Improvement of waste water quality to increase planting index in acid sulphate soil of Central Kalimantan

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Abstract. This study aimed to determine the water return effect through the application of formulas from isolates of the bacterium *Thiobacillus ferroxidan* in increasing the crop index in acid sulphate soil. This research was carried out during two planting seasons in the tidal swampland based on hydrological units and overflow types with crop production in MT 1 and MT 2. This study used the split plot design with main plots the water management system, namely: (1) control with an open water system (leaching); (2) inoculant formulas with closed systems (no leaching); (3) without formula with a closed system (no leaching). Subplots were types of organic materials, namely: (1) control; (2) multi organic compost; (3) farmer patterns; (4) rice husk biochar + multi organic compost. The results showed that application of *Thiobacillus ferroxidan* in waste channels in acid sulphate soil effectively improved wastewater quality by increasing the pH value of wastewater by 13.09%. The returning water through the application of formulas from isolates of *ferroxidan* in sewage can increase the crop index to IP ≥200 in acid sulphate soil and rice yields of 20.94% dry grain in the first planting season and yield of corn shelled by 34.57% in the second season.

1. Introduction

The reduction process in acid sulphate land takes place with the help of anaerobic bacteria and the availability of organic material. Organic matter plays a role in releasing Fe²⁺ in submerged soils because, in the reduction process in submerged soils, organic matter is a substrate for microbial reducing Fe³⁺. The reduction in the value of redox potential to -50 mV in rice cultivation in acid sulphate soils in Thailand would increase the reduction process so that the Fe³⁺ concentration increases [1]. The water factor has an essential role in the success of farming in acid sulphate land. Washing toxic materials would work well if there was enough freshwater, both from rain and from high tides and forest water [2]. Tidal dynamics influence water quality at the inlet on acid sulphate land in river water. The water quality in acid sulphate
soils in the Mekong delta of Vietnam showed that the quality of water in the drainage canals 41 and 85 days after planting was worse than in the inlet shown by pH values between 2.6-2.9, soluble aluminum 57-148 mg.kg⁻¹ and total acidity range from 11-26 mol.L⁻¹, while in the inlet water pH ranges from 6.3-6.8, soluble aluminum around 1.3-7.2 mg.kg⁻¹ and total acidity 0.15-0.56 mol.L⁻¹ [3]. This indicates that the toxic elements are washed and carried into the drainage channel so that the quality of drainage water is low.

Some aquatic plants can absorb or filter toxic substances that are in the water. Rats (Eleocharis dulcis) are aquatic plants that grow predominantly in acid sulfate soil environments and can be iron-absorbing agents through specific mechanisms that are suspected of symbiosis between plants and microorganisms. The aquatic plants that can absorb or filter toxic elements in sewage are related to the presence of microbes that can reduce heavy metals in water [4]. *Thiobacillus ferrooxidans* is a bacterium that has an iron oxidase, so it can metabolize metal ions, such as ferrous iron. *Thiobacillus ferrooxidans* is motile, gram-negative, rod-shaped, small short chains, rounded ends, obligate aerobes [5]. *T. ferrooxidans* could grow on oxidized or reduced soils (inundated for 1 month) [6]. Based on the reaction of microorganisms to oxygen (soil drying), it shows that the bacteria *T. ferrooxidans* are microaerophilic (obligate aerobic organisms that continue to thrive in low oxygen content). *T. ferrooxidans* can oxidize Fe²⁺ to Fe³⁺ and oxidize the reduced sulfur compounds and utilize this oxidant as their energy source.

In soils that have been reduced (stagnant) continuously for 1 month with an oxygen concentration of more than 1%, it is still found that there are still *Thiobacillus sp.* and *T. ferrooxidans*. The use of the *Thiobacillus ferroxidan* bacteria to improve wastewater quality not only increases rice crop production but can also reduce methane (CH₄) emissions from rice cultivation. This relates to the role of SO₄²⁻ as an electron acceptor, so there is no need to reduce CO₂ to CH₄. Thermodynamically methane (CH₄) is formed after most ferric iron (Fe³⁺) is reduced to ferrous iron (Fe²⁺). Soil microbes have a mechanism that causes changes in the mobility of metal elements so that it becomes more difficult or easier for plants to absorb. Changes in the mobility of metal elements by microbes are grouped into two namely: redox changes from inorganic metals and changes in the shape of metals from inorganic to organic and vice versa, specifically these changes are the processes of methylation and demethylation. Through oxidation of metals such as iron, microbes can obtain energy. On the other hand, a metal reduction can take place through the process of dissimilation in anaerobic respiration, when microbia use metals as terminal electron acceptors [7-9].

2. Material and method

This research was carried out for two growing seasons in selected locations on tidal swamps with an area of 500-800 m² designed in a water management unit based on hydrological units and overflow types, with rice crops in MT 1 and Corn / Soybean in MT 2. Land use planning and water management improvement were carried out in the study area. In the surjan farming, horticultural crops would be planted to diversify the plants so that the IP can increase to IP ≥200. Land structuring was done by making plots and inlet and outlet channels. For the perimeter channel also made along with the land. In the research plot, storage would be made. It was used as a place to collect wastewater before the wastewater was returned to the plot of land to be reused as a source of water for plant growth. In the outlet channel (outlet), planted rat purun plant (*Eleocharis dulcis*) was used as phytoremediation material with uniform specifications of age and performance. Then the 2017 inoculant formula chosen in 2017 was applied in the sewer to improve the quality of the wastewater.

The research for MT 1 with rice commodities used the split plot design with main plots, namely: (1) control (without formula) with an open water system (leaching process), (2) inoculant Formula with a closed system (no leaching process), (3) no formula with a closed system (no leaching process). The leaching process also affected the depletion of soil nutrients due to soil nutrient washing. Subplot was a type of organic material, namely: (1) control (without organic matter), (2)
multiorganic compost (30% straw compost combination + 30% descent compost + 40% cow manure compost) + NPK 75%, (3) pattern farmers, (4) biochar rice husk + multi organic compost (30% straw compost combination + 30% descent compost + 40% cow manure compost) + NPK 50%. Research for MT 2 with maize commodities using the split plot design with main plots, namely the water system namely: (1) control (without formula) with an open water system (leaching process), (2) inoculant Formula with a closed system (no leaching process), (3) no formula with a closed system (no leaching process). Plots were types of organic material, namely: (1) phonska NPK 450 kg/ha + urea 300 kg/ha + SP36 300 kg/ha (A1), (2) NPK mutiara 450 kg/ha + Urea 300 kg/ha + SP 36 300 kg/ha (A2), (3) Urea 450 kg/ha + SP 36 300 kg/ha + KCl 300 kg/ha (A3), (4) farmer method (NPK phonska as much as 300 kg/ha + SP 36 as much 300 kg/ha) (A4). Observation of growth was carried out when the rice and corn plants were 30, 60, 90 days after planting with height parameters for rice and diameter for corn stems. The water quality parameter in all treatments included pH, Eh, TDS, Fe, SO\(_4\), and H\(^+\). The parameters of the yield consisted of GKP, the weight of corn stover, dried corn cob (harvested), and dried corn shelled.

3. Results and discussion

3.1. Planting Season I

The results showed that through the improvement of wastewater quality, the planting index in tidal swamp land type B overflows could be improved. Wastewater quality data given in the formula application was shown in the following table.

| Treatment | Water quality parameter |
|------------|-------------------------|
|            | pH | Eh (mV) | TDS (ppm) | Fe (mg/kg) | SO\(_4\) (mg/kg) | H\(^+\) (mg/kg) |
| Without formula, purun plant (Eleocharis dulcis), leaching (P1) | 5.02 | 4.55 | 77.93 | 141.67 | 42.98 | 0.460 |
| Without formula, purun plant without leaching (P2) | 4.38 | 3.98 | 50.33 | 164.67 | 38.36 | 0.460 |
| Inoculant + purun plant without leaching (P3) | 5.04 | 4.65 | 39.30 | 152.00 | 35.23 | 0.460 |

The results of the research on the application of the *Thiobacillus* bacterial formula in the tidal swampland showed that the presence of inoculant formulas could improve wastewater quality. The effective value of increasing the pH of wastewater was 12.75% in plots without inoculants with intensive washing each large pair lower than in plots that were given inoculant formulas without washing processes the effectiveness of increasing the pH value of water was 13.09%. The higher the pH of water, the Al\(^{3+}\) and SO\(_4^{2-}\) solutions and the lower the DHL value. This was followed by the effectiveness value of the heavy metal reduction in water such as Fe was 13.97% for plots without formulas with leaching and 8.3% for plots with formulas without leaching. Giving inoculant formula in the sewer was quite effective in increasing the pH of the water and decreasing the concentration of Fe in water. The formulation of the method combined with the addition of biochar ameliorant rice husk increased the yield of unhusked rice (GKP) reaching 5.85 t/ha compared to no formula at leaching just reaching 4.48 t/ha. The effectiveness of increasing grain yields with the addition of a method combined with multi organic + biochar compost ameliorant reached 20.94%.
Figure 1. Plant performance in the vegetative phase for MT 1

Figure 2. Plant performance in the generative phase for MT 1

Figure 3. Results of GKP (t/ha) of rice plants
The results of the study for planting season 1 with rice commodity showed that the administration of formulas in waste channels combined with multi organic compost ameliorant + rice husk biochar increased GKP yield by 20.93% higher compared to the combination of multi organic compost ameliorant without biochar only reaching 7.71%.

3.2. Planting Season II
The effectiveness of the formula given in the drain canal was seen in the second crop with corn commodity in acid sulphate fields. The results showed that the effect of providing inoculant formulas in the distribution of wastes with no leaching process was quite useful because it improved soil quality in the second growing season. Whereas in this second season, rainfall from the upstream area was relatively small resulting in the tides of the Barito river which carry the water of good quality being able to enter further upstream of the secondary and tertiary channels.

![Figure 4. The dynamics of soil pH](image)

The highest pH value was shown in the plot of the treatment effect of adding *Thiobacillus ferrooxidans* bacterial inoculant formula with ameliorant Urea, SP36 and KCl, which can increase the soil pH value close to 5. Improving the soil pH value would be followed by a decrease in the soil DHL value.

![Figure 5. The dynamics of DHL](image)
Figure 6. Maize Cropping Results in the Second Season Crops

Figure 7. Maize yields in the second season
Effectiveness of application of inoculant formula with the addition of ameliorant to the second planting season corn yield increased yield of corn dry shelled by 34.57% compared without inoculant formula with the water returned to produce dry shelled of 5.09 t/ha (water content content of 15%) and 6.82 t/ha in treatment without inoculant formula with washing.

4. Conclusion

Improvement of wastewater quality using the thiobacillus ferroxidan bacterial formula in sewerage in acid sulphate land effectively improves wastewater quality by increasing the pH value of wastewater by 13.09%. The returning water through the application of formulas from isolates of *Thiobacillus ferroxidan* bacteria in sewage can increase the crop index to IP ≥200 in acid sulphate soil and rice yields of 20.94% dry grain in the first planting season and yield of corn shelled by 34.57% in the second season. Improvement of wastewater quality in acid sulphate land can increase the planting index from IP 100 to IP ≥200.

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