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Wastewater phytoremediation by *Salvinia molesta*

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ABSTRACT

In natural biological treatment systems, floating macrophytes have been used in maturation pond in recent years to upgrade effluents from stabilization ponds and are to achieve secondary treatment effluent quality from primary sewage effluent. In this study, the performance of phytoremediation by *Salvinia molesta* macrophytes on treated Palm Oil Mill Effluent (POME) is investigated. The objectives of the study are to determine the nutrient uptake by *S. molesta* from treated POME and its effect towards the biomass and biochemical content. The water quality after phytoremediation were monitored. The wastewater phytoremediation by *S. molesta* was conducted outdoor for 16 days in a raceway pond rig. The results showed that *S. molesta* achieved 95% phosphate removal efficiency from the wastewater, lowering concentration to 0.17 mg/l. Nitrate concentration was determined to be at 0.50 mg/l at the end of the experiment. Ammonia concentration showed a dynamic fluctuation trend with average value of 2.62 mg/l. For water quality assessment, turbidity decreased from 7.56 NTU to 0.94 NTU in just 2 days' time. MLVSS analysis was significantly low by day 2 of experiment. COD removal efficiency was determined at 39%. All six water quality assay met their respective statutory discharge limit. The *S. molesta* cultivated in the raceway pond rig also showed increment toward the biomass gain, carbohydrate and protein at the end of the experiment. This study indicates that *S. molesta* plants have the potential to be used in the phytoremediation of treated POME and showed a superior biochemical composition.

1. Introduction

Macrophytes are conspicuous aquatic plants that dominate wetland, shallow lakes, and streams. They grow in or near water and can be emergent, submerge or floating. They play a vital role in healthy ecosystems by serving as primary producers of oxygen through photosynthesis, providing a substrate for algae and shelter for fish and many invertebrates, helping nutrient recycling to and from sediments and aiding in stabilizing river and stream banks. They also act as food and suitable nesting habitats for the wildlife [1]. Macrophytes have the potential to be used to treat the wastewater owing to their natural characteristics. Taking duckweed as an example, they are fast growing plants double biomass between 16 h to 2 days [2] and efficient in removing nutrients and heavy metals from the water. Some of the recent researches employ them for the removal of dye and radioactive substances from polluted water. Duckweed becomes prominent in sewage treatment research apparently because of its ability to concentrate minerals on heavily polluted water. They grow on water with relatively high levels of nitrogen, phosphorus, potassium and concentrate the minerals and accumulates high protein concentration in the plant [1].

Macrophytes play crucial role in influencing biological, chemical and physical treatment processes in constructed wetlands [3]. They are able to filter off suspended solids, protect against erosion by reducing turbulence and flow velocities of water bodies which helps stabilization of sediments [4,5]. The macrophytes are also known to suppress development of wind wave in shallow waters. The reduced wave height results in reduction of bottom sediments resuspension. Less turbid and lower organic matter concentration in water body are found in the area with dense vegetation of macrophytes. Therefore, these aquatic plants are crucial in deciding water quality of shallow water columns and have potential in polishing the polluted water [6]. Metabolic functions of these aquatic plants consist of nutrient uptake and O_2 release from roots into the rhizosphere [3]. To be well adapted to anaerobic conditions, macrophytes develop internal air sacs (aerenchyma) that transport O_2 to the root zone [7]. Researchers believe that the aquatic plants are able to release the O_2 from roots to surrounding rhizosphere and providing aerobic conditions for occurrence of nitrification [8,9]. These aquatic macrophytes are important in maintaining the healthy community of aquatic environments. They also help

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in increasing habitat complexity and affect various organisms like invertebrates, fishes and water birds [10].

The macrophytes ability and capability in the nutrient removal from water bodies are currently a concern among the researchers since the last two decades [11–13]. One study demonstrated the nitrate removal efficiency from synthetic medium and groundwater in different areas in India [14]. In their study, water hyacinth, water lettuce and *Salvinia* were used. Water hyacinth achieved high nitrate removal efficiency of 83% in synthetic medium with initial nitrate concentration of 300 mg/l. This efficiency decreased as the initial nitrate concentration increased as the osmotic pressure at higher concentration supress the uptake of the nitrate. Water lettuce and *Salvinia* showed lower nitrate removal efficiencies in the same medium. Nitrate removal was greatly dependent upon the presence of other nutrients, namely sulphate and phosphate which caused lower nitrate uptake by water hyacinth. Xu and Shen [15] found that the duckweed, *Spirodela oligorrhiza* system was able to remove 83.7% total nitrogen (TN) and 89.4% of total phosphorus (TP) from swine lagoon water in eight weeks at a harvest frequency of twice a week. Total biomass harvested achieved 5.3 times that of the starting amount. Iamchaturapatr, et al. [16] studied 21 different aquatic plants in vertical free surface flow constructed wetlands. They showed that floating macrophytes like water hyacinth, water lettuce and water chestnut performed maximum nutrient removal rates according to plant weight calculation while most emergent macrophytes performed maximum nutrient removal rates based on planted area calculation. Their studies showed that the nutrient removal efficiencies can varies widely depending on the plant species and also there is paucity of data for ability of these macrophytes in improving the water quality in term of turbidity, total suspended solids, COD, nutrients (nitrate, phosphate and ammonia) concentration in the wastewater as well as their respective achievable minimum level. The different types and characteristics of wastewater used in the study do also affect the capability of the plant in nutrient removal as well. Therefore, this study wish to fill up this inadequacy and limited availability of data. The main concerns or objectives of this study are to determine the nutrients uptake of *Salvinia molesta* namely nitrate, phosphate and ammonia and its effect towards its growth (biomass) and biochemical content (total carbohydrate and total protein) as well as the water quality (COD, turbidity and MLVSS) after phytoremediation with outdoor cultivation in treated POME. *S. molesta* was chosen as the model plant for this study since it has shown to have a great potential in various pharmacological and chemical synthesis. Its extract from the plant have been used to synthesize silver nanoparticle with antimicrobial activity [17], its extracted lipid have been used to be converted into biodiesel [18] and the plantlet has shown to have antioxidant activity [19]. The biomass from the plantlet has the potential to be converted into organic fertiliser via vermiremediation [20] and animal feed [21] as well.

2. Materials and methods

2.1. Establishment of Salvinia molesta

The macrophytes, namely *S. molesta* was obtained from Nibong Tebal, Penang. They were cultivated in tap water by using basins. All the macrophytes were placed outdoor with shelter under partial sunlight condition as shown in Fig. 1(a). Every week the tap water was changed once to support the healthy growth of the macrophytes. All the macrophytes were maintained under similar condition unless stated otherwise.

2.2. Outdoor cultivation of S. molesta *in treated POME*

This experiment was carried out to study the uptake of nutrients of *S. molesta* in the treated POME and the effect towards its biochemical composition as well as the water quality after phytoremediation. The treated POME was collected from USM Environmental lab. This treated POME was obtained from raw POME had undergone aerobic treatment in a sequencing Batch Reactors (SBR). *S. molesta* macrophytes were cultivated in raceway pond rig with circulation system using the treated POME as shown in Fig. 1(b). The floating aquatic plants were placed outdoor with shelter under partial sunlight condition. The healthy macrophytes were first selected from the cultivation basins. They were weighed the amount which able to fill up the surface of the raceway pond rig with the initial weight of 438 g. The macrophytes were then placed evenly on the surface of wastewater mixture which consisted of mixture of 70 l tap water and 15 l treated POME. The wastewater mixture was continuously circulated through the raceway pond rig by the motor pump at 2.4 LPM. Mesh was installed at the end or outlet of raceway pond rig to avoid the macrophytes from moving out from the pond. Aeration was provided to wastewater mixture by applying surface agitation method. The experiment was run for 16 days. Two replicates batch was done in order to obtain average result. The schematic diagram of the raceway pond rig system with flow direction of wastewater is presented in Fig. 2.

2.3. S. molesta's *nutrients uptake and water quality after phytoremediation*

During 16 days' experimental period, 100 ml of treated wastewater sample was collected every other day starting from day 0 using the centrifuge tubes. The water level in the storage tank was ensured to maintain at the initial marked level before collection. Tap water was added to the storage tank if the water level dropped below the marked level due to evaporation. The water samples were tested for its nitrate, phosphate and ammonia concentration to determine respective nutrients uptake by *S. molesta*. COD, turbidity and MLVSS test were conducted on the samples to evaluate the water quality after phytoremediation. A control group was set up in the laboratory without the presence of *S. molesta.* 2 l of wastewater mixture with same composition as in phytoremediation group (14: 3 = tap water: treated POME) was aerated in two 1 l beakers with mini pump for 16 days. The beakers were covered with aluminium foil. 100 ml of water sample was collected every two days after ensuring that the mixture maintained at marked level and was mixed well.

2.4. Effect towards S. molesta's *growth and biochemical composition*

The *S. molesta* macrophytes were weighed before cultivating them outdoor in treated POME in raceway pond rig. This measured weight represents the initial fresh weight. After 16 days' experiment, all the macrophytes in the pond were harvested and weighed to determine its final fresh weight, thus the increment of macrophytes' biomass weight under such cultivation can be known. Two replicates, each 60 g healthy plant samples were randomly selected from harvested macrophytes. They were dried in oven at 60 °C until constant mass were gained. The dry weight of plants was recorded. Both replicates were tested for total carbohydrate and total protein content. To evaluate the changes in carbohydrate and protein of *S. molesta* before and after experiment, prior to outdoor cultivation experiment, healthy plant samples were randomly selected from the cultivation basins to undergo the same procedures to determine their total carbohydrates and total protein content.