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Article

Pollution Index Analysis of Seawater in Nickel Smelter Bantaeng's Port

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Abstract

Good water quality conditions are significant for supporting the life of organisms and providing security for community activities. Water quality status determination is needed to monitor water quality pollution. Seawater quality is a critical aspect of environmental science and ecological research due to its profound impact on marine ecosystems, human health, and various community activities. It has been a significant concern because of its direct influence on marine ecosystems, human activities, and public health. This study aims to determine the pollution index referred to as physical-chemical-dissolved metal parameters in the nickel smelter port in Bantaeng Regency. A sampling of water quality was carried out at three sampling points. Then the results were compared with seawater quality standards for marine biota referred to the Keputusan Menteri Lingkungan Hidup No. 51/2004 on Seawater Quality Standards. Observation and analysis of water conditions are conducted in situ and ex-situ, with testing carried out at Ak-Manufaktur Laboratory and BBIHP Laboratory. The results of the pollution index calculation show that the waters around the nickel smelter port are in the moderately polluted category. The pollution index values were obtained in the moderately dirty variety at points 1: 8.515, 2: 9.652, and 3: 9.792. Environmental parameters still following quality standards for marine biota include temperature, pH, salinity, DO, and nickel (Ni).
Keywords: pollution index; physical; chemical; metals; smelter.

Abstrak

Kondisi kualitas air suatu perairan yang baik sangat penting untuk mendukung kehidupan organisme dan memastikan keamanan aktivitas masyarakat. Penentuan status mutu air diperlukan sebagai acuan dalam melakukan pemantauan pencemaran kualitas air. Kualitas air laut merupakan aspek penting dalam ilmu lingkungan dan penelitian ekologi karena dampaknya yang besar terhadap ekosistem laut, kesehatan manusia, dan berbagai aktivitas masyarakat. Hal ini menjadi perhatian besar karena dampak langsungnya terhadap ekosistem laut, aktivitas manusia, dan kesehatan masyarakat. Penelitian ini bertujuan untuk menentukan indeks pencemaran berdasarkan parameter fisika-kimia dan logam terlarut di perairan pelabuhan smelter nikel di Kabupaten Bantaeng. Pengambilan sampel kualitas air dilakukan pada tiga titik pengambilan sampel, kemudian hasilnya dibandingkan dengan baku mutu biota laut berdasarkan Keputusan Menteri Lingkungan Hidup No. 51/2004 tentang baku mutu air laut. Pengamatan dan analisis kondisi perairan dilakukan secara in situ dan ex situ, dengan pengujian dilakukan di Laboratorium Ak-Manufaktur dan Laboratorium BBIHP. Hasil perhitungan indeks pencemaran menunjukkan bahwa perairan di sekitar pelabuhan smelter nikel termasuk dalam kategori tercemar sedang. Nilai indeks pencemaran diperoleh pada

variasi agak kotor pada titik1:8.515, 2:9.652, dan 3:9.792. Parameter lingkungan yang masih sesuai baku mutu biota laut antara lain suhu, pH, salinitas, DO, dan nikel (Ni).
Kata Kunci: indeks pencemaran; fisika; kimia; logam; smelter.

1. Introduction

Indonesia is the largest archipelagic country in the world, with prosperous coastal resources, and is in the equatorial region with a tropical climate (1). Indonesia's tropical marine environment, vast and rich in biological and mineral resources, is a natural condition with a comparative advantage as a lifeline and future for the welfare of the Indonesian people (2). However, the coastal ecosystem with a tropical climate is sensitive to pollution, while some Indonesian people live in coastal areas and depend on coastal ecosystems for their lives.

Water is needed in large quantities to support the activities of organisms, ranging from the consumption needs of living things to industry. Several indicators of water pollution can be observed by looking at changes in the water from normal conditions. Including changes in water temperature, changes in the level of acidity, base, and salt (salinity) of water, changes in colour, smell, and taste, sediment formation, colloids from dissolved materials, and there are microorganisms (3)

The global study has revealed a result of port challenges. Port and city authorities share the view that air, noise, and water pollution, as well as waste, are serious issues that need to be addressed. A water pollution has been identified as the most serious issue in the view of port authorities globally. This environmental awareness is not limited to certain countries or regions but is present across this global sample (4). The use of existing resources on the coast and sea often needs to pay more attention to the principles of sustainable development so that it will significantly affect the ecosystem. The sea, which contains various resources, is under much pressure due to human activities at sea and on land. Marine pollution, which is a form of pressure on the marine environment and the resources in it, can cause harm to these natural systems (5).

Smelter is located on the coast of the Bantaeng-Bulukumba road. The main gate is directly facing the harbour. A smelter is part of the process of producing minerals mined from nature. Its activity is in the form of extracting pure metal ore, in this case, Nickel. The smelting company built a port to enter and exit raw materials and extracted metals. It is feared that this activity will cause pollution of the coastal area, affecting fishermen and seaweed farmers in Bantaeng. So, research is needed to reveal the condition of the seawater by calculating the pollution index.

2. Materials and Methods

2.1 Materials and Tools

The materials used in the study included seawater samples, filter paper, HNO_3 (nitrite acid), $MnSO_4$ (manganese (II) sulphate), alkaline iodide azide solution, H_2SO_4 (sulfuric acid) p.a, $Na_2S_2O_7$ (sodium thiosulfate), starch indicator, distilled water, microbial seed suspension, $MgSO_4$ (magnesium sulphate), $CaCl_2$ (calcium chloride), $FeCl_3$ (iron (III) chloride), phosphate buffer solution, $AgSO_4$ (silver sulphate), $HgSO_4$ (mercury sulphate), ferrous ammonium sulphate (FAS). The tools used in this study include a pH meter, refractometer, DO meter, thermometer, disk buckets, glassware, Atomic Absorption Spectroscopy (AAS), oven, hotplate, and porcelain cup.

2.2 Methods

The research procedure was carried out in two stages: sampling and analysis data. This section include description about how to measure each parameter to determine the pollution index.

2.2.1 Sampling and Determination of Sample Points

Seawater samples were taken with a 500 ml polyethylene sample bottle from 0-30 cm depth (6). Based on several considerations of the coastal topography in Bantaeng, samples were taken at a depth of >100 cm. This depth is considered sufficient to represent the vertical homogeneity of pollutant dispersions, avoid surface effects, and avoid the strings of seaweed cultivation land. Determination of sampling points using the method of purposive sampling. The method of purposive sampling is one of the sampling techniques with certain conditions according to research needs. Three sampling points were chosen for this method as visualized in Figure 1.

Figure 1. Sampling Point (1) west; S 5˚35'10.4064" E 120˚03'44.7228" (2) south; S 5˚35'18.168" E 120˚03'46.1088" (3) east; S 5˚35'14.5932" E 120˚03'53.8776"

Some samples were observed in situ and ex situ, with testing carried out at Ak-Manufaktur Laboratory and BBIHP Laboratory. The types of physical, chemical, and metal parameters dissolved in seawater tested in this study, as well as the measurement methods and analytical standards used, are presented in Table 1.

Table 1. Seawater Analysis Parameters and Methods

Parameter	Analysis type	Analytical method
Physical parameters		
Temperature	In situ	thermometer
Brightness	In situ	secchi disk
TSS	AK-Man Bantaeng's Lab.	SNI 6989.3:2019
Chemical parameters		
pH	In situ	pH meter
Salinity	In situ	refractometer
DO	In situ	DO meter
BOD	AK-Man Bantaeng's Lab.	SNI 6989.72:2009
Dissolved trace metal		
Cadmium	BBIHP Makassar's Lab.	SNI 6989.16:2009
Copper	BBIHP Makassar's Lab.	SNI 6989.6:2009
Nickel	BBIHP Makassar's Lab.	SNI 6989.18:2009

To avoid chemical and biological changes that have the potential to change the natural homogeneity of the samples, the sample for heavy metals analysis was preserved by adding 1ml of concentration HNO_3. The samples were immediately transferred to icebox and transported to the laboratory for analysis. In-situ parameters such as temperature, brightness, pH, salinity, and dissolved oxygens were measured using thermometer, secchi disk, pH meter, refractometer and DO meter.

The sample is added to a saturated oxygen-diluted solution supplemented with a nutrient solution and microbial inoculum and then incubated in a dark room at 20°C for five days. BOD is calculated based on the difference in dissolved oxygen concentration between day 0 and day 5. All the parameters were measured according to the standard method for the examination of water by SNI. An Atomic Absorption Spectrophotometer (AAS) was used for metals analyses after samples were digested.

2.2.2 Data Analysis

Analysis of results from data in-situ and the results of laboratory analysis of water quality parameters was carried out descriptively, namely by comparing the results obtained with seawater quality standards for marine biota referred to the Keputusan Menteri Lingkungan Hidup No. 51/2004 on Seawater Quality Standards and regulation of the Republic of Indonesia No. 22/2021 on Implementation of Environmental Protection and Management (Annex VIII).

Determination of pollution status is determined using the pollution index referring to Sumitomo and Nemerow formulas in the Keputusan Menteri Lingkungan Hidup No. 115/2003 as shown as equation 1(7):

$$PI_j = \sqrt{\frac{\left(C_i/L_{ij}\right)_M^2 + \left(C_i/Li_j\right)_R^2}{2}} \qquad \text{(Eq. 1)}$$

Information:

L_i : Concentration of water quality parameters in the quality standard (j)
C_i : Concentration of water quality parameters because of the survey
PI_j : Pollution index for designation (j)
$\left(C_i/L_{ij}\right)_M$: Ci/Lij Maximum
$\left(C_i/Li_j\right)_R$: Ci/Lij Average

Furthermore, the relationship between the level of pollution and the criteria for the pollution index (IP) referred to the Keputusan Menteri Lingkungan Hidup No. 115/2003 on Water Quality Status determination is as follows:

$0 \leq PI_j \leq 1{,}0$: meet the quality standard (good)

$1,0 < PI_j \leq 5,0$: slightly polluted

$5,0 < PI_j \leq 10$: moderately polluted

$PI_j > 10$: heavily polluted

3. Results

The quality of seawater used for marine biota and other living creatures' activities should meet the standards set by the government. If the quality of sea waters exceeds the maximum threshold for its designation, it will include polluted water areas. The results of measurements of the water quality of the nickel smelter port in Bantaeng Regency from several physical, chemical, and dissolved trace metal parameters are shown in Table 2 following:

Table 2. Seawater Analysis Results of Nickel Smelter Bantaeng's Port

Parameter	Quality Std.[1)]	Unit	Analysis Results		
			Point 1	Point 2	Point 3
Temperature	28-30	℃	28	28	28
Brightness	>3	m	1.7	1.5	1.4
TSS	20	mg/L	3.325	3.120	3.460
pH	7-8,5	-	7.6	7.8	7.9
Salinity	33-34	‰	33	33.43	33
DO	>5	mg/L	5.43	5,36	5.36
BOD	20	mg/L	402	1.43	1220
Cadmium	0.001	mg/L	0.034	0.055	0.034
Copper	0.008	mg/L	<0.001	0.010	0.009
Nickel	0.05	mg/L	<0.03	<0.03	<0.03

Source:[1)] Keputusan Menteri Lingkungan Hidup No. 51/2004 on Sea Water Quality Standards

4. Discussion

4.1. Water Temperature

Water's temperature, salinity, turbidity, and brightness distribution influence various aspects of other parameters, such as chemical reactions and biological processes (8). The increase in temperature can cause stratification or coating of water. This stratification of water can affect the agitation of water and is needed to spread oxygen so that coating the water in the base layer does not become anaerobic. Changes in surface temperature can affect physical, chemical, and biological processes in these waters (9).

In the results of sea surface temperature measurements in situ, it was found that the temperature of the waters around the harbour at the three sampling points was 28^0C. Referred to seawater quality standards for marine biota in the Keputusan Menteri Lingkungan Hidup

No. 51, the temperature of the Bantaeng sea near the nickel smelter port is still within normal limits following the needs for the metabolism of marine biota and coastal marine ecosystems.

4.2. Brightness

Brightness is the level of water transparency that can be observed visually using *a Secchi disk*. By knowing the brightness of the water, we can discover the possibility of assimilation processes occurring in the water, which layers are not cloudy, and which are the cloudiest. Waters with a low brightness value at regular weather times can indicate the number of suspended particles in these waters (8).

Based on observations, the brightness level of the sea waters near the nickel smelter could be in better condition because the three sampling locations show a brightness level ranging from 1.4-1.7 meters. Referring to the Keputusan Menteri Lingkungan Hidup No. 51, the brightness level falls significantly below the acceptable quality standard, specifically below 3 meters. The low brightness of the water is because the sampling point is close to port activities which carry a lot of sediment, dissolved particles, and organic and inorganic materials in seawater, so the water is cloudy. Water turbidity can inhibit penetration of light that enters the waters resulting in a low water brightness value. The brightness level of seawater dramatically determines the level of photosynthesis of biota in seawaters.

4.3. Total Suspended Solid (TSS)

Total Suspended Solid (TSS) is a pollution parameter affecting coral reef ecosystems, sea grasses, and oxygen availability (10). TSS is a solid material, including organic and inorganic materials suspended in water areas. High concentrations of total suspended solids can reduce the photosynthetic activity of marine plants, both micro and macro, so the oxygen released by plants decreases and causes fish to die (11).

Based on observations in the waters near the nickel smelter, it was found that *the total suspended solid* is far above the permissible seawater quality standard, which is a maximum of 20 mg/L. The three sampling points vary, showing values from 3,120 to 3,460 mg/L. This high TSS value can be caused by soil erosion carried into water bodies (12). Referring to the Keputusan Menteri Lingkungan Hidup No. 51, seawater quality standards at the research site have entered an abnormal condition.

4.4. Degree of Acidity (pH)

The degree of acidity or pH is the number of H+ ions present in the water system, commonly known as the level of acidity. Seawater generally has a low pH (tends to be acidic), causing rapid corrosion on the surface of iron and steel. Electrolyte seawater tends to be acidic

and contains salt, which is a suitable medium for carrying out charge transfer, accelerating electrochemical processes that can cause corrosion (13). The results of pH measurements in the waters around the nickel smelter port show that the three points are in the normal pH range referring to seawater quality standards for marine biota in the Keputusan Menteri Lingkungan Hidup No. 51.

4.5. Salinity

Salinity is the saltiness or dissolved salt content in water in grams per Liter of seawater. According to measurement data, the salinity at the port near the nickel smelter is at 33‰. This level is evenly distributed at all three sampling points. There are differences, but they are tiny, meaning that the weather and wind in these locations are almost the same. It can be understood because the area is small. The salinity value is within normal salinity limits following seawater quality standards for marine biota referring to the Keputusan Menteri Lingkungan Hidup No. 51/2004.

4.6. Dissolved Oxygen (DO)

Dissolved oxygen is the amount dissolved in water, expressed in mg/L. The quantity of oxygen in a certain amount of water is vital for aquatic organisms to carry out biochemical activities, namely for respiration (breathing), reproduction, and fertility. A high DO level indicates that the water is suitable for use and good for aquatic biota. However, a low DO level indicates that the water has been polluted and can damage the water's ecosystem (14).

DO measurements at observation stations varied between 5.43-5.36 mg/L. The DO value obtained indicates that the waters are in perfect condition and meet the seawater quality standards in the Keputusan Menteri Lingkungan Hidup No. 51/2004 for marine biota. It said that with DO values >5 mg/L, DO concentrations in harbour waters near the nickel smelter in the Bantaeng district are still considered suitable for marine biota.

4.7. Biological Oxygen Demand (BOD)

Biological Oxygen Demand (BOD) is the quantity of dissolved oxygen needed to completely decompose the organic matter in the water using a measure of the biological and chemical processes in the waters (15). Biological Oxygen Demand (BOD) is a chemical parameter that determines the quality of marine waters. The BOD value is essential to indicate water quality at the Bantaeng nickel smelter port.

The results of BOD at observation station points showed that points 1 and 3 had BOD content far above the quality standard, namely 402 and 1220 mg/L, respectively. It indicates that the location has been polluted. If the BOD value exceeds the water quality standard, it can

be suspected that organic substances have been contaminated in the water (15,16). At point 2, which is at the ship's entry point at the port, the BOD value is only 1.43 mg/L. This value indicates that the condition of the waters at point 2 is perfect for marine life, referring to the Keputusan Menteri Lingkungan Hidup No. 51 for marine life with a maximum BOD value of 20 mg/L.

4.8. Dissolved Trace Metal Concentrations

Heavy metals have toxic and are essentially dissolved in water, contaminating fresh water and seawater. Many sources of heavy metal pollution come from the mining industry, metal refining, and other industry types. They can also come from agricultural activities using heavy metal fertilizers (17).

The analysis employed AAS to examine three metals, with nickel having the least concentrated presence in the water, compared to copper (Cu) and cadmium (Cd). Cd is the metal with the highest concentration exceeding the threshold. Referring to the Keputusan Menteri Lingkungan Hidup No. 51/2004 for marine biota, the allowable Cadmium level is only 0.001 mg/L. However, it has reached 0.034-0.055 mg/L. Likewise with copper, even though point 1 is still safe at points 2 and 3, it has exceeded the maximum allowable copper limit in the aquatic environment.

The presence of copper and cadmium metals in the waters near the nickel smelter aligns with previous research findings, reinforcing the established pattern of heavy metal pollution along the coastline from nickel ore mining activities (18). They found that data-heavy metals Cd (Cadmium), Cu (Copper), Cr^{6+} (Crom valence 6), and Ni (Nickel) have a very high level of contamination that can cause pollution in their study area. However, in Bantaeng, we find that the existence of nickel follows the standard.

Cadmium metal found in water can originate from ship paint, which is applied to deter corrosion and prevent the adhesion of organisms to the ship's hull (19). The elevated concentrations of the heavy metal Cd and the significant presence of heavy metal Cu in sediments due to industrial activities (20) may be attributed to a range of human activities, including industrial, agricultural, fishing, and domestic practices.

The assessment of water quality status in the harbour waters near the nickel smelters in the Bantaeng district is conducted using the pollution index method based on the Sumitomo and Nemerow formulas. A water body is considered polluted if it aligns with the criteria outlined in Keputusan Menteri Lingkungan Hidup No. 115/2003 on The Water Quality Status

Determination. The outcomes of the pollution index (IP) analysis for each sampling point in this study are illustrated in Figure 2.

Based on the pollution index (IP) calculations shown in Figure 2, all monitoring points exhibit moderate pollution levels. However, there are slight variations in the IP values among points 1, 2, and 3, precisely 8.515, 9.652, and 9.792, respectively. These discrepancies can be attributed to differing human and industrial activities at these three locations.

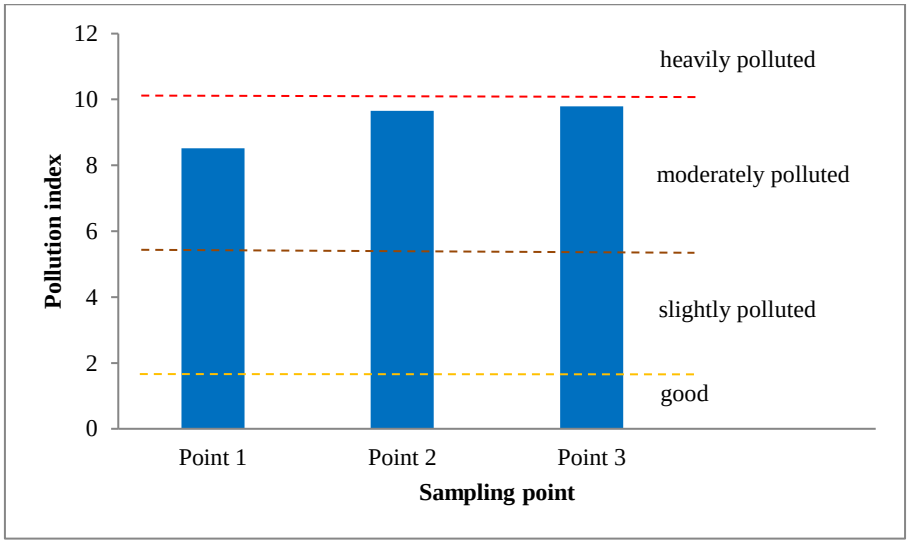

Figure 2. Graph of Pollution Index in Nickel Smelter Bantaeng's Port

The concentrations of all parameters, except for temperature, pH, salinity, dissolved oxygen (DO), and nickel (Ni), are found to be below the permissible limits set for water standards. However, concerning the quality standards for marine biota outlined in Keputusan Menteri Lingkungan Hidup No. 51, several parameters have exceeded these standards. These parameters include brightness, TSS, BOD, and heavy metals cadmium (Cd) and copper (Cu). These findings strongly suggest that the operations of the nickel smelter have had a detrimental impact on the environment. Without well-engineered intervention, this impact is likely to intensify in the future. This situation mirrors similar conditions observed in the nickel smelter in Morowali, where mineral exploration has led to adverse environmental and socio-economic consequences, notably affecting the lives of those close to the mines (21).

As time progresses, without effective pollution control measures, there is a growing risk of moderate pollution escalating into severe environmental contamination, resulting in increasingly complex and challenging-to-remediate consequences. Hence, it is imperative to

implement proactive measures for pollution prevention and management to avert the exacerbation of environmental degradation.

5. Conclusions

The water conditions near the nickel smelter in the Bantaeng district, as assessed through the Pollution Index (PI) calculation, are categorized as moderately polluted. Environmental parameters that continue to meet the quality standards for marine life encompass temperature, pH, salinity, dissolved oxygen (DO), and nickel (Ni) levels. The escalation in parameters exceeding the quality standards' upper limits may arise from industrial waste or natural sources, mainly cargo ships transporting nickel ore within the port vicinity. Collaborative efforts are imperative to ensure the safety of these water areas for residents engaging in activities such as seaweed cultivation and fishing.

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