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Decomposition of Organic Sediment in Coastal Indonesia Wetland

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A R T I C L E I N F O

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A B S T R A C T

This paper aims at describing the sediment organic feature, benthic process and decomposition model of several wetland macrophytes systems. The compared systems are (1) a system with no water circulation (TPA), (2) with water circulation (DPA) containing the floating plant Phragmites vallatoria as main vegetation, (3) combined with the addition of nitrification bacteria (DB) and (4) without its addition (TB). The effectiveness of the system in removing nitrogen 'pollutants' is determined by its ability to oxidize an input of nitrogen, in the form of ammonium addition at concentrations starting from (a) 10 ppm, (b) 20 ppm, to (c) 30 ppm. Parameters used for evaluating a consolidation mechanism of organic sediment in nitrogen removing are ammonium, nitrite, nitrate concentration, and three physical factors, i.e., dissolved oxygen, pH, and temperature. The result shows that removing ammonium has a peak of effectiveness at 30 ppm ammonium addition for DPA. Through a nitrification, BOD (Biological Oxygen Demand) will increase and oxygen concentration will decrease in the water. The pH of both of system is decrease gradually, the physical factors result shows that DPA more effective than TPA, while the temperature was relatively constant at around 22°C. The system using similar vegetation has more efficient in term of removing ammonium.

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1. Introduction

The tidalflat, wetland and coastal estuaries are transitional ecosystems between the terrestrial upland areas and open water aquatic ecosystems. They represent the aquatic edge of many terrestrial plants, and the terrestrial edge of many aquatic plant species. Small changes in a wetland's hydrology can result in significant biotic changes within the ecosystem. A wetland and constructed wetland provide a potentially inexpensive, energy-saving, and environmentally friendly alternative to wastewater handling including nitrogen-containing agricultural pollutants widely used in US and Europe but not in developing countries including Indonesia (Choesin et al., 2006).

Erosion and deposition of bottom sediments of wetland environment reflect a dynamic feature between hydrodynamic force applied to a sediment bed and condition of the bed it self including the consolidation. Erosion of fined and mixed sediment beds of wetland depends on their composition and its benthic ecosystem lived in it. This paper presents a new examination of treated sediment organic in the wetland and its effectiveness in removing nitrogen 'polutant'.

2. Decomposition and erosion of organic sediment

Erosion and deposition of bottom of organic sediments reflect a continual, dynamic adjustment between fluid forces applied to a sediment bed and the condition of bed itself. Erosion will occurred if there is a acceleration of currents. On the other hand, deposition will not be occured until just before slack water. A consolidation lag results a higher suspended sediment concentrations after erosion events.

In the mixed mud and sand cases without bioturbation, distinct layers of high and low sand content form and mud suspension are strongly limited by sand armoring. In the mixed mud and sand cases with bioturbation, suspended mud concentration are greater than or equal to either of the other cases. Low surface critical stress are mixed down into the bed, constrained by the tendency to return towards equilibrium.

The most important description of bed deposition and erosion for organic sediment is erodibitily, a combination of resistance to initial motion (often expressed as a critical stress for motion) and erosion rate (often expressed as a function of the applied stress or the difference between applied stress and critical stress). For purely fine, cohesive sediment bed, erodibitlity is a function of sediment grain size, water content, mineralogical composition, organics, cation exchange capacity, and biological activity, as well as the ionic composition, pH and temperature of the water (Sanford, 2006). General recognition that fine sediment erodibility is difficult to predict a priori has led to the development of a number of techniques to measure it directly, ranging from laboratory flume test of sediment samples from the field into field tests using either submersible flumes on the bottom or carefully collected core samples (McNeil et al., 1996).

3. Ecosystem of wetland and its function for removing nitrogen

The water quality of many wetlands including in Indonesia is usually contaminated by pollutant from anorganic fertilizer or pesticide or urea in the form of suspension in the water through the rivers. If this pollutant is not controlled, it will triggere the eutrophycation to the water and increase uncontrolled the algae and aquatic plants.

The wetland as part of the ecosystem can be as a source, sink or transformer for various chemistry pollutants. Generally speaking, the wetland can be adopted as sink or reducer for organic and anorganic compound until its output number become smaller than input number. In wetlands interact between biotic and abiotic components in the food web and transfer energy to produce an equilibrium. The pollutant material in the wetland acts as basic materials in web food or as resources of nutrition for microorganism and water biotic, and those materials become degradating in the system.

The degradation and transformation of nitrogen in the wetland can be classified into: (1) assimilation, (2) fixation, (3) amonification, (4) nitrification and (5) denitrification. Assimilation is organic nitrogen compound as protein and amino acid resulted by autotroph bacteria and aquatic plant. Fixation is a production of phototroph bacteria as ammonium and organic nitrogen into sediment. Amonification is ammonium production through mineralization of organic nitrogen in the water by plant, organism and microorganism. Nitrification is oxidation process from ammonium into nitrite and nitrate helped by aerobe bacteria. Denitrification is reduction of nitrate to nitrite, dinitrogen oxyde and nitrogen gas. The scheme of nitrogen transformation in the wetland is shown in Figure 1 after Mitsch and Gosselink, 1993.

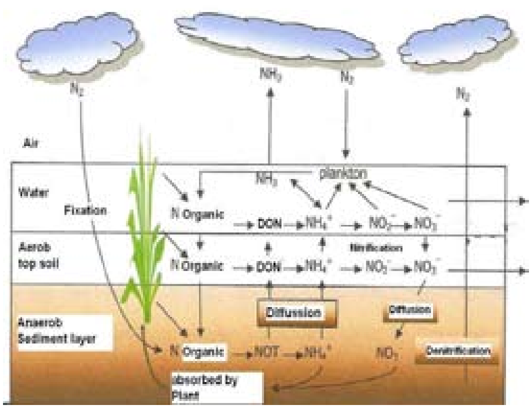

Figure 1: Transformation of nitrogen in the wetland after Mistsch and Gosselink, 1993. (DON = Dissolved Organic Nitrogen).

The effectiveness of wetland in order to normalize the polluted water is determined to the potential of system for oxidizating of ammonium compound and nitrite into nitrate (nitrification potential). The system called effective if mostly of ammonium (NH4) is oxidazed to nitrate. The typical of nitrification process generally tends to follow pattern in Figure 2.

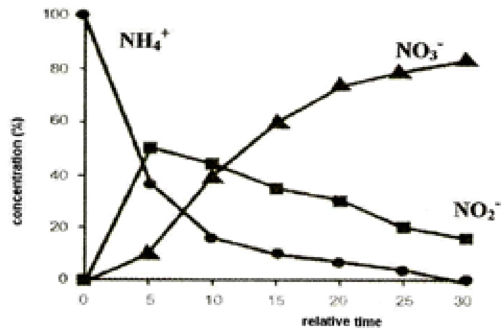

Figure 2: Time series of nitrogen compounds in a nitrification process (Sawter and McCarty, 1978 in Effendi, 2003).

4. Effect of vegetation for removing ammonium

One of wetland functions in ecosystem equilibrium is to remove ammonium pollutant in order to reduce the concentration of nitrogen in water column. This function is mainly controled by vegetation in the wetland system.

The effect of vegetation for removing ammonium is examined by the experiment started on September 2004 – July 2005 in aquatic ecosystem analytic laboratory ITB - Indonesia after Karlina, 2005. The vegetation used for the series test are Phragimates vallatoria and nitrification bacteria. The wetland is modeled by water tank sized 1m x 1 m x 0.5 m with 16 Erlenmeyer tube with capacity 100 ml for collecting measured sample, with two pumps and its accessories. The used measurements are DO-meter, pH-meter, spectrophotometer, dropping pipe-tube, 45 chimerical reaction tubes. The substrate as a model of organic sediment is mixed soil, sand and corals.

The method of experiment, firstly simulating farm polluted water in this system containing of nitrogen. The model of polluted water is mixed water containing of NH4Cl enter to system continuously, start from 10 ppm addition, 20 ppm and 30 ppm. The system of wetland is a modification between FWS (Free Water Surface) and SF (Subsurface Flow). The type of substrate is mixed coral, sand and soil with composition ratio = 2:1:1. In this experiment, there are two types of design systems: TPA (without water circulation) and DPA (with water circulation) in order to observe the effectiveness of circulation effect in the system. The difference of both systems is shown in Figure 3.

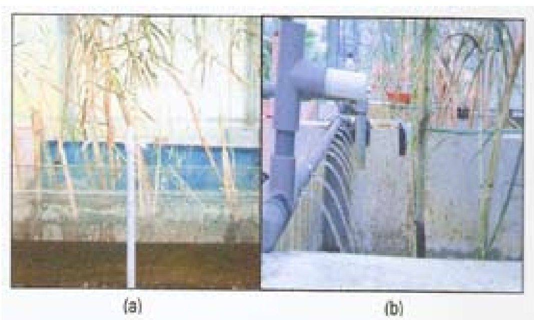

Figure 3: The wetland model in the laboratory, (a) TPA, without water circulation system, (b) DPA, with water circulation.

Karlina (2005) shows that, DO (Dissolved Oxygen) in TPA is around 6.9 – 8.3 mg/l, on the other hand, DO in DPA is around 5.2 – 6.7 mg/l. DO in TPA tends lower than DPA and it has fluctuation of concentration. This phenomenon is based on photosynthetic of the plant producing oxygen needed for microorganism in order to oxidize ammonium to nitrate. Nitrification is aerobe process using aerobe microorganism requiring oxygen. Through a nitrification, BOD (Biological Oxygen Demand) will increase and oxygen concentration will decrease in the water. Photosynthetic of plant and oxygen diffusion from atmosphere will enhance DO in the water. This process is happened in TPA and DPA system, but aeration in DPA system gives effect for stabilizes of oxygen concentration in the water.

The result of measuring pH for both of system shows the same trend, both of pH is decrease gradually. The reason because of nitrification makes acidization (Kim et al., 2000 in Suantika, 2001). The stable of pH is important for the effectiveness work of nitrification bacteria. The physical factor results show that DPA more effective than TPA, while the temperature was relatively constant at around 22oC.

Another evident for the effect of vegetations on ammonium removing is shown in examined the three variation of vegetations: (1) Canna X generalis, (2) Sagittaria montevidensis and (3) combination between Canna and Sagittaria and one addition system for without any vegetation as a comparation control. Each systems is examined with detention time for 8 days. This time is required for contamined pollutant process into a minimum level of ammonium (Merz, 2000).

The effect of vegetation variation in the system shows in Figure 4 which coresponds to Fig. 4 in term of tendency of ammonium (NH4) removing. In general situation, the system 1 is the most effective vegetation type for ammonium removing in the system. Based on this result, it is concluded that the system using similar vegetation has more efficient in term of removing ammonium.

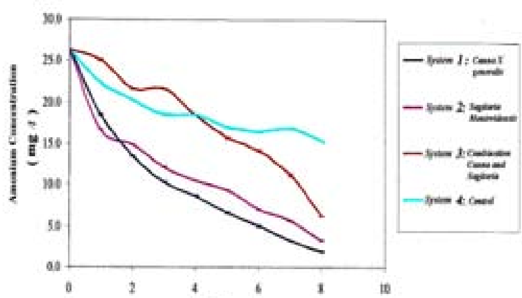

Figure 4:Time series of ammonium for several type of vegetations.

The mechanism of removing ammonium is produced by natural and biological process from vegetation and micro-organism. One of the final product of ammonium oxidation is nitrate which more stable than nitrite. The effect of variation vegetations on nitrate fluctuation is shown in Figure 5. This figure indicates the nitrate will increase gradualy in a fluctuation.

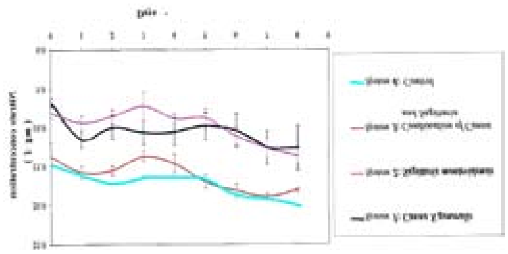

Figure 5: Time series of nitrate for several type of vegetations.

The increasing of nitrate concentration occurs in 8 days, due to a convertion of ammonium to nitrite by microorganism containing in the subtrate. Nitrite is an intermediate product of nitrification process. This ion is mostly not stable, there fore it immediately oxidized to nitrate. The decreasing of nitrate in several days occur probably due to a nitrate asimilation by vegetation and microorganism in the system.

In the oceanic and water ecosystem, assimilation of nitrate by vegetation is a dominant process due to the low capability of vegetation for fixation N2 from the air. The high of concentration of nitrate in final time shows that nitrate is not fully consumed by vegetation or microorganism containing in the wetland. This phenomenon is suggested due to the characteristic of vegetation has more effect to the ammonium than to the nitrate. The nitrate concentration is mostly stable and not related to nitrate absorbed by vegetation.

3. Conclusion

The wetland model with free water surface and Phragmites vallatoria as main vegetation can be used for removing of nitrogen pollutant in the water. Water circulation and nitrification bacteria addition will increase oxidized ammonium. The effectiveness of system is indicated by the number of ammonium oxidation and nitrite reduction to nitrate as one of indicators for consolidation of organic sediment in the wetland. The result shows that removing ammonium has a peak of effectiveness at 30 ppm ammonium addition for DPA. Through a nitrification, BOD (Biological Oxygen Demand) will increase and oxygen concentration will decrease in the water. The physical factors result shows that DPA more effective than TPA. The system using similar vegetation has more efficient for removing ammonium.

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