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Phytoremediation of Aquaculture Wastewater by *Colocasia esculenta, Pistia stratiotes,* and *Limnocharis flava*

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Abstract

Phytoremediation is one of the effective methods in the treatment of water pollutant. In this study, *Colocasia esculenta*, *Pistia stratiotes*, and *Limnocharis flava* were used in this study to remediate the contaminated aquaculture wastewater. The removal efficiency of parameter elements (Fe, Cd, and P), ability to increase DO, as well as accumulation of parameter elements (Al, Fe and Cd) were evaluated. Aquaculture wastewater taken from tilapia pond was used as influent to be treated in constructed wetland reactor tank with the selected plants. The HRT was set as 2 days for each of 6 batches. The plant sample analysis was carried out using Bruker S2 Ranger Energy Dispersive X-Ray Fluorescence (EDXRF) at the beginning and end of the whole set experiments, while the wastewater analysis was carried out using EDXRF and YSI 556 MPS before the experiment and for each batch. This study has shown the suitability to be used in phytoremediation of aquaculture wastewater was arranged ascending as *Limnocharis flava* < *Pistia stratiotes* < *Colocasia esculenta*.

1. Introduction

Recent studies have shown the pollution from pond aquaculture wastewater has become serious problems. Aquaculture sector has grown at an average rate of 8.8% per year since 1970, compared with only 1.2% for capture fisheries and 2.8% for terrestrial farmed meat production over the same period worldwide. Moreover, aquaculture industry is expanding in many regions of the world including Malaysia (Mokhtar et al., 2009). Aquaculture waste and heavy metal are wastewater related contaminant that is frequently present in aquaculture environment (Cao et al., 2007; Mohd Amin et al., 2014; Mohd Amin, 2015; Mohd Amin et al., 2016).

Phytoremediation is viewed as the innovation of remediation technology to remediate sites contaminated with organic and inorganic pollutants. Furthermore, it is one of the biological wastewater treatment methods which applied the concept of plants-based systems and microbiological processes to eliminate contaminants in nature a rather than entombing it or transporting the problem to another site (Gupta et al., 2012).

Wetlands are human engineered treatment systems utilizes natural treatment processes with high degree of treatment for pollution control in wastewater (Chavan & Dhulap, 2013). Wetland can often be an environmentally acceptable, cost-effective treatment options, especially for small communities. Wetland system with phytoremediation technique is the most suitable in terms of contaminant removal efficiency, cost reduction and simplicity (Chavan & Dhulap, 2013).

Aquatic macrophytes have tremendous potential for remediation of the heavy metal (Das et al., 2014). *Pistia stratiotes* is commonly used as the plant used for the phytoremediation agent for the wetland system (Prajapati et al., 2012). *Limnocharis flava* is a suitable plant for the phytofiltration of low-level Cadmium (Cd) contamination from water because of it has higher bioconcentration factor, translocation factor, higher relative growth rate and biomass, and easy culture (Abhilash et al., 2009). It can change the hydrology of water bodies by reducing the width of channels, thereby restricting water flow and creating silt traps. *Colocasia esculenta* is commonly known as taro, yam or keladi in Malaysia. It was studied to be wide spread in areas of Asia and Pacific. It lives as a semi aquatic submerged plant which can be found commonly in swampy areas (Tumuhimbise et al., 2009).

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2. Materials and Methods

The experiment was conducted at Agropark, University Malaysia Kelantan using the wastewater from Tilapia pond. Experimental reactor is prepared as shows in Figure 1, where three set of reactor tank were prepared for each species of plant samples (*Colocasia esculenta*, *Pistia stratiotes* and *Limnocharis flava*). The height of the reactor tanks is 45cm with the diameter 15cm. The water storing capacity of the tank was around 5 litres. Two layers of the medium which were big size pebbles and garden soil were used in this experiment. The pebbles were put on the bottom layer with 10cm height followed by 10cm height of garden soil for construction of bed. The pebbles were washed with water and distribute them to different layers (Chavan & Dhulap, 2012). Three control tank were prepared for each species of plant so that it can correct experimental result caused by the environment factor.

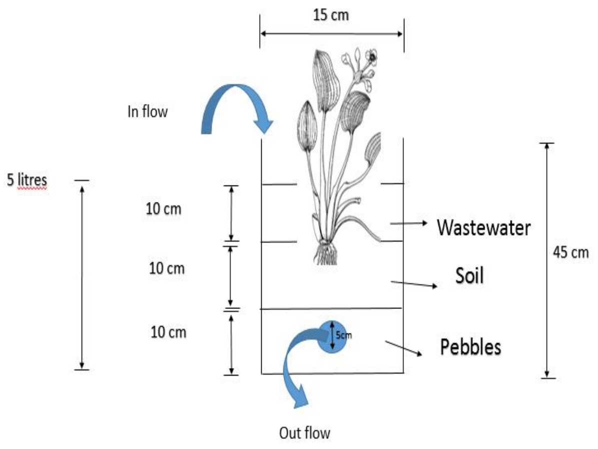

Figure 1: Experimental design of reactor tank

2.1. Characterization of Plants and Wastewater

Physico-chemical parameter analysis, were tested by taking 50 ml of wastewater and measured by using a multi-parameter unit YSI 556 MPS. The aquaculture wastewater was collected in 15 ml for the heavy metal and aquaculture waste analysis. The collected wastewater was measured by using S2 Ranger Energy Dispersive X-Ray Fluorescence (EDXRF) from Bruker AXS GmbH (2013). For metal accumulation in plant analysis, two plant samples of each species were grinded and put into oven for oven dried with 24 hours at 80ºC (Melorose et al., 2015). The plant samples also sieved through a 75-micron sieve with auto-sieve shaker.

2.2. Experimentation

The experiment was fixed at 48 hours of hydraulic retention time (HRT) for each batch of experiment (Pantip & Klomjek, 2014). The initial and final readings for 6 batches of wastewater sample analysis (physico-chemical parameter, removal and accumulation of elements) based on HRT were analysed.

2.3. The Reading Changes of physico-chemical, Efficiency of Element Removal and Bioconcentration Factor

The reading change of physic-chemical in water was calculated.

$$Changes = C_1 - C_\circ \quad (1)$$

Where $C_\circ$ and C_1 are initial and final concentration of element in medium (ppm).

The percentage of element removal efficiency in water was calculated according to (Tanhan et al, 2007).

$$Removal = \frac{|(C_1 - C_0)|}{C_0} x\ 100\% \quad (2)$$

Where $C_\circ$ and C_1 are initial and final concentration of element in medium (ppm).

Bio-concentration factor indicates the efficiency of a plant species in accumulating of elements into its tissues from the surrounding environment (Ladislas et al., 2012). The bio-concentration factor (BCF) was calculated as follows (Nazmul et.al.,1999).

$$BCF = \frac{Element\ accumulate\ in\ plant\ (ppm)}{Average\ initial\ element\ in\ wastewater\ (ppm)} \quad (3)$$

2.4. Statistical Analysis

All analysis results were subjected to statistical treatment to determine mean and standard deviation using the latest statistical software.

3. Results and Discussion

3.1. Physicochemical Parameters Remediation

The results of the average physicochemical parameters of raw aquaculture wastewater used in this study are shown in Table 1. Based on recommendation limit of Malaysian Department of Enviroment (DOE) 2012, the pond is classified as class III water body. However, results shown in Table 3 indicated that some of the physico-chemical parameters and elements contained exceeded the recommended limit set by DOE, but not in extreme values (DOE, 2009). Dissolved Oxygen (DO) is one of the most significant physicochemical parameters for aquaculture wastewater. Thus, the improvement of this parameter was evaluated. The results were shown in Table 2.

Table 1: Average physicochemical parameters of raw aquaculture wastewater (± 0.02-0.007)

Physico-chemical Parameters	Reading
DO (mg/L)	2.58
pH	6.76
TDS (g/L)	0.026
Salinity (%)	0.02
Temperature (˚C)	30.45
ORP (mv)	206.5
Conductivity (ms/cm)	0.044

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Table 2: Changes in DO concentration within 6 Batches (mg/L)

Plants	Changes in DO concentration (mg/L) in aquaculture wastewater by *Colocasia esculenta* sp, *Pistia stratiotes* sp, and *Limnocharis flava* sp							
	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5	Batch 6	Mean	SD
Pistia	0.44	3.90	0.24	-1.35	-0.93	0.27	1.19	15.23
Colocasia	0.87	4.60	1.45	3.56	3.12	-0.03	2.26	1.17
Limnocharis	1.02	-1.01	0.24	4.41	-0.16	0.03	1.15	27.05

Based on the result, *Colocasia esculenta* is more efficient than *Pistia stratiotes* and *Limnocharis flava* in increasing DO. It recorded mean DO changes of 2.26 ± 1.17 mg/L, which is significantly higher than *Pistia stratiotes* and *Limnocharis flava* that recorded 1.19 ± 15.23 mg/L and 1.15 ± 27.05 mg/L respectively. This shows its higher ability in treating low DO wastewater. The high performance of *Colocasia esculenta* was widely proved by past studies. For example, Madera-Parra et al. (2015) proved that it successfully treated low DO leachate.

3.2. Parameter Elements Removal

The parameter elements chosen: Iron (Fe), Cadmium (Cd) and Phosphorus (P) are significant elements in terms of their presence amount and adverse effects towards environment and living organism (Al-Badaii & Shuhaimi-Othman, 2014). The average initial concentration of elements found in the raw aquaculture wastewater is shown in Table 3.

Table 3: Average initial concentration of elements in raw aquaculture wastewater

Elements	Concentration (mg/L)
P	2.7644
Cl	7.1563
Fe	2.2412
Ba	0.0388
Sn	0.0085
Na	86.1765
S	0.2510
Sb	0.0051
Mg	17.8868
Al	0.6738
Si	0.0861
Cd	0.0233
Ti	0.3549
K	11.9852

3.2.1. Iron (Fe)

Figure 2 show the Fe percentage removal by *Colocasia esculenta*, *Pistia stratiotes*, and *Limnocharis flava*. Based on the result, *Colocasia esculenta* and *Pistia stratiotes* recorded a significantly high percentage removal, which is 96.67 ± 3.91 mg/L and 76.45 ± 28.41 mg/L respectively. *Limnocharis flava* does not record any removal. The same trend was observed in section 3.3, which shows that Fe accumulated only in *Colocasia esculenta* and *Pistia stratiotes*.

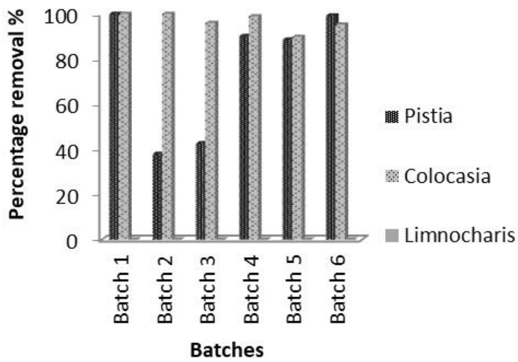

Figure 2: Removal of Fe by 3 types of plants

3.2.2. Cadmium (Cd)

Figure 3 show the Cd percentage removal by *Colocasia esculenta*, *Pistia stratiotes*, and *Limnocharis flava*. Based on the result, *Colocasia esculenta* and *Pistia stratiotes* recorded a higher percentage removal, which is 74.4 ± 30.52 mg/L and 49.88 ± 37.31 mg/L respectively. Similarly, *Limnocharis flava* does not record any removal. The same trend was observed in section 3.3, which shows that Cd accumulated only in *Colocasia esculenta* and *Pistia stratiotes*.

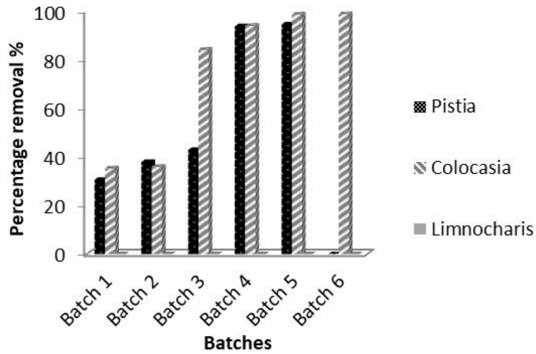

Figure 3: Removal of Cd by 3 types of plants

3.2.3. Phosphorus (P)

Figure 4 show shows the P percentage removal by *Colocasia esculenta*, *Pistia stratiotes*, and *Limnocharis flava*. Based on the result, all three plant species recorded a considerable good result of percentage removal, which is 34.73 ± 12.44 mg/L, 62.58 ± 2.41 mg/L and 42.15 ± 19.64 mg/L respectively. Surprisingly, *Limnocharis flava* recorded a higher percentage removal than *Pistia stratiotes*. This proved that *Limnocharis flava* is better in treating organic pollutant than inorganic pollutants such as heavy metal.

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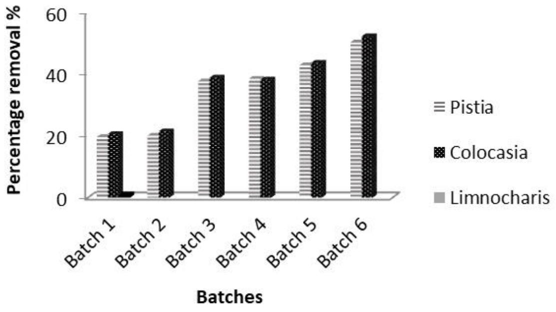

Figure 4: Removal of P by 3 types of plants

3.3. Parameter Elements Accumulation

The ability of *Colocasia esculenta*, *Pistia stratiotes*, and *Limnocharis flava* to uptake and accumulate parameter elements were evaluated based on the BCF. The results were shown in Figure 5.

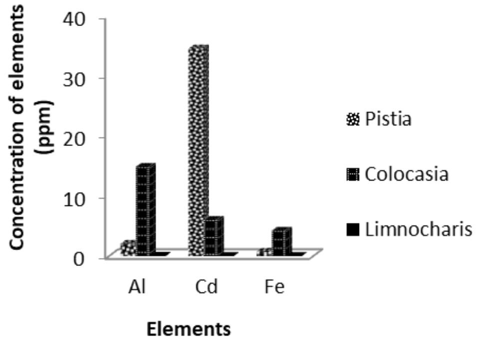

Figure 5: BCF of elements recorded by 3 types of plants

Generally, *Colocasia esculenta* and *Pistia stratiotes* has a higher ability in accumulating parameter elements and reported as a good heavy metals and contaminants hyper-accumulator (Geeganage et al., 2011; Jomjun et al., 2010; Kamal, 2004; Zhu et al., 1999). Both plant can uptake and accumulate considerable amount of both non-metal and metal parameter elements to its plant tissue as reported in the literature (Akwee et al., 2015; Geeganage et al., 2011; Kashem et al., 2013). Based on the result, different plants show good ability in accumulating different element. *Colocasia esculenta* recorded the highest BCF of 14.84 for Al and considerable BCF of 6.01 and 4.22 for Cd and Fe respectively. *Pistia stratiotes* recorded the highest BCF of 34.56 for Cd and considerable BCF of 2.03 and 0.71 for Al and Fe respectively. Contrastly, *Limnocharis flava* only recorded BCF of 0.07 for one parameter element, which is Al.

4. Conclusion

Colocasia esculenta and *Pistia stratiotes* are capable in removal of parameter elements (Fe, Cd and P). But *Limnocharis flava* tends to record a higher removal in P. On the other hand, *Colocasia esculenta* and *Limnocharis flava* are efficient in increasing DO. *Colocasia esculenta* recorded constant efficiency in BCF for all parameter elements (Al, Fe and Cd). *Pistia stratiotes* shows a relatively high BCF for Cd. *Limnocharis flava* recorded the least BCF for all elements. *Colocasia esculenta* is comparative suitable to be used in phytoremediation of aquaculture wastewater compared to the other two plants, due to its ability to reduce the concentrations of Fe, Cd and P by greater than 50 %, accumulate Al, Fe and Cd at BCF more than 1, and averagely increase DO by 2.26 mg/L in each batch.

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