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ANALYSIS OF LEAD (Pb) AND COPPER (Cu) CONTENT IN *Gracilaria* sp. SEAWEED FROM THE COASTAL WATERS OF SUMBERKIMA VILLAGE

Analisis Kandungan Timbal (Pb) dan Tembaga (Cu) Pada Rumput Laut *Gracilaria* sp. di Pesisir Desa Sumberkima

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ABSTRACT

The coastal waters of Sumberkima Village hold considerable potential for cultivating Gracilaria sp. seaweed. However, growing human activities along the coastline may introduce heavy metal pollutants that could affect water quality and the safety of cultivated seaweed. This study aimed to measure lead (Pb) and copper (Cu) concentrations in both seawater and Gracilaria sp. samples, as well as to evaluate water quality conditions along the coast of Sumberkima Village, Gerokgak District, Buleleng Regency. A descriptive quantitative approach was applied, with samples collected through purposive sampling at three observation stations. Heavy metal analysis was carried out using Atomic Absorption Spectrophotometry (AAS), while water quality measurements included temperature, salinity, pH, dissolved oxygen, and turbidity. Results showed that neither lead nor copper could be detected in any of the seawater samples examined. In contrast, lead was found accumulated in Gracilaria sp. tissues, whereas copper remained undetected. Water quality measurements recorded temperature at 25.3–25.5°C, salinity 33.161–33.730‰, pH 8.12–8.19, dissolved oxygen 6.098–6.250 mg/L, and turbidity 126.614–298.198 mg SiO_2/L. Overall, salinity, pH, and dissolved oxygen levels remained within ranges suitable for seaweed growth, although turbidity appeared relatively high. It can be concluded that coastal water quality at Sumberkima Village is generally in good condition. Nevertheless, the presence of lead in seaweed tissues indicates the need for regular environmental monitoring to support sustainable cultivation practices and ensure the safety of harvested products.

Keywords: *Gracilaria* sp.; water quality; heavy metals; lead; Sumberkima coastal waters

ABSTRAK

Wilayah pesisir Desa Sumberkima memiliki potensi yang cukup besar untuk pembudidayaan rumput laut jenis *Gracilaria* sp. Namun seiring bertambahnya aktivitas masyarakat di kawasan pantai, risiko masuknya zat pencemar berupa logam berat juga ikut meningkat, yang dapat berdampak langsung terhadap kualitas air serta keamanan hasil panen rumput laut. Penelitian ini bertujuan untuk mengukur kadar logam berat timbal dan tembaga yang terdapat pada air laut maupun pada jaringan rumput laut, sekaligus menilai keadaan kualitas air di sepanjang pantai Desa Sumberkima, Kecamatan Gerokgak, Kabupaten Buleleng. Penelitian dilakukan dengan pendekatan deskriptif kuantitatif, di mana penentuan titik pengambilan sampel dilakukan secara sengaja pada tiga lokasi pengamatan. Pengujian kadar logam berat dilakukan menggunakan alat Atomic Absorption Spectrophotometer (AAS), sedangkan hal-hal yang diperiksa meliputi suhu, kadar garam, tingkat keasaman, kadar oksigen terlarut, serta tingkat kekeruhan air. Hasil penelitian menunjukkan bahwa kedua jenis logam berat tersebut tidak terukur keberadaannya pada seluruh sampel air laut yang diperiksa. Sebaliknya, pada sampel rumput laut timbal terdeteksi keberadaannya, sedangkan tembaga tidak ditemukan. Hasil pengukuran kualitas air menunjukkan suhu berkisar 25,3–25,5°C, kadar garam 33,161–33,730‰, tingkat keasaman 8,12–8,19, kadar oksigen 6,098–6,250 mg/L, serta kekeruhan 126,614–298,198 mg SiO_2/L. Secara umum, kadar garam, tingkat keasaman, dan kadar oksigen masih berada dalam rentang yang mendukung pertumbuhan rumput laut, meskipun tingkat kekeruhan terlihat cukup tinggi. Dapat disimpulkan bahwa kualitas perairan di Desa Sumberkima masih tergolong baik, namun ditemukannya kandungan timbal di dalam jaringan rumput laut mengingatkan kita akan perlunya pemeriksaan kualitas lingkungan secara berkala guna menjamin keberlanjutan usaha pembudidayaan serta keamanan hasil panen yang dihasilkan.

Kata Kunci: *Gracilaria* sp.; kualitas air; logam berat; timbal; pesisir Desa Sumberkima

INTRODUCTION

Indonesia is the world's largest archipelagic nation, with waters covering approximately 70% of its territory and harboring abundant marine biological resources (Arbi Tarmizi, 2022). This makes the marine and fisheries sector a strategic pillar of the national economy (Yudiati et al., 2020). Seaweed farming is a rapidly growing subsector due to its high economic value, steadily rising market demand, and vital role as a raw material for the food, pharmaceutical, cosmetic, and biotechnology industries. Consequently, the sustainable development of seaweed farming is a crucial step toward boosting aquaculture productivity in Indonesia.

One widely cultivated seaweed species is *Gracilaria* sp. (red algae), a primary source of agar that also contains nutrients beneficial to health. Beyond its economic value, this seaweed plays a significant ecological role; it thrives in diverse environmental conditions and is known to absorb dissolved substances—including heavy metals—from surrounding waters. This capability gives *Gracilaria* sp. potential utility as an indicator of pollution or as an agent for remediating aquatic environmental quality.

Cultivation success relies heavily on water quality parameters such as temperature, salinity, acidity (pH), dissolved oxygen, and turbidity. Fluctuations in these values can disrupt growth processes and reduce yields. Furthermore, the presence of heavy metals like lead (Pb) and copper (Cu)—introduced through human activity in coastal areas—warrants serious attention; these substances are persistent, prone to bioaccumulation in living organisms, and can pose health risks to both marine life and human consumers.

Sumberkima Village, located in Gerokgak District, Buleleng Regency, Bali, is one coastal area currently developing *Gracilaria* sp. cultivation (Village Profile, 2023). The relatively calm and clear waters are highly conducive to such activities; however, the site's proximity to areas of human activity creates a potential risk of introducing pollutants into the aquatic environment (Prasetia et al., 2024). Unfortunately, data regarding heavy metal concentrations and water quality conditions at this location remain very limited. Therefore, this study was conducted to analyze lead and copper levels in both seawater and seaweed, as well as to evaluate water quality conditions, in order to support the sustainability of aquaculture operations in Sumberkima Village.

RESEARCH METHODS

This study employs a descriptive quantitative approach aimed at characterizing the levels of the heavy metals lead and copper in seawater and *Gracilaria* sp. seaweed, while also assessing water quality in the coastal seaweed farming area of Sumberkima Village, Gerokgak District, Buleleng Regency, Bali. The research spanned five months—from late September 2026 to late November 2026—encompassing preparation, field sampling, laboratory analysis, data processing, and report compilation. Sample testing was conducted at the Analytical Laboratory of the Integrated Laboratory Unit (UPT) and the Laboratory of the Faculty of Agricultural Technology at Udayana University.

Sampling sites were selected purposively based on environmental characteristics deemed representative of the local waters. Three observation points were established, taking into account the level of surrounding human activity. The first point was located in the harbor area, influenced by boat traffic and marine tourism activities, and was thus assumed to carry a higher risk of pollution. The second point was situated within the seaweed farming area and served as the primary research site. The third point was located in waters relatively distant from human settlements, serving as a reference point to provide a picture of more natural conditions.

Seawater samples were collected from all three locations using cleaned glass bottles, whereas seaweed samples were collected only from the second point. Seaweed specimens were selected based on their healthy appearance and relatively uniform size to ensure they represented the general conditions of the farming site. All samples were labeled according to their location and stored in refrigerated containers with ice to preserve their physical and chemical properties during transport to the laboratory. Sampling was conducted at a single time—09:00 WITA—to ensure relatively uniform environmental conditions during the process.

The parameters tested included lead and copper concentrations in both seawater and seaweed, alongside measurements of water quality indicators: temperature, salinity, pH, dissolved oxygen (DO), and turbidity. Water quality measurements and heavy metal analyses were performed once. Water quality parameter testing is conducted in the laboratory using electrometric, titrimetric, spectrophotometric, spectrometric, and thermometric methods tailored to the specific parameter being analyzed, while heavy metal concentration testing is performed using an Atomic Absorption Spectrophotometer (AAS) due to its high sensitivity and precision in detecting heavy metals in both water and biological tissues. Test results are expressed in units of weight per volume and subsequently converted into commonly used units to facilitate interpretation.

RESULT

Heavy Metal Content of Lead (Pb) and Copper (Cu) in Seawater

Heavy metal analysis of seawater samples was conducted to determine the presence of lead (Pb) and copper (Cu) at three observation sites in the coastal waters of Sumberkima Village. The analysis utilized the Atomic Absorption Spectrophotometry (AAS) method on water samples collected from each research point. Laboratory results indicated that neither lead nor copper was detected in any of the examined water samples; results from Stations I, II, and

III all showed "Not Detected" levels. The results of the heavy metal analysis in seawater are presented in Table 1.

Table 1. Results of Heavy Metal Analysis in Seawater

Heavy metal	Station I	Station II	Station III	Quality standards
Lead (Pb)	TTD	TTD	TTD	0,008 mg/L
Copper (Cu)	TTD	TTD	TTD	0,05 mg/L

Note: TTD = Not Detected.

Based on Table 1, all observation points yielded similar results: neither of the two heavy metals was detectable in the seawater samples. There were no differences in metal concentrations across locations, as all test results fell below the detection limit of the instrument used. Consequently, none of the water samples analyzed during the study showed measurable levels of lead or copper.

Water Quality Parameters

In addition to heavy metal analysis, water quality parameters were measured to provide a comprehensive overview of the aquatic conditions at the study site. The parameters measured included temperature, salinity, acidity (pH), dissolved oxygen, and turbidity. Measurements were conducted on water samples from all three stations via laboratory analysis. The results indicated that water temperatures ranged from 25.3°C to 25.5°C. The highest temperature was recorded at Station I (25.5°C), while the lowest was at Station III (25.3°C); the temperature difference between the observation points was minimal, at approximately 0.2°C.

Salinity levels ranged from 33.161‰ to 33.730‰. The highest salinity was recorded at Station II (33.730‰), and the lowest at Station I (33.161‰), with the values across the three points remaining relatively uniform. Acidity levels ranged from 8.12 to 8.19. The highest pH value was recorded at Station II (8.19) and the lowest at Station I (8.12); the differences in pH values between the points were negligible, indicating relatively similar conditions.

Dissolved oxygen levels ranged from 6.098 mg/L to 6.250 mg/L. The highest value was recorded at Station III (6.250 mg/L), while Stations I and II showed identical values of 6.098 mg/L. Turbidity exhibited the greatest variation among the measured parameters. Turbidity values were recorded as 126.614 mg SiO_2/L at Station I, 189.403 mg SiO_2/L at Station II, and 298.198 mg SiO_2/L at Station III. The highest value was recorded at Station III, while the lowest was at Station I. All water quality parameter measurement results are presented in Table 2.

Table 2. Water Quality Parameter Measurement Results

Parameter	Station I	Station II	Station III	Quality standards
Temperature (°C)	25,5	25,4	25,3	26–30
Salinity (‰)	33,161	33,730	33,517	28–35
pH	8,12	8,19	8,18	6,5–8,5
DO (mg/L)	6,098	6,098	6,250	≥5
Turbidity (mg SiO_2/L)	126,614	189,403	298,198	<10

In general, the measurement results indicate differences in the values of each water quality parameter across the three observation points. The most significant difference was observed in turbidity, whereas temperature, salinity, acidity levels, and dissolved oxygen showed relatively similar values across the locations.

Content of Heavy Metals Lead (Pb) and Copper (Cu) in Gracilaria sp Seaweed

Tests for lead and copper content were also conducted on *Gracilaria* sp. seaweed samples collected from the cultivation site at Station II. The samples were analyzed in the laboratory using the Atomic Absorption Spectrophotometry (AAS) method to determine the levels of lead and copper absorbed into the plant tissues. The test results revealed the presence of lead (Pb) in the seaweed samples, with a concentration value of 1.037406. Conversely, copper (Cu) was not detected in the samples, or its concentration was below the instrument's detection limit. The complete results of this analysis are presented in Table 3 below.

Table 3. Heavy Metal Content Test Results for *Gracilaria* sp. Seaweed

Heavy metal	Sample	Results	Quality standards
Lead (Pb)	*Gracilaria* sp.	1,037406	0,08
Copper (Cu)	*Gracilaria* sp.	TTD	0,05

Note: TTD = Not Detected

Based on the figures presented in Table 3, it is evident that only the heavy metal lead was detected in the tissues of the seaweed *Gracilaria* sp., whereas copper was not detected at all. These test results serve as the basis for discussing the extent of heavy metal accumulation in the seaweed and its relationship to the environmental conditions of the waters surrounding the study site.

DISCUSSION

Test results indicate that lead and copper levels in all seawater samples collected from three observation sites along the coast of Sumberkima Village fell below the instrument's detection limit; consequently, their presence could not be quantified. This implies that the concentrations of both metals in the water remain very low and have not reached levels that would adversely affect the aquatic environment. This condition is strongly attributed to the scarcity of direct pollution sources near the study sites, meaning dissolved heavy metal concentrations were insufficient for detection by the equipment used.

Although neither metal was detectable in the seawater, analysis of *Gracilaria* sp. seaweed samples revealed the presence of lead. This finding demonstrates the seaweed's ability to absorb and accumulate the substance from its surroundings, even when concentrations in the water are too low to measure. The seaweed's capacity to absorb dissolved substances across its entire body surface makes it a more sensitive indicator than water analysis alone. Thus, the presence of lead in the seaweed tissue suggests prolonged exposure leading to accumulation within the plant, even though levels in the water were undetectable at the time of sampling.

Water quality parameters assessed included temperature, salinity, pH, dissolved oxygen, and turbidity. Measurement results presented in Table 2 show water temperatures ranging from 25.3–25.5°C, salinity from 33.161–33.730‰, pH from 8.12–8.19, and dissolved oxygen from 6.098–6.250 mg/L. These four parameters showed relatively consistent values across sites and remained within ranges conducive to marine life, including seaweed growth. The relatively stable temperature indicates an absence of extreme fluctuations during the study, while salinity levels within the normal range reflect a well-preserved aquatic environment. Similarly, the slightly alkaline pH and dissolved oxygen levels exceeding the minimum threshold indicate that the waters remain capable of supporting the life processes of the organisms inhabiting them.

In contrast to the other parameters, the turbidity values measured at all three observation sites were notably high, ranging from 126.614 to 298.198 mg SiO_2/L. These figures exceed established limits, indicating a high concentration of fine particles suspended in the water. High turbidity can result from water movement stirring up bottom sediments or from human activities in the coastal area. Such conditions may obstruct sunlight penetration, potentially reducing the efficiency of nutrient production by the seaweed. Nevertheless, the seaweed at the study sites appeared capable of growth, suggesting that the high turbidity levels had not yet fully inhibited its development. However, if these conditions persist over an extended period, there is a concern that growth rates could decline.

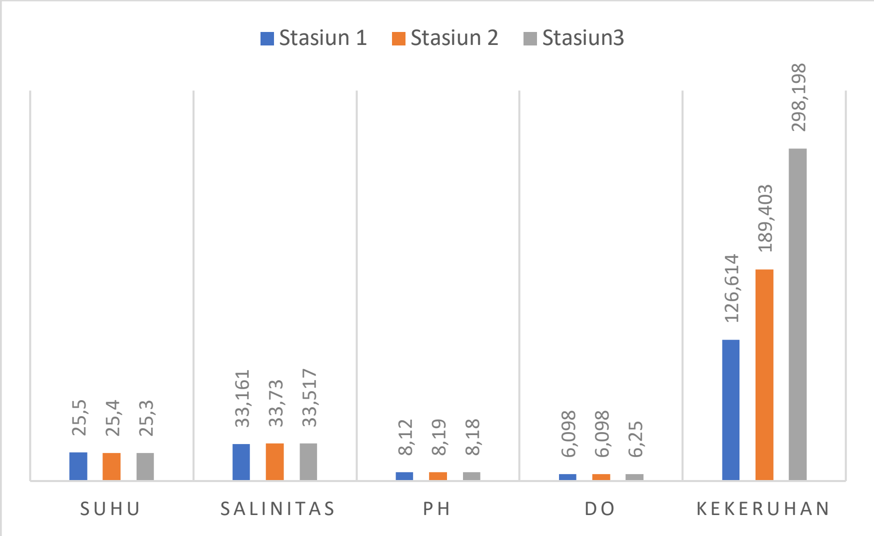

Figure 1. Water Quality Parameter Graph

Figure 1, which presents a graph of water quality conditions, shows that temperature, salinity, pH, and dissolved oxygen levels followed relatively similar patterns across all three observation points. In contrast, turbidity levels showed a significant increase from Station I to Station III. This indicates that variations in water conditions across the three study sites were driven more by changes in turbidity than by other physical or chemical parameters. This condition warrants attention, as high levels of suspended fine particles can impede sunlight penetration and reduce water productivity in the seaweed farming area.

In addition to monitoring environmental conditions, this study examined the challenges faced by farmers at the research sites. Observations revealed that conventional seaweed farming methods were underperforming due to pest infestations and unfavorable weather conditions. Pests rapidly consumed the seaweed seedlings, while heavy rainfall reduced the amount of sunlight penetrating the water. To address these issues, a cultivation trial was conducted using floating rafts equipped with protective baskets. The baskets served to shield the seaweed seedlings from pests, while positioning them at a depth of approximately 30 cm ensured the seaweed received adequate sunlight.

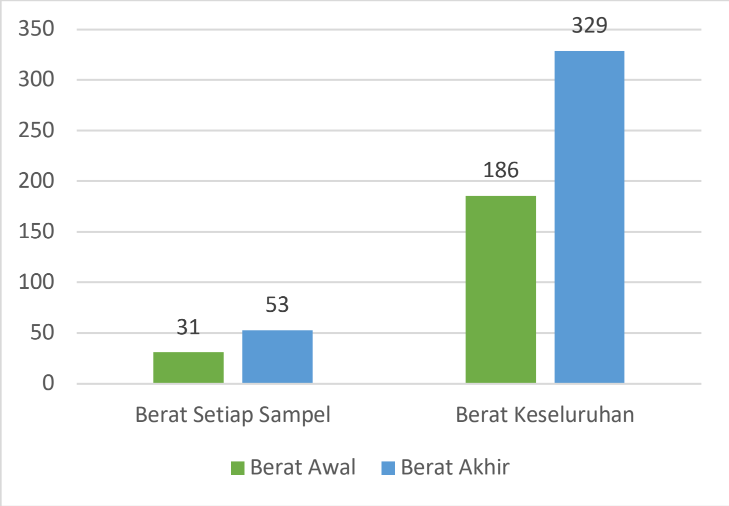

Figure 2. Growth graph of *Gracilaria* sp. over 15 days

Growth monitoring results over a 15-day period, presented in Figure 2, show an increase in seaweed weight across all cultivated samples. The average initial weight of 31 grams rose to 54 grams by day 15, while the total weight increased from 186 grams to 329 grams. The weight gain observed in all samples during the cultivation period demonstrates that the method utilizing floating rafts and protective baskets creates a superior growing environment compared to conventional practices. In addition to providing protection against pests, this method ensures the seaweed receives adequate sunlight, thereby facilitating effective nutrient synthesis. These results indicate that this cultivation technique is suitable for adoption by the coastal community of Sumberkima Village to enhance the success of future seaweed farming operations.

CONCLUSION

Based on the research activities that have been carried out, it can be concluded that:

1. Neither lead nor copper was detected in any of the seawater samples analyzed. This indicates that the water quality during the study remained good and showed no signs of contamination by these two metals. However, lead was detected in the *Gracilaria* sp. seaweed samples at a concentration of 103.7406 mg/L, whereas copper was not found. These findings demonstrate that the seaweed is capable of absorbing and accumulating lead from the aquatic environment even when levels in the water itself are undetectable, suggesting its potential use as an indicator of heavy metal pollution in coastal areas.
2. Measured levels of temperature, salinity, pH, and dissolved oxygen (DO) remain within ranges that comply with quality standards and are highly conducive to seaweed growth. Conversely, turbidity levels were recorded as relatively high, potentially hindering sunlight penetration and reducing the efficiency of nutrient synthesis in the seaweed. Overall, the coastal waters of Sumberkima Village remain suitable for supporting marine life and seaweed farming activities. This is evidenced by the absence of detectable lead or copper in the seawater and the favorable status of other water quality parameters. Although water temperatures were slightly below standard limits and turbidity was relatively high, these conditions have not significantly impeded seaweed growth. Nevertheless, the detection of lead in seaweed tissues highlights the plant's capacity to absorb pollutants from its surrounding environment. Therefore, periodic monitoring of water quality and heavy metal content remains essential to preserve the coastal environment, ensure the sustainability of farming operations, and guarantee the safety of the seaweed harvested in Sumberkima Village.

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