightness measurement, it has an average value ranging from 28 to 39 cm, where this value is still in accordance with the quality standard. The classification of water brightness will determine the rate of sunlight penetration into the water column for the photosynthesis process (Muqsith *et al*., 2022). Based on the results of the brightness analysis that has been conducted on the seaweed cultivation area, the value is still in accordance with the quality standard set by the Ministry of Marine Affairs and Fisheries Regulation No. 75 of 2016, where the range is 30 to 45 cm, while the smallest value is at point T10, which is 28 cm, and the largest value is at point T11, which is 44 cm. Good water brightness for seaweed cultivation is more than 1 m (Nikhlani and Kusumaningrum 2021). This good brightness value greatly supports the growth of seaweed. Many factors can influence the ability of sunlight to penetrate into the water, namely water color, organisms, organic materials, plankton, microorganisms, and detritus. The cause of the turbidity of the seaweed cultivation pond is the presence of mud, soil, organic substances that are dispersed, and others.

Depth

Differences in depth in the water cause the intensity of sunlight that enters to vary at each point, resulting in differences in seaweed growth. Depth is one of the factors that affects light absorption by seaweed, because it is closely related to the photosynthesis process that produces food (Nikhlani and Kusumaningrum, 2021). Based on the results of depth measurements in the seaweed cultivation area of Kedungpandan Village, the average depth value ranges from 0.51 to 1.24 m, where this value does not meet the quality standards for seaweed cultivation (Indrayani *et al*., 2021). Ideally, seaweed cultivation should have a depth of 0.3 to 0.6 meters at the lowest tide, using the bottom-free method, and in locations with strong currents. Seaweed cultivation using the floating method has a pathway system and ideally has a water depth of 2 to 15 meters; this method is carried out to avoid drought in seaweed and to optimize seaweed cultivation results (Rifdah Mawaddah R., 2023).

B. Karekteristik Kimia

pH

Based on the results of the pH analysis that has been conducted, it shows values that exceed the threshold set by the Ministry of Marine Affairs and Fisheries Regulation No. 75 of 2016, which is in the range of pH 7.5 to 8.5, while the analysis results show the highest average value of pH 8.83 at point T6, while the smallest value is at pH 8.26. This is in line with Khasanh *et al*. (2016) that the appropriate pH range for seaweed cultivation is slightly alkaline, with a pH above 7.0. The optimal acidity level for seaweed growth ranges from 6.0 to 9.0 (Risnawati *et al*., 2018).

Very acidic or alkaline waters can endanger the life of organisms, as they can cause metabolic and respiratory disturbances. pH itself can affect the solubility of heavy metals in the water. Low pH conditions can lead to relatively high solubility of heavy metals due to the transfer process of metals from the solid phase to the liquid phase, which increases with the higher concentration of free metal ions in the water. A decrease in pH acidity in the water will cause sedimentation at the bottom of the water. Conditions of pH approaching normal cause solubility to tend to be stable. The pH value is greatly influenced by biological activity, for example photosynthesis and respiration, temperature, and the presence of ions or mineral content in water.

Based on the results of the pH analysis that has been conducted on the Porong River (T1, T2, and T3) in Kedungpandan Village, Jabon District, Sidoarjo Regency, the lowest pH value at point T1 is 7.3, at point T2 it has a value of 7.5, and for point T3 it has a value of 7.4 which is located around the estuary. In line with previous research conducted by Didi *et al*. (2009) which states that the pH value in the estuarine waters of the Porong River ranges from 7 to 7.6 and is relatively neutral, it can be concluded that the pH value in these waters tends to remain unchanged. However, changes in pH values can occur due to the influence of rain or the influx of materials originating from the river.

Salinity

The results of observations and measurements of salinity in the seaweed cultivation area in Kedungpandan Village, Jabon District, Sidoarjo Regency range from 25.95 to 28.78 ppt, indicating values that still meet the threshold set by the Ministry of Marine Affairs and Fisheries Regulation No. 75 of 2016. A decrease in salinity can cause a reduction in complexing agents in the water. Heavy metals will be found more in free ions if there is a decrease in salinity, making it easier for heavy metals to enter the bodies of marine biota. Optimal salinity can allow seaweed to grow optimally due to the balance of cell membrane function. Salinity is a chemical factor that affects the physical properties of water, including the osmotic pressure present in seaweed with the liquid in the environment. This balance will help in the absorption of nutrients for photosynthesis, thus the growth of seaweed will be optimal (Yuliyana *et al*., 2017).

Based on the analysis of source water conducted in the Porong River in Kedungpandan, the lowest salinity is found at point T1, which is located far from the estuary, while the highest is at point T3, which is close to the estuary. The salinity value at point T3 has the highest value, which is suspected to be caused by the influence of water temperature. According to Lesmana (2001) states that the increase in temperature will affect salinity. The distribution of salinity concentration at the research location moves towards the east. The further east towards the sea, generally the salinity concentration is higher. Salinity is greatly influenced by the tides of the water; when the water is receding, the salinity value will rise because the intensity of river water entering the sea is greater than during high tide, thus making the salinity low.

Heavy Metal Iron (Fe)

Based on the analysis results of Fe conducted in the seaweed cultivation pond in Kedungpandan Village, Jabon District, Sidoarjo Regency, it has a value ranging from 0.10 to 0.44 mg/L, which exceeds the quality standards set by the Ministry of Marine Affairs and Fisheries Regulation No. 75 of 2016. The available iron content is very high when flooded and becomes dissolved, and in large quantities can increase the toxicity to plants. According to Sari *et al*. (2022), high iron content can lead to iron poisoning (Fe 2+). Iron compounds in dry soil conditions will have oxidized Fe 3+ reduced to Fe 2+, which is toxic to plants. Prasetyo *et al*. (2011) added that when iron is available and flooded, iron can be absorbed by plants, and when the soil is dried, some of the remaining Fe 2+ ions will change to Fe 3+, which easily reacts with other elements and cannot be absorbed by plants.

C. Bioconcentration Factor (BCF)

Based on the calculation results of the bioconcentration factor (BCF), the results are as follows:

BCF Plant Seaweed								
T4	T5	T6	T7	T8	T9	T10	T11	T12
0.4	0.36	0.57	0.72	0.49	0.58	0.82	0.43	0.72

Note:
T4 T12: Points located in the seaweed cultivation pond.

Based on the bioconcentration factor values categorized by Baker (1981), the obtained results indicate that the bioconcentration factor values the text is categorized as BCF < 0.1 1.0 which indicates that the cumulative level of cultivated seaweed in Kedungpandan Village, Jabon District, Sidoarjo Regency is classified as moderate. The level of accumulation of toxic substances is influenced by the success of the biota's body in the detoxification and excretion processes, so the toxic effects of heavy metals can still be tolerated by the biota's body (Yulaipi & Aunurohim, 2013). Generally, the ability to absorb heavy metals by aquatic plants is by storing them in parts of the plant. The cell wall is the main defense to prevent the entry of toxic metal ions (Purnamawati *et al*., 2015).

D. Relationship of Plant Chlorophyll and Heavy Metal Fe

Based on the analysis results that have been conducted, the values are as follows:

Parameter	Unit	Quality Standards	Everage pond water and seaweed								
			T4	T5	T6	T7	T8	T9	T 10	T 11	T 12
Chemistry											
Fe water	mgL	0.003	0.24	0.10	0.27	0.16	0.24	0.27	0.44	0.20	0.26
Plant											
Fe	mgL	-	0.10	0.07	0.15	0.12	0.12	0.16	0.08	0.19	0.19
Klorofil a	mgL	-	0.317	0.509	0.331	0.435	0.535	0.487	0.289	0.312	0.462
Klorofil b	mg/L	-	0.039	0.113	0.057	0.096	0.140	0.106	0.069	0.069	0.108

Note: Meets the quality standards set by Kepmen No. 75 of 2016 and Government Regulation No. 20 of 2021.

Based on the explanation above, this research activity is necessary to determine the content of chlorophyll a and heavy metal iron (Fe). The value of chlorophyll a at all points (T4 T12) is classified as high and there are differences. The lowest chlorophyll value is at point T10 with a value of 0.289 mg/L, as well as the lowest heavy metal Fe content in the plant, which is 0.08 mg/L, while the available heavy metal Fe in water is very high at 0.44 mg/L. This is influenced by several factors, including the depth of the water, which averages 0.91 m. This causes the intensity of sunlight entering to be low, leading to differences in the absorption of heavy metal Fe and also the photosynthesis process of seaweed. The photosynthesis process is a metabolic process that stimulates seaweed to absorb more nutrients, and the difference in sunlight intensity causes differences in absorption chlorophyll a content where the increasing depth in the water, the intensity of light that enters will decrease and the process of photosynthesis will experience a decline.

Plants need iron which plays a role in the enzyme system and electron transfer in the photosynthesis process. According to Jovita (2018), Fe in plants is about 80% found in chloroplasts or cytoplasm. The process of mineral and water absorption in seaweed is carried out through all parts of its body. Fatma *et al*. (2013) state that iron (Fe) is absorbed in the form of ferric ions ($Fe3+$) or ferrous ($Fe2+$). Fe can be absorbed in the form of chelates (metal bonds with organic materials) stating that iron (Fe) is one of the essential nutrients for plants. The function of Fe is to play a role in the formation of chlorophyll. Therefore, optimal availability of Fe is needed by plants. If Fe in the nutrient solution is insufficient, then the formation of chlorophyll will not be perfect (Fatma *et al*., 2013).

Seaweed undergoes growth processes through respiration and photosynthesis as well as from the quality of water and nutrients contained within it (Cokrowati *et al*., 2019). In the growth of seaweed in cultivation activities, it is not only influenced by techniques and water quality but also photosynthetic pigments are related such as chlorophyll a. If the chlorophyll a content absorbs enough light, then the photosynthesis process runs normally and growth in seaweed will increase. The content of chlorophyll a is very important for defense or competition for life for seaweed in a certain habitat.

The absorption of heavy metal Fe supports the photosynthesis process of seaweed plants which is greatly influenced by light; light is an important source in carrying out the photosynthesis process where in the photosynthesis process seaweed can enhance its ability to obtain nutrients for its growth. Light penetration is one of the limiting factors in growth carried out by seaweed; if the light received is not appropriate, then the energy to carry out photosynthesis will be unbalanced, and conversely, if the light received is continuous, the plants will die (Chen & Lee, 2012).

The entry of light into the seaweed cultivation waters is also influenced by the depth of the water. According to research by Akmal *et al*. (2012), at a depth of 20 cm, there is damage to chlorophyll a caused by excessive light intensity and the influence of ultraviolet radiation due to excessively high light. High light intensity will reduce the activity of nitrate reductase, which will inhibit the reactions of photosynthesis and respiration (Peni & Solichatun, 2003). Meanwhile, at a depth of 51 cm, the average content of chlorophyll a is classified as low. It is suspected that at this depth, the seaweed becomes dense, so when the seaweed grows larger, it covers each other's thallus and obstructs the intensity of light entering the cell walls of the seaweed, thus reducing the chlorophyll a content. Seaweed living in deeper layers will receive little light with an effective wavelength absorbed by chlorophyll that drives the process of photosynthesis.

CONCLUSIONS

The conclusions obtained from the research "The Effect of Heavy Metal Content of Iron (Fe) on the Porong River Flow in Seaweed Plants" include:

1. The level of heavy metal content of iron (Fe) in the seaweed cultivation area of Kedungpandan Village, especially in the pond water, ranges from the lowest to the highest value of 0.10 to 0.44 mg/l, while the heavy metal iron (Fe) in seaweed plants is 1.8 to 5.1 mg/l.
2. The T-test results for the heavy metal iron (Fe) parameter show a difference in concentration between the ponds located south of the Porong River and those located north of the Porong River.
3. Based on the studies conducted, the chlorophyll content in each seaweed plant from points (T4 to T12) shows differences due to the seaweed's absorption of iron (Fe) being less than optimal. This is influenced by several factors, namely water depth, brightness, sunlight, and salinity.

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Heavy metals are a matter that must be considered, especially the heavy metal iron (Fe) content levels, living beings (humans, animals, and plants greatly need heavy metal iron (Fe) for metabolism and also as a supporter of chlorophyll formation in plants, but if consumed by humans in large amounts, it can have adverse effects on health, even death. It is hoped that further research can significantly ensure that seaweed plants grow well in cultivation areas that have high heavy metal iron (Fe) content and can ensure that the ponds of Kedungpandan Village, Jabon District, Sidoarjo Regency meet the growth requirements for seaweed plants.

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