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Total organic matter, carbon organic, nitrate, phosphate content in sediment at mangrove ecosystem of Angke Kapuk Protected Forest, DKI Jakarta

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Abstract. The Angke Kapuk Protected Forest (AKPF) as a mangrove ecosystem faces contamination due to the presence of waste. The waste influence the nutrient content in ecosystem. This research aims to measure the content of total organic matter (TOM), organic carbon (C-Organic), nitrate, and phosphate content in the sediments of the AKPF, DKI Jakarta. The study used a survey method, sample selection using purposive sampling technique. TOM was observed using loss on ignition (LOI), C-Organic gravimetric method, while nitrate and phosphate potentiometric methods. The nutrient content in the mangrove sediments of AKPF was varied from low to high fertility. The average TOM in 3 sampling station 1 were classified as high fertility (17.39% – 26.14%). The average C-Organic in 3 sampling station were classified as moderate fertility (10.09% – 15.17%). The average nitrate in station 1 (0.385 mg/100 g), station 2 (0.28 mg/100 g) were classified as moderate fertility, while station 3 was classified as low fertility (0.195 mg/100 g). The average phosphate in 3 sampling station were classified as low fertility (0.05 mg/100 g – 0.07 mg/100 g). The nutrients were influenced by a large amount of plastic waste, such as buried and hard-to-decompose plastic packaging of household products and other pollutants mixed with the sediments.

1 Introduction

Mangrove ecosystems, situated at the interface between the ocean and land, play a crucial role in maintaining coastal ecological balance and delivering diverse ecosystem benefits to both humans and the environment. Serving as habitats for coastal organism spawning and nurturing, aquatic biota propagation, erosion mitigation, and waste absorption, mangrove ecosystems have been extensively studied [1-5]. Sediments, constituting the foundational substrate of these ecosystems, are a pivotal factor affecting their functionality and

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sustainability. These sediments comprise a plethora of organic and inorganic components, significantly influencing the quality and productivity of mangrove ecosystems.

Soil suitability stands as a paramount determinant of mangrove survival and growth. Distinct soil conditions and oceanographic activities are principal considerations for mangrove's thriving [6]. Household and industrial waste, in forms of carbon, nitrogen, and phosphorous, when present in the soil, can disrupt the environment and pose a threat to mangrove growth within the ecosystem.

Sediment types influence the nutrient content contained therein, and nutrients are vital factors affecting mangrove growth. Each mangrove species possesses distinct abilities to absorb and store nutrients for their growth. Total organic matter, organic carbon, nitrate, and phosphate stand as essential nutrients for mangrove fertility [7]. Among these, organic matter, particularly in substantial quantities, is of utmost importance. Nutrient content variations may be attributed to environmental factors and mangrove characteristics [8].

Organic carbon constitutes a component of soil organic matter originating from plant and animal residues, whether in the form of native tissue or weathered remnants. Organic matter contributes to nutrient retention and turnover, soil structure, water absorption capacity, moisture retention capacity, pollutant degradation, carbon absorption, and microorganism biological activities [9].

One notable mangrove ecosystem embodying such significance is the Angke Kapuk Protected Forest (AKPF) situated within Jakarta. The mangrove ecosystem in AKPF provides diverse ecological, economic, and social benefits to the local community and its surrounding environment. Mangroves play a biological role as coastline protectors and stabilizers, sites for waste assimilation, natural water pollution absorbers, mud binders, and natural habitats for various organisms [10]. For communities, mangroves serve as land used in various human activities, including aquaculture, fishing, boating activities, recreational facilities, relaxation areas, and other traditional activities [11, 12]. However, similar to many other coastal ecosystems, the mangrove ecosystem in AKPF also confronts various challenges and threats, stemming from human activities and environmental changes. The northern coastal area of Jakarta is considered to have a bad environment due to the problem of tidal flooding, garbage and waste that affects the quality of the area [12].

Nutrients and organic matter essential for mangrove growth can originate from various sources. Natural organic material, such as mangrove litter, including leaves, propagules, and branches [13]. Human activities, such as household and industrial waste which flow from Jakarta bay and several river in Jakarta that eventually will introduce carbon, nitrogen, and phosphorous into the soil, affecting nutrient balance [14]. Environmental factors, such as oceanographic processes and tidal influences from Java sea that can transport nutrients and organic matter into the mangrove ecosystem [15].

This study aims to analyze and categorize the content of total organic matter, organic carbon, nitrate, and phosphate within sediments in the mangrove ecosystem of the Angke Kapuk Protected Forest, Jakarta. This research endeavors to furnish insights into nutrient content and its impact on the mangrove ecosystem, thereby establishing a foundation for sustainable management efforts concerning the mangrove ecosystem within the Angke Kapuk Protected Forest, Jakarta.

2 Materials and method

The research was conducted from January to July 2023 within the mangrove ecosystem of the Angke Kapuk Protected Forest (AKPF), Jakarta which can be seen in Figure 1. Nutrient content analysis in sediments was carried out at the Soil Chemistry and Plant Nutrition Laboratory, Faculty of Agriculture, Universitas Padjadjaran.

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Fig. 1. Map of Research Location

Sample collection employed the purposive sampling technique, selecting stations based on differing conditions and distances. Sampling was conducted over a 1-month period at 3 research stations: Station 1 located at the outermost point directly adjacent to Jakarta Bay, Station 2 situated along the immediate coastline, and Station 3 positioned at the river estuary's edge. Consequently, a total of 6 samples were collected. Sample retrieval was synchronized with tidal data sourced from the National Geospatial Information Agency.

The process of determining the total organic matter content in mangrove sediment adheres to the guidelines outlined in the SNI 19-7030-2004 standard [16]. The procedure begins with the collection of approximately 20 grams of sediment sample, which is then carefully placed into a porcelain crucible. Subsequently, the collected sample undergoes drying within an oven set at 60°C for a duration of 4 hours, effectively eliminating any moisture present. Once dried, the sediment sample is finely homogenized to ensure uniformity. Following homogenization, a precise weighing of around 0.5 grams of the prepared sample takes place, preparing it for the subsequent steps. The subsequent stage involves subjecting the weighed sample to combustion using a furnace operating at a temperature of 550°C for 4 hours. This combustion process serves to remove organic components from the sample. After the combustion process, the sample is weighed again, and the weight of the sample post-drying is recorded for future analysis.

The content of total organic matter in the sediment is then calculated using the Loss On Ignition method [17]. This method relies on the difference in weight before and after combustion, indicating the weight loss due to the removal of organic matter.

$$\%\text{TOM} = \frac{\text{Wo}-\text{Wt}}{\text{Wo}} \text{ x } 100\% \quad (1)$$

Organic Carbon Analysis is conducted using the gravimetric method in accordance with SNI 19-7030-2004 [16]. Around 1 gram of the sample is combusted within a furnace at a temperature of 500°C overnight. The combusted sample is then dried in a desiccator until it reaches room temperature. The sample is weighed to determine its final weight. Record the organic carbon content value on the digital scale.

In the LOI method, it is not only organic carbon that is measured, but also other organic materials beyond carbon such as nitrogen, sulfur, and others. A regression equation can be utilized to predict the carbon concentration based on the organic material content obtained from the Loss On Ignition calculations [18]. The carbon concentration in the sediment can be calculated using the following method:

$$\%C_{org} = 0,415 \times \%TOM + 2,89 \quad (2)$$

Nitrate measurement is carried out using the Kjeldahl method in accordance with SNI 19-7030-2004 [16]. The process begins with sample preparation, where a sample weighing 0.5 grams is weighed using an analytical balance and then placed into a reflux flask. Subsequently, 2 mL of paraffin is added to the sample using a micropipette. In addition, an empty Erlenmeyer flask is taken and placed in a distillation apparatus. Before the distillation process starts, 10 mL of 1% borate acid and a few drops of Conway indicator are added to the reflux flask. As the next step, NaOH is added until the volume reaches 20 mL before distillation, and then the sample is waited upon until its volume reaches 100 mL. During this process, the initial sample color changes from pink to green. Once the sample reaches room temperature, 0.25 grams of Devarda alloy is added to the sample container. The container is then placed back into the distillation apparatus, and the sample is allowed to reach a volume of 100 mL. The green solution is then titrated using 0.05 M H_2SO_4 until it slightly turns red. The amount of H_2SO_4 used in the titration process is calculated.

Phosphate measurement in sediment follows SNI 19-7030-2004 [16], starting with drying and grinding. Next, 0.5 grams of the sample are weighed and placed into a Kjeldahl flask. To continue the process, 5 mL of HNO solution is added to the sample, stirred, and left to settle overnight. Subsequently, the sample is heated in a digestion block at a temperature of 100°C and gradually increased to 200°C until yellow vapors cease. The destruction process ends when white vapors emerge, and the liquid in the ash remains at around 0.5 ml. The sample is cooled and diluted with distilled water to a volume of 50 mL, then stirred until homogeneous. Next, the sample is left overnight or filtered to obtain a clear extract (Extract A). From Extract A, 1 mL is taken and placed into a 10 mL measuring flask. One drop of PP indicator is added, followed by the addition of 40% NaOH until a pink color appears. Subsequently, 2 mL of vanadate reagent is added and diluted with distilled water to the mark, left for 15 - 25 minutes. The sample is measured using a spectrophotometer at a wavelength of 400 nm. The absorbance values are recorded and calculated.

3 Result and discussion

The water quality in mangrove ecosystems is closely related to the nutrient content found in mangrove sediments. These sediments serve as a reservoir of nutrients that are vital for the growth and productivity of the mangrove ecosystem. The primary nutrients contained within mangrove sediments include total organic matter (TOM), organic carbon (C-Organic), nitrogen in the form of nitrate, and phosphorus in the form of phosphate.

During the data collection period, several indicators of poor water quality were observed in the mangrove ecosystems. These indicators included unpleasant odors, dark water colors, and the presence of oil on the water surface. Additionally, construction waste, such as residual building materials like stone, sand, and concrete, was identified in both sediments and water surfaces within the AKPF mangrove ecosystem. Moreover, domestic waste, including household wastewater and feces generated by the local community, particularly field officers during the reclamation process, had a noticeable impact on water quality in the AKPF mangrove ecosystem. Through sampling and getting the sediment, many one-time-used plastic especially from the household packaging product which were hard-to-decompose were found settled and mixed with the sediment.

Notably, a significant amount of garbage was discovered at station 1, which directly faces Jakarta Bay. At this location, a small sea dike boundary constructed from wood and bamboo

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separates AKPF from Jakarta Bay. The presence of such waste materials and pollutants in the water can have adverse effects on water quality and mangrove ecosystem in the area.

The differences in water quality and nutrient content in the sediment between the mangrove ecosystem stations can be attributed to several factors related to their specific locations and environmental conditions. Station 1, being located at the outermost point directly adjacent to Jakarta Bay, is likely to experience more direct influences from the open sea, including tidal flows, wave action, and the inflow of water from Jakarta Bay. These factors can lead to the mixing of bay and oceanic waters. Station 2, situated along the immediate coastline, may experience intermediate conditions compared to Stations 1 and 3. It is influenced by both the coastal environment and the proximity to Jakarta Bay, resulting in unique water quality characteristics. Station 3, positioned at the river estuary's edge, is likely to be strongly influenced by the freshwater inflow from the river. River water often carries different nutrients and contaminants compared to seawater, which can affect the nutrient composition in the sediment.

The variations in water quality and sediment nutrient content between these mangrove ecosystem stations can be attributed to a combination of natural factors related to their geographical locations and anthropogenic influences from human activities in the surrounding areas. Human activities in the vicinity of these stations can also impact water quality and sediment nutrients. The presence and health of mangrove vegetation influence nutrient dynamics. Different mangrove species and their growth conditions may affect nutrient uptake and cycling. Land use in the surrounding areas, such as agriculture, industry, and urban development, can contribute to nutrient runoff into the ecosystem. The movement of sediments, both within the ecosystem and from external sources, can influence the composition of sediments at different stations.

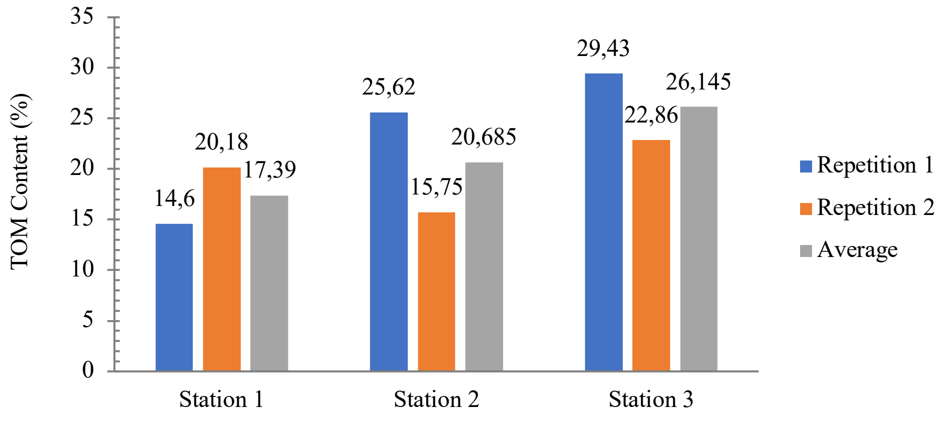

Fig. 2. TOM Measurement Results

Based on laboratory analysis, the content of TOM in sediment at the research location with two samplings is shown in Figure 2. The TOM values at station 1 during the first sampling and station 2 during the second sampling fall within the moderate category, ranging from 7% - 17%. Meanwhile, TOM values at station 2 and 3 during the first sampling, as well as station 1 and 3 during the second sampling, are classified as high, ranging between 17% - 35%. The classification of total organic matter content in sediment places <3.5% as very low, 3.5 - 7% as low, 7 - 17% as moderate, 17 – 35% as high, and >35% as very high [19].

The increase in TOM content is attributed to the amount of litter produced by mangrove trees. TOM and mangrove litter have a close relationship within the mangrove ecosystem, where litter represents organic material residues that settle and undergo decomposition by microorganisms, ultimately contributing to TOM in the ecosystem [20]. Additionally, the sampling from three stations shows variations in organic material content influenced by location. The lowest TOM content is observed at station 1, which directly borders Jakarta Bay. Mangrove areas bordering the sea experience a reduction in organic material content due to wave and current influences carrying sediment materials directly into the ocean [21].

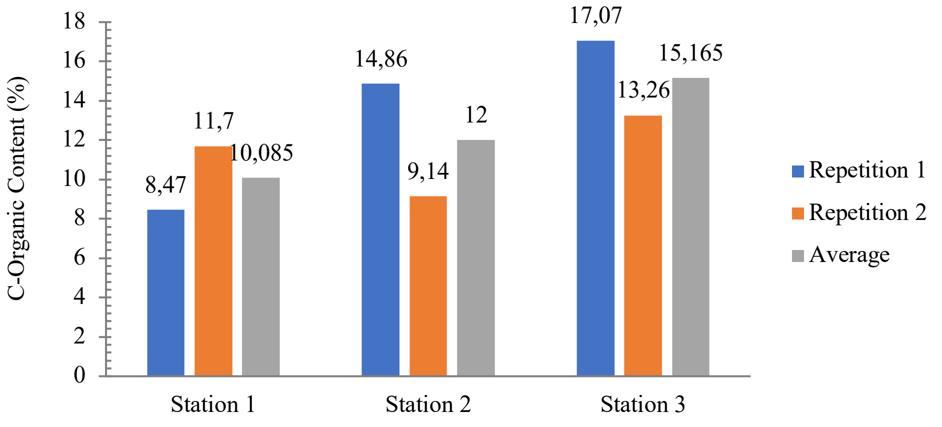

Fig. 3. C-Organic Measurement Results

Based on laboratory analysis, the C-Organic content of sediment at the research location with two samplings is presented in Figure 3. Laboratory analysis results indicate that C-organic content in sediment at research stations 1 and 2 meet criteria, falling within the moderate category with a range of 7 - 17%. On the other hand, samples from station 3 during the first sampling fall within the high category, ranging from 17 - 35%. The classification of organic carbon content in sediment places <3.5% as very low, 3.5 - 7% as low, 7 - 17% as moderate, 17 – 35% as high, and >35% as very high [19].

The content of organic carbon (C-organic) in mangrove sediment samples is influenced by litter production levels, accumulation, and decomposition rates, affected by factors such as temperature, humidity, oxygen, and nutrient availability [14]. Litter from trees (leaves, propagules, branches) and sub-surface root growth provides significant input as organic carbon from mangrove sediment [20]. The mangrove environment holds significant potential as a global carbon sink [22, 23]. The highest amount of waste is found at station 1, which directly faces Jakarta Bay, with a small wooden and bamboo seawall acting as a barrier between AKPF and Jakarta Bay. The abundance of plastic waste, domestic waste, and other contaminants mixed with sediment also contributes to the decrease in carbon content within mangrove sediment along the Jakarta Bay coast [24].

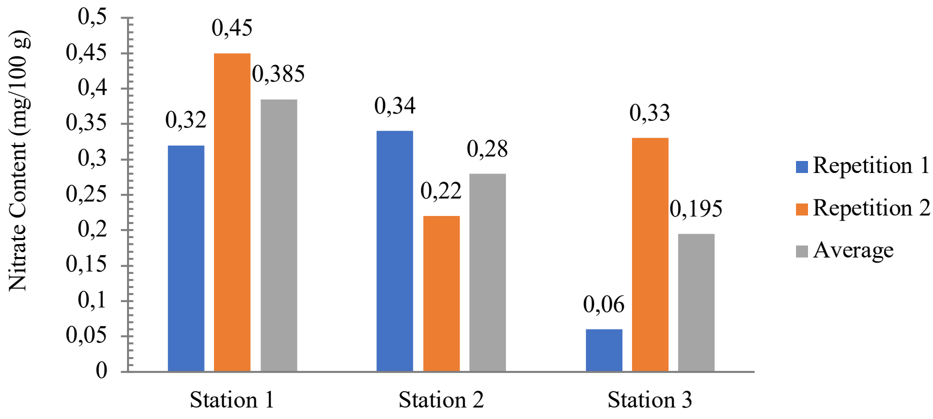

Fig. 4. Nitrate Measurement Results

Based on laboratory analysis, the nitrate content of sediment is shown in Figure 5. Based on fertility classification, nitrate values generally fall within the low category with values < 2.27%. The low nitrate content in mangrove sediment is explained by various factors. The classification of phosphate content in sediment places <2.27 mg/100 g as low fertility, 2.27 - 11.29 mg/100 g as moderate fertility, and 11.30 - 112.50 mg/100 g as high fertility [25].

The highest nitrate nitrate was found at station 1 bordering Jakarta bay and near the Java sea. The nitrate content is getting higher towards the coast and the highest content is usually found in estuarine areas, due to the source of nitrate from land in the form of waste discharges from anthropogenic activities [26]. Mangroves possess a complex and robust root system that efficiently absorbs nutrients from sediment, including nitrate. These nutrients can be rapidly absorbed by mangroves before reaching significant concentrations in the sediment [27]. Nitrates play an important role in building and repairing body tissues and providing energy. Plants and animals need nitrogen for protein synthesis. Nitrate absorption by mangrove plants is used in several processes such as photosynthesis, respiration, protein synthesis and as a constituent of genes and growth of organisms [20].

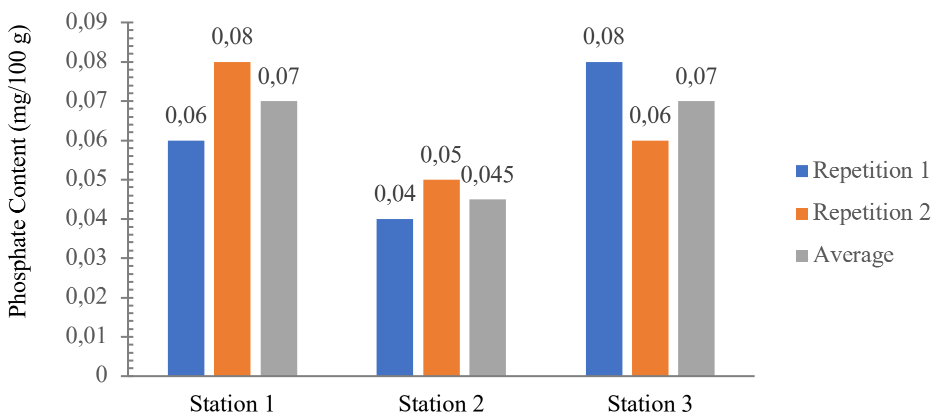

Fig. 5. Phosphate Measurement Results

Based on laboratory analysis, the phosphate content in sediment at the research location with two samplings is depicted in Figure 4. Laboratory analysis results indicate that the majority of phosphate content in sediment at research locations, except for station 3 during the first sampling, falls within the moderate category with values ranging between 0.21 - 0.50, whereas samples from station 3 during the first sampling fall within the low category with values ranging between 0.51 - 1. The classification of phosphate content in sediment places 0 – 0.20 mg/100 g as low fertility, 0.21 - 0.5 mg/100 g as moderate fertility, 0.51 - 1 mg/100 g as high fertility, and >1 mg/100 g as very high fertility [25].

The highest phosphate content is at station 1 which is close to the sea and is affected by currents. Phosphate content is influenced by the location and currents of the high seas that carry phosphate sources from marine life that have died and decomposed [28]. Phosphate content in mangrove sediment is influenced by various factors, including phosphate sources, microorganism activity, oxidation-reduction conditions (redox), and interactions with living organisms [29]. The simultaneous involvement of all these factors forms a nutritional balance, collectively influencing phosphate availability in the mangrove ecosystem.

Location is one of the crucial factors determining nutrient content in mangrove ecosystems. In general, the closer the location is to the sea, the higher the organic material content [30]. However, other studies have yielded contrasting results, indicating that the content of organic material, phosphate, and nitrate tends to be lower when closer to the sea [31]. The highest organic material content in the Betahwalang coastal mangrove ecosystem, Demak, was found at stations located in coastal areas far from the mangrove ecosystem and close to the sea. This content was classified as very high, measuring 66.99% during high tide and 74.87% during low tide [30]. The highest nutrient content in the Tapak Tugurejo Village mangrove ecosystem, Semarang, was observed at stations located closer to the mainland. Organic material content was 13.77%, classified as moderate fertility, phosphate content was 2.42 mg/100 g, classified as very high fertility, and nitrate content was 7.5 mg/100 g, classified as moderate fertility. Conversely, nutrient content decreased as stations approached the sea, with organic material measuring 9.85%, classified as moderate fertility, phosphate content at 0.38 mg/100 g, classified as moderate fertility, and nitrate content at 4.55 mg/100 g, classified as moderate fertility [31].

4 Conclusion

The types of sediments present influence the amount of nutrients contained within them. These nutrients play a crucial role in regulating mangrove development. Across various observation stations, the average Total Organic Matter (TOM) content at Station 1 is 17.39%, Station 2 is 20.68%, and Station 3 reaches 26.14%. The average content of Organic Carbon (C-Organic) at Station 1 is 10.09%, Station 2 reaches 12%, and Station 3 reaches 15.17%. Consistently, the average nitrate levels at Station 1 are 0.07 mg/100 g, Station 2 is 0.05 mg/100 g, and Station 3 is 0.07 mg/100 g. Concerning phosphate content, Station 1 has 0.385 mg/100 g, Station 2 is 0.28 mg/100 g, and Station 3 is 0.195 mg/100 g. The nutrient levels in the ecosystem were significantly impacted by the presence of a substantial quantity of plastic waste, including buried and slow-to-degrade plastic packaging from household products and other contaminants mixed within the sediments. This pollution introduced additional challenges to the mangrove ecosystem's nutrient balance and overall health.

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