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NUTRIENT AVAILABILITY OF N AND P ELEMENTS FROM MANGROVE LITTERS IN THE SOPPENG RIAJA, BARRU, SOUTH SULAWESI

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Abstract

The mineralization process is responsible for N element availability in the water. The phosphate in the water changes continuously as the results of decomposition and mineralization process between organic and inorganic shapes conducting by microbes. This research aimed to analyze the mangrove litter types to provide nutrients of N and P elements. This study was carried out in a laboratory-scale using a completely randomized design consisting of three treatments and duplicates, and the data were analyzed descriptively. The result showed that the mangrove species *A. marina* had the best releasing times with concentrations of ammonia, nitrite, nitrate and phosphate occured on day 3 (22.523 mg L^{-1}), day 2 (0.005 mgL^{-1}), day 7 (3.644 mgL^{-1}), and day 5 (24.35 mgL^{-1}), and releasing rates of those N-elements were 0.097 mg/L/hour, 0.004 mg/L/hour, 0.3289 mg/L/hour, respectively. The *Bruguiera* spp. had the best releasing times with the concentration of ammonia, nitrite, nitrate and phosphate happened on day 1 (8.093 mg L^{-1}), day 2 (0.011 mg L^{-1}), day 3 (4.339 mg L^{-1}), and day 2 (9.56 mg L^{-1}), and its releasing rates of those N-elements were 0.011 mg/L/hour, 0.003 mg/L/hour, 0.0358 mg/L/hour, respectively. Moreover, the *R. mucronata* had the releasing times with the concentration of ammonia, nitrite, nitrate and phosphate occured on day 1 (7.035 mg L^{-1}), day 2 (0.004 mg L^{-1}), day 7 (26.154 mg L^{-1}), and day 5 (8,72 mg L^{-1}), and its releasing rates of those N-elements were 0.0511 mg/L/hour, 0.031 mg/L/hour, 0.2105 mg/L/hour, respectively.

Key words: *ammonia, litter,mineralization, nitrite, nitrate, phosphate, releasing rate,*

Introduction

The diversity of mangrove ecosystem types in Indonesia is quite high compared to other countries in the world. The number of mangrove species in Indonesia reached 89 consisting of 35 species of trees, 5 species of terna, 9 types of shrubs, 9 species of lianas, 29 species of epiphytes and 2 types of parasites (Nontji, 1987). Among 35 species of trees, the species commonly found on the coast are Avicennia sp, Sonneratia sp, Rizophora sp, *Bruguiera* sp, Xylocarpus sp, Ceriops sp dan Excocaria sp. Mangrove litter is a very important source of organic matter in the supply of nutrients through the process of decomposition by the active role of organisms. Bacteria and fungi are microorganisms that carry out decomposition. Decomposed mangrove litter will produce nutrients that are useful for plant growth (Ariyanto *et al.,* 2018a) and are used by microorganisms (Ariyanto *et al.,* 2018b; Ariyanto 2019) on the forest floor and some will be dissolved and carried by the water recede into the surrounding waters.

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Nitrogen mineralization consisting of proteins and amino acids will produce inorganic nitrogen, namely ammonia (NH_3), nitrites (NO_2) and nitrates (NO_3). Mineralization is a process that is responsible for the availability of N element in water. Mineralization requires weathering organic material which involves the ability of enzymes to hydrolyze complex proteins. According to Handayanto (1999), litter quality factors had the most influence on NH_4 mineralization and NO_3 (nitrification) formation. Nitrogen availability is an indicator of water quality and the environment (Watts *et al.,* 2007). N mineralization is a parameter that can be used to determine the availability of N in waters and is an important process in the nitrogen cycle. N mineralization is a change in shape from organic to inorganic compounds through the results of microbial activity (Gilmour, 2011). The inorganic N forms resulting from mineralization are ammonium (NH_4^+) and nitrate (NO_3^-).

Phosphate (P) is an important nutrient in biochemical reactions in the body of living things (Westheimer 1987). Phosphorus in waters and sediments are mainly originated from phosphorus deposits, industry, domestic waste, agricultural activities, and phosphate rock mining and deforestation (Ruttenberg 2004). This study aimed to determine the time and rate of release of N and P elements resulting from mangrove litter mineralization. The results of the study can be used as a reference to stimulate the growth of plankton in pond waters.

Materials and methods

This research was conducted at a laboratory scale, at the Aquatic Environment Productivity Laboratory of the Faculty of Fisheries and Marine Sciences, IPB University. The study was conducted from January to June 2018, with a completely randomized design (CRD) with 3 three treatments and three replications.

P1 = *Avicenia marina* litter (A)

P2 = *Bruguiera* spp. litter (B)

P3 = *Rhizophora mucronata* litter (R)

Experimental Procedure

Litter samples were dried then each litter was weighed as much as 20g. It was put in a winkler bottle and 1000 ml of artificial sea water was added. The material was centrifuged for 30 min and pH and dissolved oxygen (DO) was measured. The glucose as much as 2g was added and again it was centrifuged for 30 min and pH and dissolved oxygen (DO) was measured. The samples were stored at 20°C for 16h. The N and P content were analyzed and the pH and DO of each sample were measured. The sample was then incubated for 24 h. The N and P content were analyzed and the pH and DO of each sample were measured every day. The graph of N and P was plotted then the N and P climax was observed every day.

Data Analysis

Descriptive analysis of the time and rate of N and P of each litter, the rate of ammonia or nitrite oxidation was determined based on the concentration of ammonia or nitrite at the beginning of the study until the ammonia or nitrite reached its maximum concentration. The nitrification rate was adapted from the previous work of Spotte (1979) as follows:

LPA = [(At-Ao)+(Nit-Nio)+(Nat-Nao)]/t

LPA = Ammonia production rate (mg O_2/L/h)

At = Concentration of nitrogen ammonia at time *t* (mg/L)

Ao = Concentration of nitrogen ammonia at the beginning of study (mg/L)

Nit = Concentration of nitrogen nitrite at time *t* (mg/L)

Nio = Concentration of nitrogen nitrite at the beginning of study (mg/L)

Nat = Concentration of nitrogen nitrate at time *t* (mg/L)

Nao = Concentration of nitrogen nitrate at the beginning of study (mg/L)

t = Duration of observation (h)

LPNi = [(Nit-Nio) + (Nat-Nao)]/t

LPNi = nitrite production rate (mg O_2/L/h)

LOA = 1, 5 × LPA/BA × BM O_2

LOA = ammonia oxidation rate (mg O_2/L/h)

BAN = atomic weight of nitrogen (14)

$BM0_2$ = atomic weight of oxygen (32)

LONi = 0, 5 × LPNi/BA N × BM O_2

LN = LOA + LONi

LN = nitrification rate (mg O_2/L/h)

Results and Discussion

The results of measurements of carbon, nitrogen and C/N ratios for each litter, as well as the oxidation rate of ammonia, nitrites and nitrates are presented in Table 1.

The content of carbon nutrients in *A. marina* litter was 36.16%, *Bruguiera* spp. was 39.12% and *R.*

Table 1: Carbon, nitrogen and C / N ratio content, as well as ammonia, nitrite and nitrate oxidation rates in each litter sample.

Description	Type of Litter		
Nutrient Content	*A. marina*	*Bruguiera* spp.	*R. mucronata*
C (%)	36.16	39.12	42.66
N (%)	3.09	1.77	1.89
C/N ratio	11.7	22.1	22.6
Oxidation rate (mg O_2/L/h)			
Ammonia (NH_3-N)	0.0097	0.011	0.051
Nitrite (NO_2-N)	0.004	0.003	0.031
Nitrate (NO_3-N)	0.0289	0.0358	0.2105

mucronata was 42.66%. Ariyanto *et al.*, (2019) reported that the decomposition rate of mangrove leaves is related to organic C and nitrogen content. Nitrogen nutrient content of *A. marina* litter was 3.09%, *Bruguiera* spp. was 1.77% and *R. mucronata* was 1.89%. (Table 1). Nutrient content in mangrove litter is related to mangrove condition itself, Ariyanto *et al.*, (2018c) mentioned that nutrient content is strongly related to mangrove productivity.

Ammonia (NH_3-N)

Ammonia (NH_3-N) is easily soluble in water. Ammonia is another form of nitrogen in nature as well as a pollutant that is harmful to the aquatic environment and can generate strong odors. The existence of ammonia is the result of the decomposition process of organic materials that contain high nitrogen compounds by microbes (ammonification). Fig. 1 presents observations results on the ammonia mineralization time in each treatment.

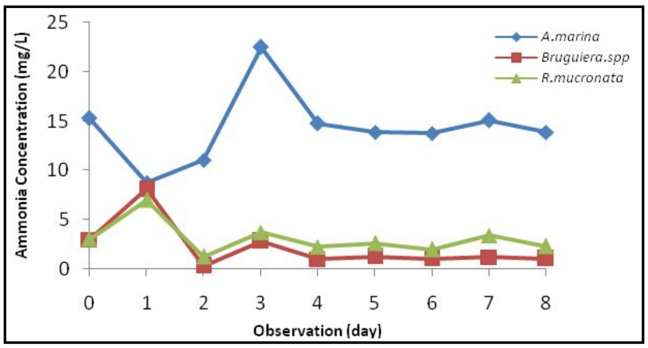

Fig. 1: Changes in ammonia concentration on each day of observation in each treatment.

The fastest ammonia releasing time occurred in *R. mucronata* and Brugeuira spp., which was on day 1 with concentration values of 7.035 mg/L and 8.092 mg/L, respectively. For *A. marina*, the release of ammonia occurred on day 3 with a concentration of 22.523 mg/L (Fig. 1). The earlier time of *Bruguiera* spp. and *R. mucronata* to release ammonia was due to the high C content of each litter which was around 39.12% and 42.66% and also because of the C/N ratio of each litter which was 22.1 and 22.6, respectively (Table 1). As for ammonia oxidation rate, *A. marina* litter was 0.097 mgO_2/L/hr, *Bruguiera* spp. was 0.011 mgO_2/L/hr and *R. mucronata* was 0.051 mgO_2/L/hr (Table 1). The litter material that has a high C/N ratio is more difficult to decompose than the litter material that has a low C/N ratio (Murayama & Zahari, 1992; Kochy & Wilson, 1997; Krishna and Mohan 2017).

Nitrite (NO_2-N)

Nitrite in the waters indicates the amount of nitrogen which is partially oxidized. Nitrite is an intermediate product in the transformation process of organic substances into nitrate, therefore generally, the presence of nitrite does not last long. The amount of nitrite in nature is small, and under sufficient oxygen conditions, nitrite turns into nitrate while under anoxic conditions, nitrite turns into ammonia. Fig. 2 presents the rate of nitrite mineralization in each treatment.

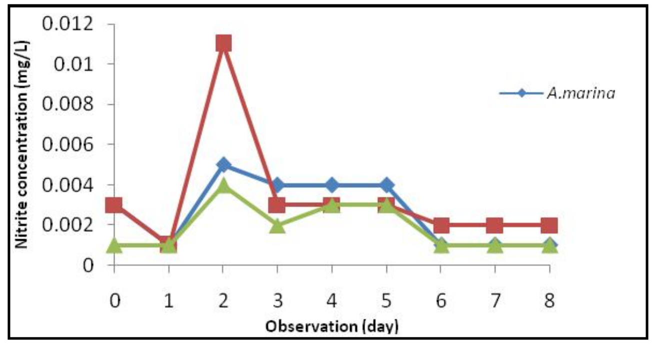

Fig. 2: Changes in nitrite concentration (*NO_2-N*) on each day of observation in each treatment.

Based on Fig. 2, the bacteria can carry nitrification activities on day 1 to day 5. Nitrite release for the three types of mangroves (A. marina, *Bruguiera* spp. and *R. mucronata*) occurred at the same time, which was on day 2. The nitrite concentration of *A. marina* was 0.005 mg/L, *Bruguiera* spp. was 0.011 mg/L, and *R. mucronata* was 0.004 mg/L. At the beginning of the treatment, the concentration of ammonia and nitrite was dropped, this was due to the adaptation of the bacteria to the new condition, after a few days, the bacteria were able to perform the nitrification process under anaerobic conditions. The nitrite oxidation rate for *A. marina* litter was 0.004 mgO_2/L/hr, *Bruguiera* spp. was 0.003 mgO_2/L/hr, and *R. mucronata* was 0.031 mgO_2/L/hr (Table 1).

Nitrification is the transformation process of nitrogen from ammonium ions to nitrate ions. Barbarick (2006) stated that this process is an enzymatic oxidation process by specific microorganisms that occurs in two continuous stages, which are ammonium oxidation and nitrite oxidation. The first stage involves the obligate autotroph bacteria known as *Nitrosomonas*, with the result of nitrite ions. Several factors must be considered to control the nitrification process in the soil, which are: 1) the availability of $NH4^+$ ions, 2) the concentration of oxygen and carbondioxide, 3) pH, and 4) temperature. The concentration of $NH4^+$ ions in waters is the beginning of the nitrification process. This process is greatly influenced by the rate of mineralization and nitrogen fertilization which contains ammonium, because at the low rate of mineralization and the low addition of nitrogen fertilizer, nitrification will also be suppressed. The concentration of oxygen and carbon dioxide in the waters, in general, will support the nitrification process (Sepehri and

Sarrafzadeh 2019).

Nitrate (NO_3-N)

Nitrate is the main form of nitrogen in waters and is the primary nutrient for plant and algal growth. Nitrate is soluble in water, stable, and not toxic to aquatic organisms. Fig. 3 shows the laboratory analytical results of the rate of change in the concentration of nitrate (NO_3) of each treatment.

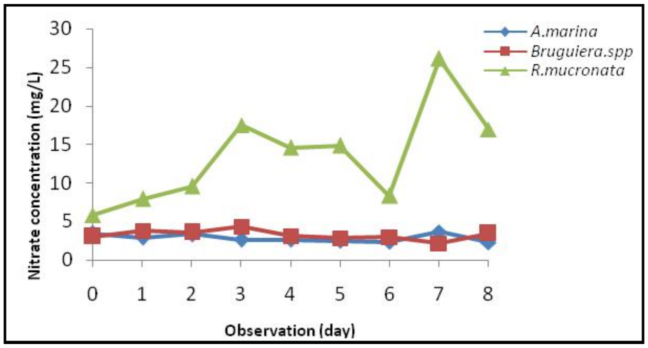

Fig. 3: Changes in nitrate concentration (NO_3-N) on each day of observation in each treatment.

The fastest release of nitrate occurred in *Bruguiera* species, which occurred on day 3 with a concentration of 4.339 mg/L. The nitrate release of *A. marina* occurred on day 7 with a concentration of 26.154 mg/L, and it was the same for the *R. mucronata* which also occurred on day 7 with a concentration of 3.644 mg/L (Fig. 3). The fast time of *Bruguiera* spp. to release nitrate was due to the smallest N content of 1.77% while also showed a C/N ratio of 22.1 (Table 1). Nitrate oxidation rate of each treatment of *A. marina* litter was 0.0289 mgO_2/L/hr, *Bruguiera* spp. was 0.0358 mgO_2/L/hr, and *R. mucronata* was 0.2105 mgO_2/L/hr (Table 1).

The rate of nitrate mineralization depends on temperature, pH, and C/N ratio. The higher C/N ratio results the faster rate of nitrate mineralization (Rahn *et al.*, 2003). The rate of nitrate mineralization was determined through a curve, in which the rate of mineralization of *R. mucronata* litter took place quickly, whereas in the litter of *A. marina* and *Bruguiera* spp., the rate of mineralization was slowly. Besides functioning as a nutrient enhancer, organic matter is also used as an amendment material. This is based on biochemical potential and the ability to mobilize nitrogen nutrients, especially organic matter with a high C/N ratio, while organic matter with a low C/N ratio can stimulate the rate of clean N mineralization. The results of experiments that have been carried out by Rahn, *et al.*, (2003) by using various sources of organic matter with varying C/N ratio indicate an obstacle to the rate of clean N mineralization in the decomposition process of sugar cane leaves in sandy loam soils by organic matter with high C/N ratio. The process of nitrification from nitrite to nitrate occurred on day 4, except for *R. mucronata*, which occurred at the beginning and will be used by plankton for growth and metabolism.

Orthophosphate (PO4)

Phosphate compounds are essential compounds in metabolism and reproduction. Phosphate compounds are generally present in the oxidation stage either in the form of orthophosphate organic ions or in organic forms which are mostly biogenic compounds. Fig. 4 presents the rate of change in the orthophosphate concentration in each treatment.

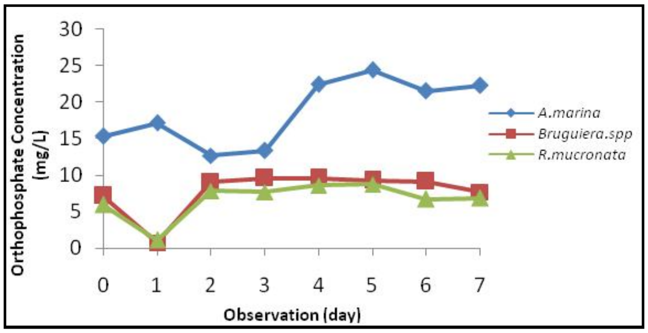

Fig. 4: Changes in orthophosphate concentration on each day of observation in each treatment.

Fig. 4 shows the release of orthophosphate on the second day of *Bruguiera* spp. species with concentration of 9.56 mg/L), *A. marina* and *R. mucronata* on day 5 with each concentration of 24.35 mg/L and 8.72 mg/L. Orthophosphate is a form of phosphate that can be used directly by aquatic plants, whereas polyphosphates must undergo hydrolysis to form orthophosphate first, before it can be used as a source of phosphate. Phosphate and nitrate are the nutrients required and have an influence on the growth and development of living organisms in the waters. Phytoplankton is one of the biological parameters which is closely related to phosphate and nitrate. High and low abundance of phytoplankton in the waters depends on nutrient content in the water including phosphate and nitrate nutrients.

Fig. 4 shows the change in orthophosphate concentration was more increased in stable ammonia and nitrate conditions. Phosphate is an important factor for the growth of phytoplankton and other organisms. Phosphate is needed as a form of energy transfer from the outside into the cell of organisms (Sharma *et al.*, 2013).

Dissolved Oxygen (DO)

Dissolved oxygen in the waters illustrates the amount of oxygen gas content dissolved in water. Dissolved oxygen in water generally comes from photosynthesis by phytoplankton and diffusion from the air. Oxygen solubility is influenced by temperature, partial pressure of gases in the air and water, salt content and the presence of easily oxidized elements or compounds contained in water. The dissolved oxygen content was measured every day in each treatment (Fig. 5).

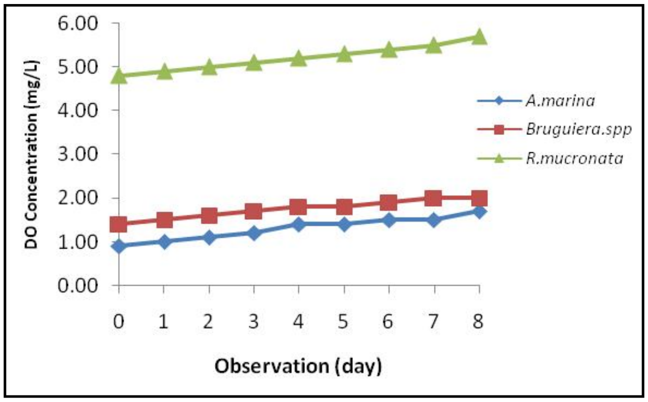

Fig. 5: Change in dissolved oxygen concentration on each day of observation in each treatment.

Dissolved oxygen of mangrove *Avicennia*, *Bruguiera* and *Rhizophora* litters at the beginning of the study had values of 0.90, 1.4 and 4.80 (mg/L), respectively. The mineralization process occurred along with the increase in dissolved oxygen with values of 1.70, 2.0, and 5.70 (mg/L) (Fig. 5). Dissolved oxygen is needed for respiration and decomposition of organic substances by microorganisms (Patty *et al.*, 2015). Wang *et al.*, (2018) mentioned that the required dissolved oxygen content plays a role in the decomposition process because macrophyte as decomposers need oxygen for their lives. Factors that can reduce oxygen levels in water are an increase in temperature, the respiration process, the input of organic waste, increased salinity and the decomposition process of organic matter by microorganisms.

pH

pH is the result of measurements of hydrogen ions in the waters and shows the quality of waters as the environment. The presence of nutrients can indirectly be affected by changes in pH values, the pH value of each treatment is presented in Fig. 6. pH affects the activities of microorganisms on aquatic biodegradation processes (Krachler *et al.*, 2012). One of the processes is the denitrification that is a microbiological process where nitrate and nitrite ions are converted to nitrogen molecules (N_2) and the final production of the process will produce an inert gas that cannot be used directly. This will have an impact on nutrient content, in which the nutrient content that can be utilized will decrease.

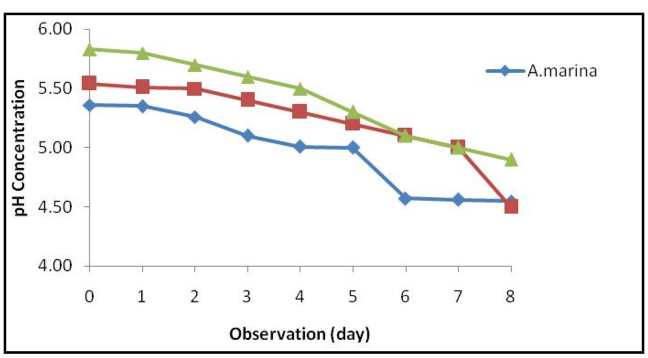

Fig. 6: Change in pH concentration on each day of observation in each treatment.

In general, the pH value in a waters ranges from 4 to 9, while in mangrove areas the pH value can be lower due to high organic matter content. The results of pH measurements from the beginning to the end of the study were *A. marina* litter had pH of 5.36-4.55, *Bruguiera* had a pH of 5.54-4.50 and *R. mucronata* had a pH of 5.83-4.90 (Fig. 6).

Conclusion

The availability of high N and P nutrients in waters was originated from mangrove litter *R. mucronata*, but the time required was relatively long. In contrast, *Bruguiera* spp. had a low nutrient availability, but the time required was relatively fast, whereas *A. marina* had a low nutrient availability and required a long time. The highest oxidation rate of element N was found in the *R. mucronata* litter followed by *Bruguiera* spp. and finally the lowest was of *A. marina* litter. For the continuous availability of nutrients, it is necessary to combine the three types of mangrove litters. Dissolved oxygen and pH affected the time and rate of the mangrove litters.

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