**Analysis of Lead (Pb) Content and Its Effect on Water Quality and Substrate in Mandalle Coastal Waters, Pangkep Regency, Indonesia**

**ABSTRACT**

Coastal regions are naturally prone to environmental contamination, including the presence of lead pollutants. Therefore, this research aimed to determine the condition of Pb content in the Mandallle Coast of Pangkep Regency concerning water (temperature, salinity, dissolved oxygen, and pH) and substrate quality (pH, organic matter, and texture). The method adopted was explanatory analysis, directed towards obtaining comprehensive insights into the presence of Pb metal within the waters, water quality parameters, and substrate characteristics of Mandalle Beach along the coast of Pangkep Regency. The research was performed over a duration of three months, spanning from April to June at the precise locale of Mandalle Beach situated in the Mandalle District of Pangkep Regency, Indonesia. The selection of Mandalle Beach stemmed from allegations of lead pollution plaguing the environment and the frequent community activities transpiring in the area amplify the potential for Pb contamination. The results showed that the content of heavy metals was in the non-hazardous range based on the analysis of Pb using an Atomic Absorption Spectrophotometer because the research locations had a lead content below 1 ppm. The constituents of water quality, including temperature, salinity, pH, and oxygen levels are within ranges conducive to the sustenance of aquatic organisms. The analysis of substrate attributes, including pH, organic composition, and texture, indicates that these parameters remain well-suited for the habitation of various organisms.

**Keywords**: Lead (Pb), Coastal, Beach, Water quality, Substrate

1. **INTRODUCTION**

Coastal regions are essential parts of marine environments susceptible to pollution. The susceptibility stems from the fact that marine areas serve as convergence points for diverse river channels and effluents stemming from human and industrial operations. Therefore, the ocean becomes a receptacle for pollutant agents transported by the currents of water [1]. The origins of pollution agents that infiltrate aquatic ecosystems can be categorized into two distinct classes, namely pollution resulting from natural sources and human or anthropogenic interventions [2]; [3]. Due to heavy metal pollution, which is toxic, the waters experience a decrease in diversity, leading to the extinction of populations of aquatic organisms [4]. This has resulted in changes in water quality, reduced fishery resources, and a loss of biodiversity in recent years [5].

The Mandalle coastal waters of Pangkep Regency are one of the areas suspected of experiencing pollution, starting in the north, which borders Barru Regency. The area has carried out many community activities such as pond cultivation, seaweed cultivation, and various fishing activities by fishermen. Several humans are suspected of having the potential to cause pollution in the form of household waste. Similarly, a range of communal undertakings transpires situated adjacent to the premises of the Politeknik Pertanian Negeri Pangkep. These activities include the cultivation of seaweed, the rearing of fish and shrimp within ponds, fishing endeavors, and the presence of a pier frequently used as a docking site for fishing vessels. However, the expanse has diminished due to the expansion of pond cultivation by the local populace to the southern extent. In the southern region, a minor river also flows, serving as a conduit linking the different ponds and rice fields. The coastal areas of Mandalle Beach are suspected to be polluted, specifically with heavy metals. According to [6], there is a rapid increase in industry, specifically industries that use metal burning and the use of metal as a raw material located around the coast, and increasing urbanization, specifically in coastal areas. This can result in a decrease in the quality of seawater, which can have a negative impact on organisms in the waters and humans using the waters and the biota. Furthermore, [7] stated that the toxicity of heavy metals in the marine environment should be a concern. This was because it potentially posed a risk to several flora and fauna species in marine waters and also had an impact on humans through the food chain.

Pb or black lead is a heavy metal in the crust of the earth and is spread in small quantities through natural and artificial processes [8]. The element is a type of heavy metal that is dangerous for aquatic ecosystems [9]. Lead is a hazardous substance known to induce both acute and chronic poisoning. Heavy metal content is needed by living things in small amounts but possesses toxic properties for living things [10]. Various human activities that occur on land can have an impact on water, such as waste disposed through rivers flowing into the sea [11]. Disposal of waste into the sea can cause pollution of sea waters, and one of the main pollutant substances is toxic heavy metals [12]. Under natural conditions, the metals are needed by organisms to carry out the growth and development of their lives [13]). Conversely, waste containing heavy metals is a very dangerous material, toxic to animals, plants, and humans, and is persistent in the environment [14]. Heavy metals are toxic and have a negative impact on the environment and organisms [15]. The presence of heavy metals is still toxic to humans even in low concentrations [16].

Chronic poisoning occurs due to the absorption of small amounts of lead, which over a long period accumulates in the body [17]. One of the detrimental consequences stemming from the disposal of toxic waste is the deleterious effect imposed on coastal ecosystems, particularly when domestic waste is directly discharged into the water. The persistence of this practice portends a substantial escalation in pollution along the coast, and Mandalle Coastal Beach stands as an example, presenting an elevated likelihood of pollution incidence. In heavy metal contamination, involving Pb, the ramifications extend to the direct or indirect compromise of water quality.

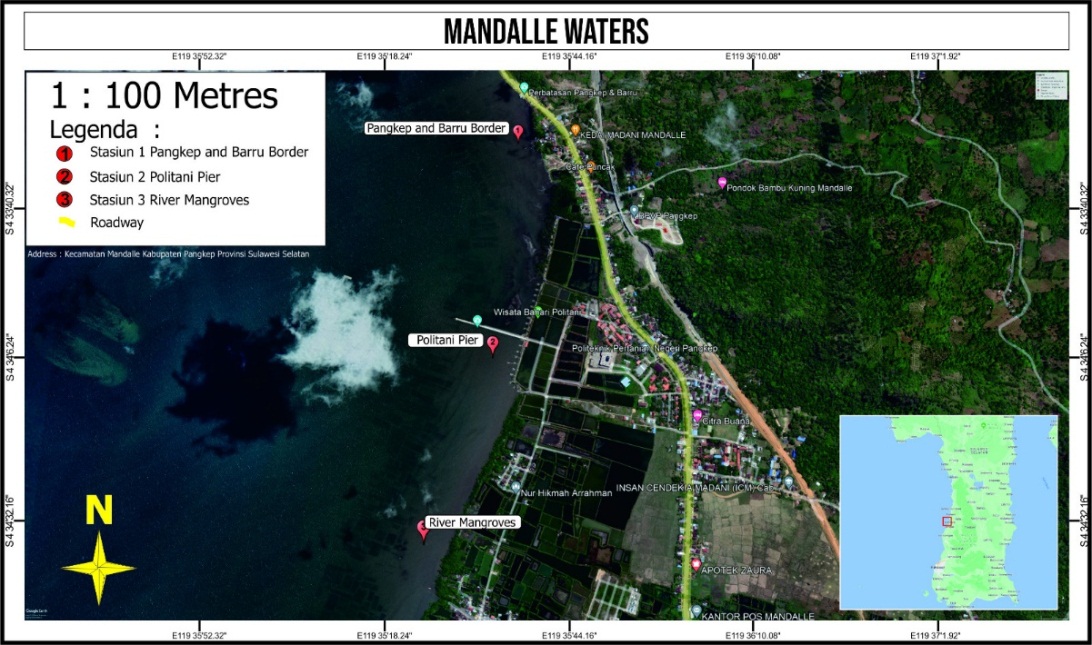
The quality of seawater is influenced by natural factors and interactions with the land environment. Mandalle Beach is an area where Pb pollution can occur due to the many activities, such as a large number of fishing boats, seaweed farming, and fish farming, affecting Pb pollution. A pivotal factor contributing to the deterioration of seawater quality is the improper management and persistent discharge of pollutant waste from terrestrial sources. This continuous influx over an extended period surpasses established quality thresholds, culminating in the onset of marine pollution [18]. Water quality parameters can affect the concentration of heavy metals in the water [19]. There is an increase in fishing activity in the Mandalle Beach area, as fishermen catch fish and cultivate seaweed, and other activities are suspected of causing Pb pollution in these waters. Therefore, a research was carried out on the possibility of heavy metal pollution, specifically types of lead. Since no analysis has been conducted concerning the condition of Pb, this research analyzes the content of heavy metals along the coast of Mandalle Beach, Pangkep Regency, Indonesia.

1. **MATERIALS AND METHODS**

**2.1 Types and Research Locations**

The design was explanatory to obtain clarity on the condition of lead metal Pb in water, water quality, and substrates on the coast of Mandalle Beach, Pangkep Regency. Mandalle Village had a hot climate, specifically with a rainfall of 1553 mm/year and temperatures in the range of 25–34oC, affecting Pb pollution. Sampling areas were taken by analyzing and suspecting that these locations ranged from the spread of Pb metal, such as river estuaries, wharves, fishing activities, pond cultivation, and areas suspected of having a lot of household waste, which can be a source of Pb metal pollution. The database was obtained on the condition of the distribution of Pb metal on the coast of Mandalle Beach to create a management model safe for the environment. This research was carried out for three months, from April to June, at the coast of Mandalle Beach, Mandalle District, Pangkep Regency, and the activities included the preparation of tools, sampling, analysis of samples in the laboratory, and analysis of data. The analysis of heavy metal Pb using the Atomic Absorption Spectrophotometer method was performed at the Laboratory of the Faculty of Marine and Fisheries, Hasanuddin University [20]; [21]; [22].

The determination of locations was based on differences in environmental characteristics at each research location. At Station 1 (Latitude 4°33'34.02"S and Longitude 119°35'37.74"E), it was located on the beach, which borders Barru Regency. In the location, there were characteristics where there are shrimp and fish pond cultivation locations, seaweed cultivation, and places for fishing by fishermen, specifically fishing gear with residential areas. Station 2 (Latitude 4°34'7.13"S and Longitude 119°35'34.28"E), had characteristics, namely being around the Pier of the Politeknik Pertanian Negeri Pangkep, fishermen carrying out seaweed cultivation activities, fishing, there were also Politeknik Pertanian Negeri Pangkep ponds, with a small river connecting residents activities. Meanwhile, Station 3 (Latitude 4°34'33.37"S and Longitude 119°35'25.08"E), was in the vicinity of a mangrove forest, and there was a small river mouth with many fishing boats moored and pond cultivation activities (Fig. 1).



**Fig. 1. Research locations**

**2.2 Materials and Tools**

The materials were samples of seawater and soil substrate and the tools and methods used to measure or retrieve the water quality data are presented in Table (1).

**Table 1. Tools and methods for collecting physical and chemical data**

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Unit** | **Tools and Methods** |
| - Temperature  - Salinity  - pH  - Dissolved oxygen | oC  ppt  -  ppm | Thermometer /*insitu*  Hand refractometer /*insitu*  pH meter/*insitu*  Dissolved oxygen meters /*insitu* |

**2.3 Research Procedure**

Measurement of water quality included physical and chemical parameters. For Pb analysis of seawater, water samples were taken and then analyzed in the laboratory of the Faculty of Marine and Fisheries, Hasanuddin University. The method used referred to [11], where sampling was carried out using a 500 ml sample bottle previously soaked and rinsed with 1:1 nitric acid to remove interfering ions. Sampling was conducted six times at a depth of approximately 1 meter from the water surface. The sample was then filtered with filter paper, put into the sample bottle, and stored in the freezer. In the laboratory, the sample was stored in a cool box and water samples were acid-destructed before being measured with AAS. The detrusion procedure was initiated by inserting 100 ml of water sample into an Erlenmeyer flask, then adding 5 ml of nitric acid and heating until the solution was almost dry. The solution was filtered into a 100-ml measuring flask and diluted with distilled water until sufficient. Subsequently, 20 ml of the test sample was pipetted and put into six volumetric flasks of 25 ml, and the standard addition solution was added. The sample was diluted with distilled water up to the tera mark, and measured with SSA. Water quality measurements were also carried out in the form of temperature, salinity, dissolved oxygen, and pH. The physical parameters measured were water temperature, while the chemical parameters were Salinity, dissolved oxygen (DO), and pH. The measurement of these two parameters was carried out directly at the research location (in situ). For substrate analysis, the samples were taken from the coast of Mandalle Beach, Pangkep Regency. Retrieval of the substrate was performed on the ground with a depth range of 15-35 cm and taken from three points at predetermined sampling locations. The substrate was a soil sample representing the sampling location used for testing soil pH, organic matter, and texture.

**2.3.1 pH Substrate**

The method used to measure the pH of the substrate was the calorimeter. In this method, after taking soil samples at a specified point with a depth of 20 cm, the soil was put into a test tube with half a spatula spoon (0.5 ml), added to 4 ml of pH-1 reagent, and stirred until evenly distributed using a glass stirrer. Subsequently, 2 drops of the pH-2 reagent color indicator were added before waiting for 10 minutes until the suspension produced a precipitate to form a color in the clear liquid at the top. The color in a clear solution on the soil surface was compared to the soil pH color chart [23].

**2.3.2 Total Organic Matter of Substrate**

BOT content analysis was carried out using the Loss On Ignition (LOI) method. The LOI method aimed to determine the total organic matter (organic carbon) content in sediments, hence the depositional environment was known and the process of sediment occurrence was based on the organic carbon content of sediment samples. This method was carried out in the chemistry and soil laboratory of the Politeknik Pertanian Negeri Pangkep. The steps for analyzing the total organic matter (organic carbon) content used the LOI method based on laboratory procedures at the University of Pittsburgh and the provisions of [24]) are as follows:

Where:

Li = Loss on Ignation (%)

Wo = Beginning weight (g)

Wt = Final weight (g)

**2.3.3 Texture of Substrate**

Soil texture was determined by taking soil samples and analyzing them based on existing references, namely the technique in the field [25]. The determination was conducted as follows: the soil mass was moistened with water and massaged with the index finger and thumb. Furthermore, a moist ball was formed, rolled up, and seen for its resistance to pressure and stickiness when the index finger and thumb were separated.

**2.4 Data analysis**

Data obtained from several research stages were analyzed descriptively to determine the accumulation of the heavy metal Pb in water, water quality, and substrate quality on the coast of Mandalle Beach, Pangkep Regency. The descriptive analysis aimed to provide an explanation of the research subject based on the data from the variables obtained from the subjects [26]. The data was analyzed using a comparative descriptive analysis technique, namely comparing this data to obtain differences between variables [27].

**RESULTS AND DISCUSSION**

**3.1 Water Pb Analysis**

Pb measurements were carried out during the east monsoon, namely from April to June 2023. Under these circumstances, the potential for Pb solubility within the water matrix becomes heightened. This scenario contrasts with activities conducted during the rainy season when the dilution mechanism facilitated by rainwater comes into play. This is particularly relevant, particularly when prior precipitation of Pb within the aquatic environment has occurred. A heavy metal that has settled on the bottom of the waters can spread in all directions due to tidal currents, affecting marine biota [14]); [28]. The results of the analysis of the content of Pb in the three locations, namely Station 1 was located on the waterfront bordering Barru Regency, Station 2 had the characteristics of being around the Pier of the Politeknik Pertanian Negeri Pangkep, and Station 3 was in the vicinity of the Mandalle Village mangrove forest, indicating a value below or less than 0.001 pp, as seen in table (2).

**Table 2. Results of laboratory analysis of lead (Pb) content in water samples**

|  |  |  |
| --- | --- | --- |
| **No.** | **Research Locations** | **Lead-Pb content (ppm)** |
| 1 | Station 1 | < 0,001 |
| 2 | Station 2 | < 0,001 |
| 3 | Station 3 | < 0,001 |

Source: Laboratory Test Results (2023)

Laboratory test results for Pb heavy metal analysis were still lower than the results of a research conducted [19], who carried out research in Padelegan Pamekasan Waters with a Pb value of 0.63-1.08 ppm. The Pb levels in this research were still below the seawater quality standards set by Decree of the Minister of Environment of Indonesia No. 51 of 2004 of 0.008 ppm based on Government Regulation of Indonesia No. 82 of 2001 concerning water quality management and water pollution control, namely 0.03 ppm. The results [19] also showed that the sampling points closest to land had high Pb concentrations caused by the entry of waste from land activities through river mouths and influenced by tides. These currents carried a mass of water containing the heavy metal Pb from the estuary and coastal waters to the open sea [19]. The tides that occurred continuously caused a movement of currents [29].. However, the content and influence of these currents did not affect the Pb content at the three location stations. The high levels of Pb in the high seas originated from sea transportation activities, fishing boats, and diesel fuel spills at sea. High levels of heavy metals were distributed to parts of the human body, while some were accumulated [19];[30].

The lead concentration value was still lower than the results of research conducted by [5], with a value of 0.0295 ppm. According to [31], the concentration of the heavy metal lead depended on the time of disposal of waste, and the level of treatment. Furthermore, it was influenced by the season, including weather conditions several days and weeks before sampling in rainy conditions. According to [32], the marine organism test material showed that the content of Pb metal in water at a concentration of 2.75–49 mg/L caused the death of crustaceans after 245 hours, while insects died in a short time of 168 hours. [33] stated that lead was accumulated directly from water and sediment by marine organisms, and the high level of pollution in coastal areas was caused by anthropogenic activities such as heavy metal and nutrient pollution [34]. Heavy metals were difficult to degrade in water and were toxic, unlike other organic parameters degraded or decomposed [35]. The entry of heavy metals into the waters came from anthropogenic factors including agriculture, animal husbandry, domestic use, and industry [36]. Pb pollution levels had a very large impact on the survival of aquatic organisms, resulting in the extinction of organisms with a major role in maintaining the balance of the food chain cycle in an ecosystem and the preservation of aquatic functions [37].

According to [38], with a quality standard value for ports, marine tourism, and biota of 0.05 ppm, 0.005 ppm, and 0.008 ppm, the concentration of Pb in the coastal waters is still safe and not yet dangerous. This is because the concentration has a value of <0.001 ppm, but this condition must be continuously maintained to exceed safe limits and prevent sub-lethal and lethal impacts on fish and shellfish. The Pb content of the water is also low compared to the results of a research conducted by [39] regarding the content of heavy metal Pb in Lekok Waters. Therefore, the Pb content is also quite high due to ship activities from the nearest port, the process of washing and maintaining fishing boats, and fuel oil falling into the waters. The research conducted by [40], showed that the concentration of Pb in the coastal waters of Kupa Kupa Village, South Tobelo District, ranged from 0.50-0.78 ppm. This concentration passed the quality standard for seawater, which had a higher lead content than the results of this research. High metal concentrations are associated with sediments that have small grain sizes to bind metals in sediments properly. The coastal waters of Mandalle, Pangkep Regency, have not been contaminated with Pb, which will be very dangerous for marine biota and have an impact on human health [33]; [41]); [42]. The low levels of Pb metal in seawater at the three stations were because most of the sea ions were adsorbed by the high suspended solids. Since the water conditions prevented the metal levels from being detected by [34], total suspended solids played a role in absorbing dissolved metals, which were precipitated (sinking processes) to the bottom of the waters [43].

**3.2 Water Quality Analysis**

Good water quality is the main requirement for the creation of a healthy environment. Various domestic and non-domestic wastes are sources of pollutants cumulatively affecting environmental quality. Changes in the quality of the environment left uncontrolled decreases the level of environmental health [44]. Furthermore, changes in water quality can be the start of pollution when the parameter values have passed seawater quality standards [40] and industrial activities produce metal residues in the aquatic environment [45]. The decline in water quality is caused by the presence of organic and inorganic contaminants, including dangerous heavy metals. These heavy metals are known to accumulate in the bodies of organisms and remain for a long time as accumulated poisons [32]. The presence of heavy metals in water is very dangerous directly to the life of organisms or human health. Lead and its compounds can be naturally present in water bodies due to human activities. The presence of heavy metal lead that accumulates in water and sediments enters into the lives of organisms. Heavy metals at certain concentrations accumulate in water, biota, and sediment can have toxic effects on the organisms [35]. According to [14], deep sea life is less affected than shallow sea life.

**3.2.1 Water temperature (oC)**

The average water temperature during the research showed that the highest temperature occurred at Station 2, which was 29.28oC, followed by Station 1 with an average of 29.01667oC, or 29.02oC, and the lowest at Station 3 for 28.81667oC, or 28.82oC (Fig. 2). Meanwhile, the temperature of the waters was in the range of 28.82–29.28oC (Fig. 3).

**Fig. 2. Average water temperature during research**

**Fig. 3. Water temperature range during research**

Temperature is an external factor that is easy to study and determine, but greatly influences the life of aquatic organisms, specifically metabolic activity. In addition, it is an important parameter in water, affecting the growth of aquatic organisms [40]. The high average temperature of the waters at Station 2 is caused by the fact that the research location is directly facing the sea, while the low temperature at Stations 1 and 3 is because these locations are influenced by the surrounding environment and mangrove vegetation. [46] stated that the temperature of the waters also affected the presence of Pb concentrations. Therefore, the temperature of seawater is very influential on changes in Pb levels in the water. [47] stated that high temperatures accelerate the reaction for the formation of metal ions because the temperature is a factor causing changes in chemical reactions and a decrease in gas. The water temperature is not different from the results of [29], who conducted research in Padelegan waters, with an average temperature of 29.4 oC to 31.2°C. The higher the temperature in the feeding waters, the faster the reaction for the formation of the ions [29]. However, [48] stated that temperature variations in tropical waters ranged from 27oC to 32 oC. The results of measuring temperature parameters are still lower than [48], who conducted research at the Kupa-Kupa Village Beach with a range of 32oC to 34°C. Depth, season, latitude, and cloud cover are factors affecting water temperature in a lake [49]). In addition, temperature also affects the toxicity of heavy metals to biota (Indirawati *et al*., 2022 [50], where when there is an increase, the solubility and toxicity of heavy metals become high [51]. Temperature affects the process of incorporating heavy metals into the body, which increases and the reaction for forming bonds also accelerates [52]. This variable plays a role in the reaction for the formation of heavy metal ions. The higher the temperature in the feeding waters, the faster the reaction for the formation of these ions [29].

**3.2.2 Water Salinity (ppt)**

Salinity is the level of saltiness or dissolved salt content in water, where the distribution is influenced by factors such as water circulation patterns, evaporation, rainfall, and river flow [40]. The high salinity of the waters at Stations 1 and 2 is because the research location is directly facing the sea and there is no river flow, while at Station 3 there is a small river flow with mangrove vegetation. The value of salinity was affected by evaporation in the sea [53]. The optimum salinity for bivalves ranges from 5-25 ppt [54], affecting the early stages of development and physiological processes of bivalves such as endogenous rhythm, respiration rate, excretion, absorption, and assimilation efficiency [34]. The results are slightly higher than [55], who conducted research in Padelegan Pamekasan Waters with a scientific range of 26–29 ppt. Meanwhile, [40], who conducted research on the waters of Kupa-Kupa Beach, obtained salinity in the range of 27–34 ppt. The variable affected the level of accumulation of heavy metals, and the greater the salinity in the waters, the smaller the level of accumulation [56]. [57] stated that a decreased salinity value led to an increase in the toxic power of heavy metals and a greater level of accumulation. The highest mean water salinity was at Station 1, which was 33.17 ppt, followed by Station 2 at 31.5 ppt, and the lowest at Station 3 was 23.83 ppt (Fig. 4). The range of water salinity in the three stations was in the range of 17–34 ppt (Fig. 5).

**Fig. 4. Average water salinity during research**

**Fig. 5. Water salinity range during research**

**3.2.3 Dissolved oxygen (ppm)**

Dissolved oxygen stands as a critical determinant influencing the viability of aquatic biota. In instances of inadequate availability, the insufficiency directly impinges on the behavioral patterns and physiological processes of aquatic organisms [40]. The high dissolved oxygen at Station 3 was due to the movement of water, triggering oxygen content. According to [58], the relationship between dissolved oxygen and the presence of heavy metals is that in areas lacking oxygen, solubility is lower, difficult to dissolve, and easily precipitates. Elevated temperature and salinity levels can lead to diminished solubility of oxygen. This manifests as a consequence of various interrelated factors, including the microbial decomposition of organic matter and the respiratory activities (oxygen consumption) of aquatic organisms [59]. In addition, regular circulation of seawater, freshwater, shallow waters, waves caused by wind, and the process of photosynthesis are factors affecting oxygen in the waters [60]. The dissolved oxygen value is still lower than the results conducted by [40] in the range of 7.88–7.91 ppm. Therefore, only station 3 is under seawater quality standards concerning marine biota. [61] states that the DO value for marine biota is >5, and below 5 ppm at Stations 1 and 2. According to [58], the oxygen content in water affects the solubility of heavy metals, and in areas lacking the element, solubility becomes lower. The average dissolved oxygen showed that the highest oxygen was obtained at Station 3 at 5.137 ppm, followed by Station 1 at 4.165 ppm, and the lowest at Station 2 was 4.163 ppm (Fig. 6). Furthermore, the dissolved oxygen was in the range of 3.07-6.7 ppm, as shown in Fig. (7).

**Fig. 6. Average water dissolved oxygen during research**

**Fig. 7. Water dissolved oxygen range during research**

**3.2.4 Water pH**

The high pH value of the water at Stations 1 and 3 is because these two stations are directly facing the sea. The low value of the substrate at Station 3 is due to the location being close to mangrove forests and the presence of freshwater channels. However, the pH value of the substrate at the three research locations is relatively high above pH 7. This is consistent with [62], where soil pH affects the transportation and availability of nutrients needed by plants, and mangrove soil has a pH between 6-7. [29] and [63], stated that the solubility of heavy metals is high when the pH in these waters is low. This is because an increase in the pH value changes the heavy metals from carbonates into hydroxyl forms, which form bonds with particles in water bodies. The relationship between pH and metal toxicity is more complicated depending on chemical bonds [42], and pH can control the type and reaction rate of some materials [64]. The pH of the water affects photosynthetic activity, temperature, and the presence of cationic anions, which are factors influencing the life of organisms and other needs [59]. The high pH value greatly determines the presence of phytoplankton, which directly affects the fertility level of the waters where the presence is supported by the availability of nutrients in marine waters [65]; [66]. The pH value of the water was lower than the results conducted by [40], who conducted research in Kupa-Kupa Village with a pH value in the range of 8.89.3. According to [59], pH 6.5–8.5 is the ideal pH value for aquatic life. The pH value in the coastal waters of Mandalle and Kupa Kupa Village has exceeded the safe limit but can still be tolerated by aquatic biota. The relationship between the pH of water and heavy metals was established by [52], where the variables affect each other. Therefore, pH is one of the determinants of Pb concentration in the waters of Mandalle Beach, Pangkep Regency, Indonesia. The pH value of the water at all observation stations showed that the highest water pH was at Station 1 of 6.8, followed by Station 3 of 6.7, and the lowest water pH value was at Station 2 (Fig. 8). The range of pH values measured was in the range of 6-7 (Fig. 9).

**Fig. 8. Average water pH during research**

**Fig. 9. Water pH range during research**

**3.3 Substrate Analysis**

The substrate pH was in the range of 7.07-7.42, where the highest and lowest values were obtained at Stations 2 and 3, which were 7.42 and 7.07, respectively (Fig. 10).

**Fig. 10. Substrate pH range during research**

The organic component of the substrate or soil comes from biomass, which characterizes the active soil. Non-living organic components are formed through chemical and biological weathering, specifically from plant materials [67]. The high organic matter content of the substrate at Station 3 was because the location is in the vicinity of a mangrove forest and there is a small river connecting the community ponds. The low organic content of the soil is caused by an imbalance in the role of organic matter from the soil through biological oxidation processes [68]. The influence of organic matter on soil fertility cannot be denied [69] and the high content can affect the amount of heavy metal content. Contamination in the substrate also affects water quality and metal bioaccumulation in aquatic organisms, resulting in potential long-term implications for human and ecosystem health [70]; [71]. [72] stated that excess heavy metals in soil poison plants and organisms with implications for environmental pollution. Meanwhile, harmful heavy metals in soil are in dissolved form [73].The results showed that the organic matter of the substrate was in the range of 7.93-15.21%, where the highest occurred at Station 3, which was 15.21% (Fig. 11).

**Fig. 11. Range of substrate organic matter during research**

**3.3.1 Substrate texture**

The composition of the substrate is determined by identifying the constituent fractions, namely clay, silt, and sand. Based on the results of laboratory analysis, the texture at the research site was at Stations 1, 2, and 3 with a sandy, sandy loam, and dusty clay texture. Station 1 had a sandy texture because there were no nearby river mouths that could carry silt. In addition, Station 2 had a sandy loam texture, consisting of sand and clay in different proportions. Station 3 possessed a dusty clay texture because the location was close to mangrove vegetation and there was a small river mouth in the vicinity. The results were in line with [74], where in the estuary waters, several silts served as a good growing medium for mangroves. According to [75], in terms of soil texture, clay-textured soil had a larger surface area with the capacity of holding water and providing high nutrients. The composition of mangrove soil particles affected permeability and also determined the water content and nutrient state of the soil. The Pb content in the waters was still in the low category and the water and substrate quality content were within the limits suitable for the life of aquatic organisms.

**Conclusion**

The lead (Pb) content of water in the waters of Mandalle Beach, Pangkep Regency, Indonesia, is still below the dangerous threshold for both water quality and subgrade quality, with water Pb values below <0.001 ppm. Even though there has been a lot of fishing activity, and aquaculture businesses are suspected of causing Pb content in these waters. The water quality content, consisting of temperature, salinity, dissolved oxygen, and water pH, is still within appropriate limits, as is the substrate quality, consisting of substrate pH, organic matter, and texture.

Disclaimer (Artificial intelligence):

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

**References**

1. Ishak, N.I. 2017. Risk Analysis Of Heavy Metal Weight Mercury in Sea Sediment in the Coastal Areas of Makassar City. Promotif. Journal of Public Health., 7(2):88-92. <Https://Doi.Org/10.31934/Promotif.V7i2.80>.
2. Effendi, H. 2003. Study of Water Quality for Management of Aquatic Resources and Environment. Kanisius (Ikapi Member), Jakarta.
3. Sutamihardja. 2006. Environmental Toxicology. Textbook of Environmental Science Study Program. University of Indonesia, Jakarta
4. Kurniawati, A: Nugroho, A. S; and Kaswinarni, F. 2015. The Impact of Leachate of the Jatibarang Landfill on the Diversity and Abundance of Plankton in the Kreo River Waters, Semarang City. XII National Seminar on Biology Education FKIP UNS., 2008:708-713.
5. Febriani, B.A. 2022. Analysis of Lead (Pb) Metal Concentration in Water, Fish and Oysters in the Central New Coastal Region of Balikpapan City. Thesis. Faculty of Public Health, University of Mulawarman Samarinda, P.170
6. Bridiatama. 2014. North Coast Sea Water Pollution Index of Tuban Regency with Metal Parameters. Department of Environmental Engineering, Faculty of Civil Engineering and Planning. Sepuluh Nopember Institute of Technology (ITS), Surabaya.
7. Permanawati, Y; Zuraida, R; and Ibrahim, A. 2013. Content of Heavy Metals (Cu, Pb, Zn, Cd, and Cr) in Water and Sediments in Jakarta Bay Waters. Journal of Marine Geology., 11(1): 9-16.
8. Desriyan, R; Eka, W; and Kancitra, P. (2015). Identification of Lead (Pb) Heavy Metal Pollution in the Waters of the Upper Sitarum River, Dayeuhkolot Segment to Nanjung. Journal of Environmental Engineering National Institute of Technology., 3(1): 1-12.
9. Hasyim, U.H. 2016. Review: Study of Adsorption of Metals in Used Lubricants and Prospects for Their Utilization as Fuel. J. Konversi., 5.(1):11-16. DOI: <https://doi.org/10.24853/konversi.5.1.11-16>
10. Begum, A; Krishna, H; and Irfanulla, K. 2009. Analysis of Heavy Metals in Water, Sediments and Fish Samples of Madivala Lakes of Bangalore, Karnataka. International Journal of ChemTech Research., 1(2).
11. Lessy, M.D. 2006. Qualitative Distribution of Heavy Metal Pb in Water, Sediment and Seagrass Enhalus acoroides in Coastal Waters of Ternate City, North Maluku. Thesis. Hasanuddin University Postgraduate Program, Makassar
12. Hala, Y; Wahab, A.W; and Meilanti H. 2005. Analysis of Lead and Zinc Ion Content in Blood Clams (*Andara gronosa*) in Parepare Port Waters. Journal of Marina Chimica Acta., 6(2):12-16.
13. Satmoko. 2006. Conditions of Heavy Metal Pollution in DKI Jakarta River Waters. Environmental Technology Center-BPPT, Jakarta
14. Darmono. 2001. Environment and pollution Relation to the Toxicology of Metal Compounds. University of Indonesia Publisher, Jakarta
15. Ma’rifah, A; Siswanto; A.D; and Romadhon A. 2016. Characteristics and Influence of Currents on Accumulation of Heavy Metal Lead (Pb) in Sediments in Kalianget Waters, Sumenep Regency. Proceedings of the 2016 Maritime National Seminar. Trunojoyo University, Madura. Matter., 32-88.
16. Zeraatkar, A.K; Ahmadzadeh, H; Talebi, A.F; Moheimani, N.R; and McHenry, M.P. 2016. Potential Use of Algae for Heavy Metal Bioremediation, a Critical Review. Journal of Environmental Management., 181:817-831. DOI: https://doi.org/10.1016/ j.jenvman.2016.06.059
17. Wardalia. 2017. Effect of Rice Husk Waste Adsorbent Mass on Lead Concentration Absorption. Journal of Teknika., 13(1):71-80. DOI: <http://dx.doi.org/10.36055/tjst.v13i1.5848>
18. Ruslan. 2008. Determination of Complexing Capacity and Conditional Stability Constants of Copper Heavy Metal in Palu River Water. Journal of Marina Chimica Acta., 1(2): 6-10.
19. Hariyanti, A; Jayanthi, O.W; Wicaksono, A; Kartika, A.G.D; Efendy, M; Putri, D.S; and Rahmadani, P.A. 2021. Distribution of Heavy Metal Lead (Pb) in Seawater as Raw Material for Salt in Padelegan Pamekasan Waters. Juvenile. Marine and Fisheries Scientific Journal., 2(4): 272-287.
20. Christian, G.D. 1994. Analytical Chemistry 5th Edition. New York: John Willey and Sons, Inc.
21. Harmita. 2004. Guidelines for Implementation of Pharmaceutical Science and Method Validation., Vol 1.
22. Firmansyah, M.A; Sabikis; and Pri I.U. 2012. Analysis of Lead Heavy Metal Levels in Guci Mountain Springs Using Atomic Absorption Spectrophotometer Method. Journal of Pharmacy., 9(3): 100-110
23. Novia, W; and Fajriani. 2021. Comparative Analysis of Acidity (pH) of Paddy Soil Using Calorimeter and Electrometer Methods in Matang Setui Village. Journal of Hadron., (3)1: 10-12.
24. Allen, S.E; Grimshaw, H.M; Parkinson, J.A; and Quarmby C. 1974. Analysis of Soil in Chemical Analysis of Ecological Materials. Oxford, Blackwell Scientific Publication, Oxford.
25. Suin, M. N. 1997. Soil Animal Ecology. Bumi Aksara, Jakarta.
26. Azwar, S. 2014. Research methods. Pustaka Pelajar, Yogyakarta
27. Sanjaya, W. 2013. Educational Research. Kencana Prenada Media Grup, Jakarta
28. Selpiani, L; and Rosalina, D. 2015. Concentration of Heavy Metals (Pb, Cu) in Dara Shells (*Anadara granosa*) in the Keranji Beach, Central Bangka and Bay Kelabat Beach, West Bangka. Oseatek., 9(1): 21-34.
29. Rezki, C.T; Petrusm S; and Sri, Y.W. 2013. Study of Distribution of Heavy Metal Pb (lead) in Bottom Sediment of Slamaran Beach, Pekalongan City. Journal of Oseanografi., 2(1):9-17.
30. Rahmadani, T; Sri, M.S; and Irwan, S. 2015. Analysis of Zink (Zn) and Lead (Pb) Metal Content in Mamboro Coastal Seawater, North Palu District. Journal of Akademika Kimia., 4(4): 197-203.
31. Amin, B; and Wahono. 2013. Concentration and Distribution of Heavy Metals Pb, Cu and Zn in Water, Sediments and Blood Clams (Anadara granosa) in the Waters of the Indragiri River Estuary, Riau. X Annual National Seminar on Marine and Fisheries Research Results. UGM, Yogyakarta.
32. Palar, H. 1994. Heavy Metal Pollution and Toxicology. Rineka Cipta, Jakarta
33. Rochyatun, E; Kaisupy, M.T; and Rozak, A. 2006. Distribution of Heavy Metals in Water and Sediments in the Cisadane River Estuary. Makara, Science., 10(1):35-40.
34. Sari, M.P; Riyantini, I; and Ihsan, Y.N. (2022). Pb (Lead) Metal Contamination on Anadara granosa on the North Coast of Cirebon Regency. Marina Oceanographic Bulletin., 11(3): 248-254.
35. Sembel, L. 2012. Analysis of Pollution Load and Assimilation Capacity in the Belau River Estuary, Lampung Bay. Maspari of Journal., 4(2):178-183.
36. Patty, J.O; Siahaan, R; and Maabuat, P.V. (2018). Presence of Heavy Metals (Pb, Cd, Cu, Zn) in Water and Sediments of the Lowatag River, Southeast Minahasa-North Sulawesi. Journal of Bioslogos., 8(1):15-20. doi:10.35799/jbl.8.1.2018.20592
37. Lubis, H; and Aman, C. 2008. Examination of Mercury, Lead and Cadmium Metal Content in Fresh Crab Meat Derived from TPI Gabion Belawan Using Atomic Absorption Spectrophotometry. Archipelago Medical Magazine., 41(1):39-42.
38. Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning Implementation of Environmental Protection and Management, Jakarta.
39. Haryono, M.G; Mulyanto; and Kilawati, Y. 2017. Heavy Metal Content of Pb in Sea Water, Sediment and Green Mussel Meat Perna Vidis. Journal of Tropical Marine Science and Technology., 9(1):1-7. DOI: <https://doi.org/10.21107/jk.v13i2.8270>
40. Fendjalang, S.N.M; Rupilu, K; Simange, S.M; and Paparang, A. 2022. Analysis of Lead (Pb) Content in Coastal Waters of Kupa Kupa Village, South Tobelo District, North Halmahera Regency. Journal of Tropical Fisheries Management., 6(2): 126-133.
41. Maslukah, L. 2013. Correlation between Heavy Metal Concentrations of Pb, Cd, Cu, Zn with Organic Matter and Grain Size in Sediments in the West Flood Canal Estuary, Semarang. Marina Oceanographic Bulletin., (2): 55-62.
42. Purbonegoro, T; Damar, A; and Arifin, Z. 2014. Heavy Metals (Cd and Pb) in Suspended Solids and Sediments of Muara Kapuas, West Kalimantan. Oceanology and Limnology in Indonesia., 40(1): 55-70.
43. Arifin, Z. 2011. Concentration of Heavy Metals in Water, Sediment and Biota in Kelabat Bay, Bangka Island. Journal of Tropical Marine Science and Technology., 3(1):104-11. doi: 10.28930/jitkt. v3i1.7839
44. Rijalinoor. 2003. Study of Pb Heavy Metal Content in the Kenjeran Canal and Mussels in the Estuary of the Channel. Journal of Info-Teknik., 4(1): 34-43.
45. Kurniawan, A; and Mustikasari, D. 2019. Reviews; Mechanism of Heavy Metal Accumulation in the Post-Tin Mining Ecosystem. Journal of Environmental Science., 17(3):408-415
46. Rachmaningrum, M; Wardhani, E; and Pharmawati, K. 2015. Cadmium (Cd) Heavy Metal Concentration in Upper Citarum River Waters Dayeuhkolot-Nanjung Segment. Journal of Environmental Engineering., 3(1):1-11. DOI:https://doi.org/10.26760/rekalingkungan.v3i1.%25p
47. Rizki, C.T; Subardjo, P; and Wulandari, S.Y. 2013. Study of Distribution of Heavy Metal Pb (Lead) in Bottom Sediment of Slamaran Beach, Pekalongan City. Journal of Oseanografi., 2(1):9-17.
48. Putra, A; and Husrin, S. 2017. Post-Marine Pollution Water Quality at Kuta Beach, Bali. Journal of Tropical Marine Science and Technology., 9(1):57-66.
49. Novita, P; Subariyanto; and Patang. 2019. Effect of Mangrove Habitat on Reducing Lead Contamination Levels at the Tallo River Estuary. Journal of Agricultural Technology Education., 5(1):69-82.
50. Indirawati, E; Musada, Z; Tantu, A.G; and Renal. 2022. Status of Lead and Cadmium Heavy Metal Pollution in the Tallo River Using Oreochromis niloticus Tilapia Bioindicators. Ecosystem Scientific Journal., 22(2): 348-361. DOI:10.35965/eco.v22i2.1562
51. Li H; Shi A; Li M; and Zhang X. 2013. Effect of pH, Temperature, Dissolved Oxygen, and Flow Rate of Overlying Water on Heavy Metals Release from Storm Sewer Sediments. Journal of Chemistry., 1-11.
52. Budiastuti, P; Rahadjo, M; and Dewanti, N.A.Y. 2016. Analysis of Lead Heavy Metal Pollution in the Babon River Body, Genuk District, Semarang. Journal of Public Health., 4(5):119-124. DOI: <https://doi.org/10.14710/jkm.v4i5.14489>
53. Islami, M.M. 2013. The Effect of Temperature and Salinity on Bivalvia. Oseana., 38(2):1-10.
54. Kustiyarini, L; and Djaja, I. 2011. Diversity of Bivalvia in Payumb Beach, Samkai Village, Merauke District. Journal of Agricola., (2):99-107.
55. Hariyanti, A; Jayanthi, O.W; Wicaksono, A; Kartika, A.G.D; Efendy, M; Putri, D.S; and Rahmadani, P.A. 2021. Distribution of Heavy Metal Lead (Pb) in Seawater as Raw Material for Salt in Padelegan Pamekasan Waters. Juvenile. Marine and Fisheries Scientific Journal., 2(4): 272-287.
56. Wardani, D.A.K; Dewi, N.K; and Utami, N.R. 2014. Accumulation of Heavy Metal Lead (Pb) in Green Mussel Meat (Perna viridis) in the West Flood Canal Estuary of Semarang. Unnes Journal of Life Science., 3(1):1-8.
57. Eshmat, M.E; Gunanti, M; and Boedi, S.R. 2014. Analysis of Lead (Pb) and Cadmium (Cd) Heavy Metal Content in Green Mussels (*Perna viridis* L.) in Ngemboh Waters, Gersik Regency, East Java. Fisheries and Marine Scientific Journal., 6(1): 101-108.
58. Nadia, N; Siti, R; and Haeruddin. 2017. Spatial Distribution of Heavy Metals Pb and Cd in the Water and Sediment Columns in Muara Cisadane Waters, Banten. Journal of Maquares., 6 (4):455-462.
59. Siburian, R; Simatupang, L; and Bukit, M. 2017. Analysis of Marine Water Quality on Activities in the Port of Waingapu-Alor, East Sumba. Journal of Community Service., 23(1):225-232. DOI: <https://doi.org/10.24114/jpkm.v23i1.6639>
60. Romimohtarto, K; and Juwana, S. 2001. Marine Biology: The Science of Marine Biota. Djambatan Jakarta. Indeks of Bibliografi, pp. 473-483.
61. Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning Implementation of Environmental Protection and Management, Jakarta.
62. Murdiyanto, B. 2004. Know, Maintain and Preserve Mangrove Ecosystems. Coastal Community Development and Fisheries Resource Management Project. Directorate General of Capture Fisheries. Ministry of Maritime Affairs and Fisheries. Jakarta, pp. 1-40.
63. Eshmat, M.E; Gunanti, M; and Boedi, S.R. 2014. Analysis of Lead (Pb) and Cadmium (Cd) Heavy Metal Content in Green Mussels (*Perna viridis* L.) in Ngemboh Waters, Gersik Regency, East Java. Fisheries and Marine Scientific Journal., 6(1): 101-108.
64. Desriyan, R; Eka, W; and Kancitra, P. (2015). Identification of Lead (Pb) Heavy Metal Pollution in the Waters of the Upper Sitarum River, Dayeuhkolot Segment to Nanjung. Journal of Environmental Engineering National Institute of Technology., 3(1): 1-12.
65. Megawati, C; Yusuf, M; and Maslukah, L. 2014. Distribution of Water Quality in View of Nutrients, Dissolved Oxygen and pH in the South Bali Waters. Journal of Oceanography., 3(2):142-150
66. Wahyuningsih, N; Suharsono, S; and Fitrian, Z. 2021. Seawater Quality Study in Bontang City Waters, East Kalimantan Province. Development Research Journal., 4(1):56-66. DOI: <https://doi.org/10.36087/jrp.v4i1.94>
67. Tan, K.H. 1992. Soil Chemistry Fundamentals. Universitas Gadjah Mada Press, Yogyakarta
68. Victorius. 2012. Determination of P, K, and C-Organic Status for Soil and Inorganic. Graha presindo, Jakarta
69. Hardjowigeno, S. 2003. Geologi. PT Medityatama Sarana Perkasa, Jakarta.
70. Fernandes, C; Fontainhas-Fernandes, A; Peixoto, F; and Salgado, M.A. 2007. Bioaccumulation of Heavy Metals in Liza Saliens from the Esomriz-Paramos Coastal Lagoon, Portugal. Ecotoxicology and Environmental Safety., 66: 426-431.
71. Abdel-Baki AS; Dkhil MA; and Al-Quraishy S. 2011. Bioaccumulation of Some Heavy Metals in Tilapia Fish Relevant to Their Concentration in Water and Sediment of Wadi Hanifah, Saudi Arabia. African Journal of Biotechnology., 10: 2541-2547.
72. Alloway, B.J. 1995. Heavy Metals in Soils. Blackie Academic & Professional, London.
73. Slamet, Y.S. 1996. Environmental Health. Gajah Mada University Press,Yogyakarta.
74. Arisandy, K.R; Herawati, E.Y; and Suprayitno, E. 2012. Accumulation of Heavy Metal Lead (Pb) and Histological Features in Avicennia marina (forsk.) Vierh Network in Coastal Waters of East Java. Journal of Fisheries Research., 1(1): 15-25.
75. Murdiyanto, B. 2004. Know, Maintain and Preserve Mangrove Ecosystems. Coastal Community Development and Fisheries Resource Management Project. Directorate General of Capture Fisheries. Ministry of Maritime Affairs and Fisheries. Jakarta, pp. 1-40