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Water Hyacinth (*Eichhorniacrassipes*) a Challenge for Water Body Management

Hong Siew Yi[1], Roslinda Seswoya[1,2]*

[1]Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, Parit Raja, Johor, 86400, MALAYSIA

[2]Micropollutant Research Centre, Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, Parit Raja, Johor, 86400, MALAYSIA

*Corresponding Author

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Abstract:Water hyacinth is one of invasive aquatic plant, and grow abundantly in the water body. The water body conditions and water hyacinth reproductive mechanism are the main reasons for its rapid growth. The excess of water hyacinth in the water body not only affecting the water quality but also form thick mats of water hyacinth on the water surface which have blocked the sunlight to reach the deeper part of the waterbody. Therefore, maintenance works to remove the invasive aquatic plants are essential to decrease the negative impacts on environments.The machinery is used to remove the water hyacinth from the water body. The removed water hyacinth was sent to another place for dumping and bring the environment problem as the water hyacinth degrade gradually. Anaerobic digestion could be applied to the water hyacinth to avoid environmental issues due to the dumping of water hyacinth on the land. Water hyacinth is a biomass which is high in moisture content and carbon to nitrogen ratio, indicating that the anaerobic digestion is preferable for the biomass stabilization. Few studies had proved that the water hyacinth is anaerobically digested and resulted in the methane yield up to 190 ml CH_4/g Vs.Anaerobic digestion of water hyacinth to produce methane yield is a sustainable alternative method in which the eco-friendly energy is generated. At the same time, water hyacinth can be managed better. This review aims to summarise information on 1) water hyacinth, 2)negative impact of water hyacinth towards the environment, 3) managing the excessive water hyacinth and 4) anaerobic digestion as a sustainable approach for managing water hyacinth.

Keywords: Growth, Water Quality, Energy

Corresponding author: roslinda@uthm.edu.my

1. Introduction

The excessive grown of invasive aquatic plants which including floating, submerged and emergent plants have caused environmental problems in lake and river[1]. Based on U.S. Department of Agriculture (USDA) – National Invasive Species Information Centre, plants which under invasive aquatic plants are the plants with the members of the kingdom Plantae and algae which are primitive organisms containing chlorophyll. Invasive aquatic plants grow partially or entirely submerged in water which is included plants that are rooted in the sediment with part or all the plant underwater, as well as plants that float freely without contacting the sediment. Aquatic plants may invade both marine and freshwater environments which including the habitats such as lakes and rivers [2]

Invasive species are defined as non-native species that cause economic and environmental harm in areas where they are grown. The most damaging invasive species in the world are freshwater aquatic plants [3]. Most of the invasive aquatic plants (146 species, 96.05%) are suited to freshwater environments. The commonly invasive aquatic plants are water hyacinth (*Eichhorniacrasspies*), hydrilla (*Hydrilla verticillata*), alligatorweed (*Alternanthera philoxeroides*), Eurasian watermilfoil (*Myriophyllum spicatum*), water pennywort (*Hydrocotyleranunculoides*), water lettuce (*Pistia stratiotes*) and giant water fern (*Salvinia molesta*) [4].

The invasive aquatic plants had caused negative impacts on ecosystems and economies. The floating invasive aquatic plants can cause more negative consequences such as can reduce access to freshwater for extraction, change the water cycling and reduce the harvest of fish and other resources. Besides, overgrow of floating invasive aquatic plants can cause the changing of food webs and shade out other aquatic plants [5]. The excess grows of water hyacinth will affect the ecology of aquatic organisms and the loss of biodiversity of aquatic life [6]. Therefore, maintenance of the rivers or lakes to remove the invasive aquatic plants are essential to decrease the negative impacts on environments [5].Furthermore, the cost of management and removal of the invasive aquatic plants from the lake are expensive and sometimes it only partially successful in removing the invasive aquatic plant [7]. Other research had suggested using the invasive aquatic plant for biogas production [7] Thus, this review aims to summarise information on 1) water hyacinth, 2) negative impact of water hyacinth towards the environment, 3) managing the excessive water hyacinth and 4) anaerobic digestion as a sustainable approach for managing water hyacinth.

2. Water Hyacinth

Water hyacinth is one of the invasive aquatic plants. Water hyacinth (*Eichhorniacrassipes*) is a perennial, herbaceous, free-floating aquatic plant which originating in the Amazon Basin, South America [8]. Water hyacinth has distributed throughout the world. Water hyacinth can reproduce both sexually and asexually. Sexually reproduction is by seed, and asexually reproduction is by budding and stolen production. Both climatic and water body conditions will affect the rapid reproduction rate of water hyacinth. The main factors which will affect the growth of water hyacinth are temperature, salinity, pH, disturbance, reproduction systems, eutrophication and sunlight shading [9].Water hyacinth is one of the invasive alien species (IAS) in Malaysia [10]. Water hyacinth is a native of Amazonian, Brazil. It was first brought into Singapore from Hong Kong in 1963. In Malaysia, water hyacinth thrives in still or slowly moving waters. It spreads very rapidly through seeds and offsets. Water hyacinth has a high rate of reproduction and occupies a large area of the lake [11].Water hyacinth is the most severe invasive aquatic plant in the world, and its dominance could bring about elimination or reduction of other species[10].

According to [9] water hyacinth favourable conditions are stagnant water and the depth of water which is less than 6 m. At the same time, the bed surface is covered with accumulated soil which rich in organic matters and essential elements such as phosphorus and nitrogen are available in nutrients. Besides, the nutrients absorbed by the roots from the water are not sufficient for optimum the growth of water hyacinth. Therefore, sunlight is essential for photosynthesis of water hyacinth. Moreover, the temperature for the optimum growth of water hyacinth is between 28 ℃ and 30 ℃. Furthermore, floods, currents and waves are the main obstacles to water hyacinth stability. The high currents, waves and flooding can flush out the water hyacinth to downstream. The nutrients such as

nitrates, sulphates and phosphates will be polluted by the water, which has the nutrients from industrial zones, residential areas and agricultural fields [9]. The summary of optimum conditions suitable for water hyacinth growth is shown in Table 1. It shows that the optimum value for lake depth is less than 6 m, the temperature of the lake is between the range 28 to 30 °C, less than 2% of the salinity, and the optimum pH value is between 6.5 to 8.5. Water with the presence of nutrients in the form of nitrate (N), phosphate (P) and potassium (K) suitable for the growth of water hyacinth.Figure 1 shows the view of a lake which entirely covered by water hyacinth.

Table 1: Optimum condition for Water Hyacinth growth

Parameters	Optimum value	Reference
Lake depth	< 6 m	[9]
Temperature	28 – 30 ℃	[12]
Salinity	< 2 %	[12]
Nitrate (N)	5.5 – 20 mg/L	[9]
Phosphate (P)	1.66 – 3 mg/L	[9]
Potassium (K)	Up to 53 mg/L	[9]
pH	6.5 - 8.5	[12]

Figure 1. Water hyacinth in the lake [13]

3. Negative Impact of water Hyacinth Towards the Environment

The presence of water hyacinth has caused negative impacts on the environment, which include thereduction of water quality and loss of biodiversity.The thick mats of water hyacinth on the surface of the lake had blocked the light to reach the deeper part of the waterbodies [11]. Water hyacinth absorbs large amounts of phosphorus and nitrogen from the water [9].The water body with the presence of water hyacinth ishigh in turbidity, chemical oxygen demand (COD), and chlorophyll and low in pH, dissolved oxygen (DO), nitrates as compared to the water bodies without water hyacinth [9].The presence of water hyacinth mats can decrease the fish populations through altering trophic dependency and at the same time, reduce the dissolved oxygen (DO) in water [14]. Water hyacinth dense mats have reduced light transmission to submerged plants and competed with other plants (Kriticos& Brunel, 2016). In addition,water hyacinth form mats to cover the top surface of the water, and this will reduce the dissolved oxygen in the water because the photosynthesis of the submerged plant is inhibited[13]

The rapid growth of water hyacinth has brought a negative social impact in the way thatsome recreational water activities, such as boating,wasinhibited[15]. Moreover, overgrow of floating invasive aquatic plants such as water hyacinth can increase the prevalence of human disease from the creation of breeding habitat for vectors such as mosquitoes [5]. The bilharzia (schistosomiasis) intermediate snail host and most mosquito also found in a dense mat of water hyacinth, which can cause the transmission of malaria, filariasis and encephalitis [11].

4. Managing the Excessive Water Hyacinth

The maintenance work to clear the invasive aquatic plants from the water bodies is essential to decrease the negative impacts [5]. Excessive water hyacinth also increases the maintenance cost of the water body. The small boats had been used to move out water hyacinth mats to the waiting excavator [16]. Besides, the boat-loaded and boat-ferried system were used to remove the water hyacinth mats in the water body. The "boat-loaded" method is to gather water hyacinth biomass into a boat and transport it to the shore where a winch-driven machine removes water hyacinth from the boat and puts it in the collection area. While for the "boat-ferried" system is to leave the water hyacinth in the water and use a buoyed line to tethers it to the boat [6].

According to investigations by the Ministry of Environmental Protection of China, water hyacinth is the worst among the species of invasive aquatic plant. In China, the number of provinces affected by water hyacinth has increased rapidly from 3 countries (Taiwan, Guangxi, and Guangdong) in 1940 to 19 countries in 2004. During the period, economic losses due to water hyacinth accounted for approximately 14% - 17% of the total financial losses. Every year, the total cost for controlling water hyacinth is more than 12.35 million US dollars or equal to 51.35 million Ringgit Malaysia in China [17].

5. Anaerobic Digestion As A Sustainable Approach For Managing Water Hyacinth

Anaerobic digestion has been used to emphasize energy conservation and recycling, as well as the desire to obtain beneficial use of organic waste [18].The biomass which has the higher moisture content will be more suitable to use as a substrate for undergoing anaerobic digestion [19].Water hyacinth has higher moisture content indicating that water hyacinth requires less water in the digester during anaerobic digestion, and it is more suitable for undergoing anaerobic digestion [13]. However, the pretreatments such as chopping, crushing and cleaning is a must for the digestion of water hyacinth. Besides, because of the abundance and high carbon-nitrogen ratio of the water hyacinth, water hyacinth can be used as a possible biomass for the anaerobic digestion[19].At the same time, Among the invasive species of aquatic plants, water hyacinth is commonly used as a substrate in anaerobic digestion due to its large quantity (rapid growth)[20]

The main component of the gases through anaerobic digestion are methane, carbon dioxide, nitrogen, hydrogen sulphide and hydrogen [19]. The methane gas can be used for lighting, powering an engine to provide shaft power or as a fuel for cooking [21].Anaerobic digestion of water hyacinth to produce methane yield is a sustainable alternative method to have eco-friendly energy, and at the same time, water hyacinth can be managed better [22]. Several invasive aquatic plants for anaerobic digestion such as Water Hyacinth, Cabomba and Salviniawere studied, and the results were tabulated in Table 2 [20]. Water Hyacinth resulted in higher methane production and methane yield, each at 260 L and 140 L methane/kg VS respectively. In another study, the methane yield from the digestionofwater hyacinth is between 60 – 190 mL CH_4/g VS[23].

Table 2: Biogas and methane yields produced from Water Hyacinth, Cabomba and Salvinia [20]

Substrates	Total biogas production (L)	Total methane production (L)	Total biogas yield (L kg VS^{-1})	Total methane yield (L kg VS^{-1})
Water Hyacinth	500	260	267	140
Cabomba	288	140	221	109
Salvinia	285	152	155	84

Modified Gompertz model is widely used to estimate the production of methane yield and determine the kinetic parameter for anaerobic digestion in batch mode [24]. The methane production modelling enables to analyse the kinetic model and other parameters. At the same time, this methane production modelling also can be used for designing and scaling up the laboratory tests into applications of industrial-size[25].The modified Gompertz model for the methane kinetics of water hyacinth from different water types (brackish and freshwater)was applied [24].Budiyono, et.al., (2014) had reported that the prediction of biogas yield using the modified GompertzModel is good with a fitting error of 10% or less. The ultimate methane yield of 192 ml CH_4/g VS was measured from the digestion of water hyacinth under the batch mode. The difference between ultimatemethane yield observe from the modelling analysis, and laboratory observation was about 4%[27].

6. Conclusion

Invasive aquatic plants are one of the challenging problems for water ecosystem. Water hyacinth is one of the common invasive aquatic plants can be seen anywhere. Water hyacinth has a high rate of reproduction due to two reproductive mechanisms (sexually and asexually).Besides, the water bodyconditions which is lesser than 6 m depth, the temperature ranged between 28ºC to 30ºCand the presence of nutrientssuch as nitrate (N), phosphate (P) and potassium (K) favourfor water hyacinth growth. Water hyacinth caused a destructive impact on the environment, social and economic. As for the environmental condition, water hyacinth caused higher turbidity, COD, and chlorophyll in the water. On the contrary, reduce the dissolved oxygen concentration of the water. Human is affected by the presence of water hyacinth in such way that recreational water activities are restricted, and human health is under risk. The dense floating mat of water hyacinth possibly becomes the breeding habitat for mosquitos subsequently spreading the disease. The massive amount of money is used to get rid of the dense mat of water hyacinth; this becomes the financial burden to the associate authority mainly when boat and excavator were used. Managing the excessive water hyacinth by utilising the machinery is no longer the best option.

Water hyacinth is biomass characterised with higher moisture content and carbon to nitrogen ratio. Based on these criteria, water hyacinth is possible biomass to serve as a substrate for the anaerobic digestion. Several researchers had conducted the biodegradability test of water hyacinth. They found that the ultimate methane yield ranged between 60 to 192 ml CH_4/g VS. The methane yields could be small. Still, more research on increasing the methane yield from the digestion of water hyacinth can be initiated in future. Methane can be used for electricity generation. Considering this, it is a waste to ignore the methane potential of water hyacinth. After all, take out water hyacinth from the water bodyand dump it into another place still not a proper organic waste decomposition; can cause environmental harm such as unpleasant the odour. Besides, the leachate (water as a result of the biological degradation) can cause water pollution, either groundwater or surface water mainly during the rain.

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