Journal of Engineering Research and Education
Volume 11, 2019 [59-68]

Uptake of Zn and Fe from Wet Market Wastewater Through Phytoremediation: Potential of Floating Plants

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ABSTRACT

In Malaysia, wet market wastewaters are discharged directly into receiving water without any treatment which may affect both of human and aquatic life if not treated properly. Thus, this study was conducted to assess the potential of phytoremediation in removing the heavy metals, which is one of contaminants in wet market wastewater collected from Pasar Borong Kangar, Perlis by using two species of floating plants, Eichhornia crassipes (water hyacinth) and Lemna minor (duckweed). Results show that 99.57% of Zn and 97.91% of Fe were removed by duckweed while, 98.34% of Zn and 97.05% of Fe were removed by water hyacinth. The relative growth of duckweed and water hyacinth recorded are 1.05 and 0.73, respectively. The Bioconcentration Factor of Zn and Fe for duckweed are 100 and 98, respectively while for water hyacinth are 98 and 97, respectively. Translocation Factor of Zn and Fe for duckweed are 0.06 and 0.02, respectively while for water hyacinth are 0.17 and 0.41, respectively. Overall, duckweed is a better floating plant in removing Zn and Fe from wet market wastewater compared to water hyacinth.

Keywords: Duckweed, Phytoremediation, Water Hyacinth, Wet Market Wastewater.

1. INTRODUCTION

In Malaysia, discharge of wastewater from various activities contributes to water pollution. The contents of discharged wastewater especially the heavy metals cause degradation of water quality. Besides industrial activities, wet market activities such as washing, handling and selling food and wet products such as meat, fish, poultry, and vegetables are also not excluded from discharging wastewater containing of heavy metals.

The technology of prevailing purification, for example, is one of technique that can be applied in wastewater treatment for heavy metals removal. However, not many agencies show their interests for this kind of treatment due to the very high costs of implementation. Other than that, it is also not environmental friendly since it gives negative effects to the environmental.

Phytoremediation is one of the alternatives to overcome problem related to heavy metals in wastewater. Nowadays, phytoremediation is widely used in developing countries because it is less destructive to the environment and very cost effective. In phytoremediation, floating plants such as water hyacinth, duckweed and water lettuce is used. However, the ability of each type of plant in removing the heavy metals is not similar. Therefore, this study is carried out to assess the effectiveness of phytoremediation using floating plants, *Eichhornia crassipes* (water hyacinth)

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and *Lemna minor* (duckweed) to remove selected heavy metals (Zn and Fe) from wet market wastewater.

2. MATERIAL AND METHODS

2.1 Collection of Wastewater

The wet market wastewater was collected at the final discharge of Pasar Borong Kangar, Perlis during peak hour of market operation. Grab water sample was applied using water sampler into pre-soaked in HNO_3 and copiously rinsed with deionized water HDPE bottles. The water sample was stored in 4°C for analysis.

2.2 Plants Preparation

Water hyacinth and duckweed were collected from two different canals in Kuala Perlis, Perlis. After being collected, they were transferred into clean plastic bags and sent to the laboratory. The plants were washed thoroughly to remove adhered soil particles before being planted into two different containers containing tap water exposed to sunlight for one week for new environment adaptation purposes.

2.3 Phytoremediation Study

Three same size containers were prepared for the phytoremediation study. Each container was filled up with 3L of wet market wastewater. The first container was planted by 60 g of water hyacinth, the second container by 60 g of duckweed and the last container was maintained without any plants (control). All of the containers were placed at the location that exposed them to sunlight within 10 days of phytoremediation.

2.4 Determination of Heavy Metal Concentration in Wastewater

100 ml of wastewater sample were collected from all three containers on 0th, 2nd, 4th, 6th, 8th and 10th day of the experiment. HNO_3 for heavy metals digestion were used in this study which the procedures were according to Gupta et al. (2008). Atomic Adsorption Spectrometry (AAS) was used to obtain the heavy metal concentration.

2.5 Determination of Heavy Metal Concentration in Plants

At the end of the experiment (10th day), all water hyacinth and duckweed were harvested from their containers. They were weighed to obtain their final fresh weight and cut into two different parts; roots and stem before being dried in the oven 70°C for two days. Then, the dried samples were ground for analysis by following Xia and Ma (2006). Atomic Adsorption Spectrometry (AAS) was used to determine the concentration of Zn and Fe.

2.6 Data Analysis

The ability of plants in removing the heavy metals from the wet market was expressed in term of percentage efficiency and calculated as in equation 1.

$$Removal\ Efficiency = \frac{C_o - C_i}{C_0} \times 100 \qquad (1)$$

where Co represents initial heavy metal concentration in wastewater while *Ci* represents the heavy metal concentration on *i*-day.

For the relative growth of the plants, it was determined using equation 2.

$$Relative\ Growth = \frac{Final\ Fresh\ Weight}{Initial\ Fresh\ Weight} \quad (2)$$

In order to calculate Bioconcentration Factor (BCF) of plants for each heavy metal, equation 3 was applied:

$$BCF = \frac{Concentration\ of\ Metal\ in\ Plant\ Tissue\ (\frac{mg}{kg})}{Initial\ Concentration\ of\ Metal\ in\ External\ Solution\ (\frac{mg}{L})} \quad (3)$$

Meanwhile, metals translocation of plants from root to shoot known as Translocation Factor (TF) was calculated using the formula in equation 4.

$$TF = \frac{A_s(mg/kg)}{A_r(mg/kg)} \quad (4)$$

where A_s and A_r represent the concentration of heavy metals accumulated in tissues of shoot and root, respectively.

3. RESULTS AND DISCUSSION

3.1 Removal Efficiency of Heavy Metals by Water Hyacinth and Duckweed

The removal efficiency of Zn and Fe from wet market wastewater by the water hyacinth and duckweed within 10 days of treatment are assessed and presented in Figure 1 and Figure 2, respectively.

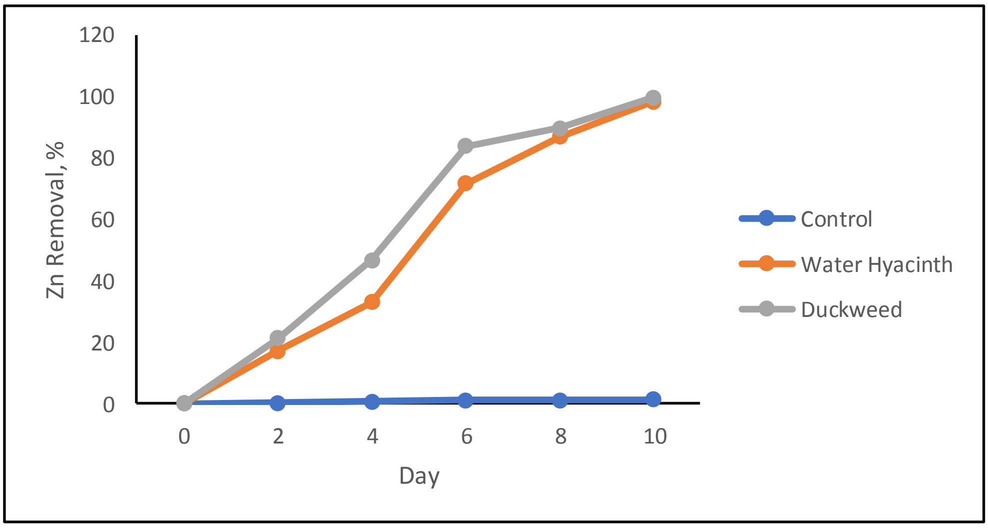

Figure 1. Removal of Zn by water hyacinth and duckweed.

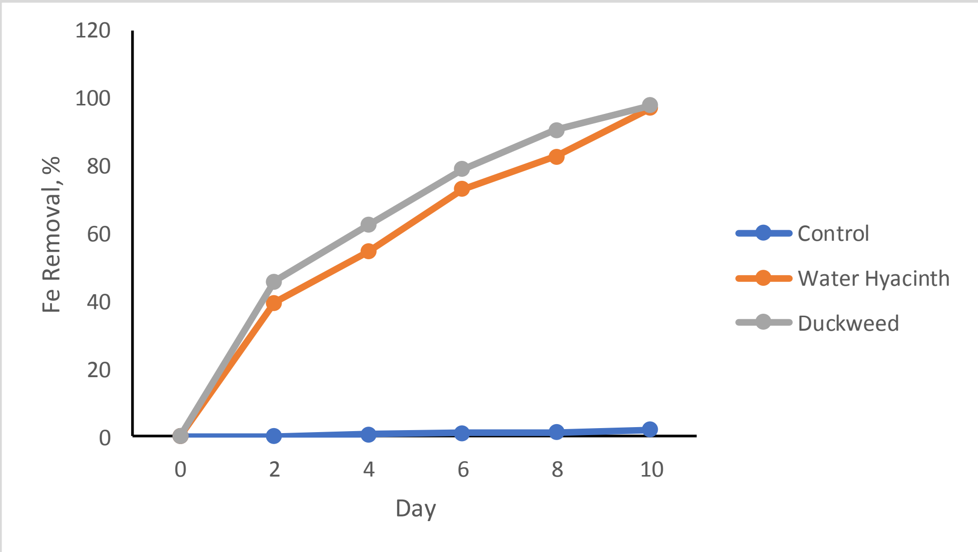

Figure 2. Removal of Fe by water hyacinth and duckweed.

After 10 days of treatment, the result shows that the highest removal of Zn is goes to duckweed, followed by water hyacinth and control. Duckweed successfully removed 99.59% of Zn while water hyacinth and control removed 98.34% and 1.38% of Zn, respectively. As for Fe removal, duckweed also recorded the highest percentage compared to water hyacinth and control. At the end of the treatment, 97.91% of Fe was removed by duckweed, 97.05% by water hyacinth and 1.91% by control.

Results also show that a rapid removal of the Zn from wastewater by both water hyacinth and duckweed is recorded between 4^{th} to 6^{th} day of treatment. Meanwhile, for Fe removal, both plants recorded their rapid removal during 0^{th} to 2^{nd} day of treatment. During that time, the sharp decrease in both Zn and Fe concentration occurred because of fast attainment of a saturation state. As the saturation state was achieved, the plants seemed had a little difficult in absorbing the Zn and Fe, till the concentration decreased with the passage of time (Swain, 2014).

In this study, it is obvious that duckweed is better in reducing both of Zn and Fe from wet market wastewater compared to water hyacinth. However, based on a study conducted by Mishra et al. (2008), water hyacinth is the most effective floating plants in removing fives types of heavy metals including Zn and Fe compared to the duckweed and water lettuce. In this study, water hyacinth seems failed to reflect the previous study. This might occur due to the present of other nutrients such as nitrate-nitrogen in the water sample (Tolu and Atoke, 2012). The presence of nitrate-nitrogen can affect the effectiveness of water hyacinth in removing heavy metals. This is because according to Jayaweeera et al. (2008), nutrient-poor conditions are suitable for water hyacinth in removing heavy metals from wastewater.

3.2 Relative Growth

Relative growth of the plant can be defined as the growth rate relative to size of the plants. There are several factors that can affect the relative growth of plants and one of them is the concentration of heavy metals. Figure 3 illustrates the relative growth of water hyacinth and duckweed after 10 days of treatment.

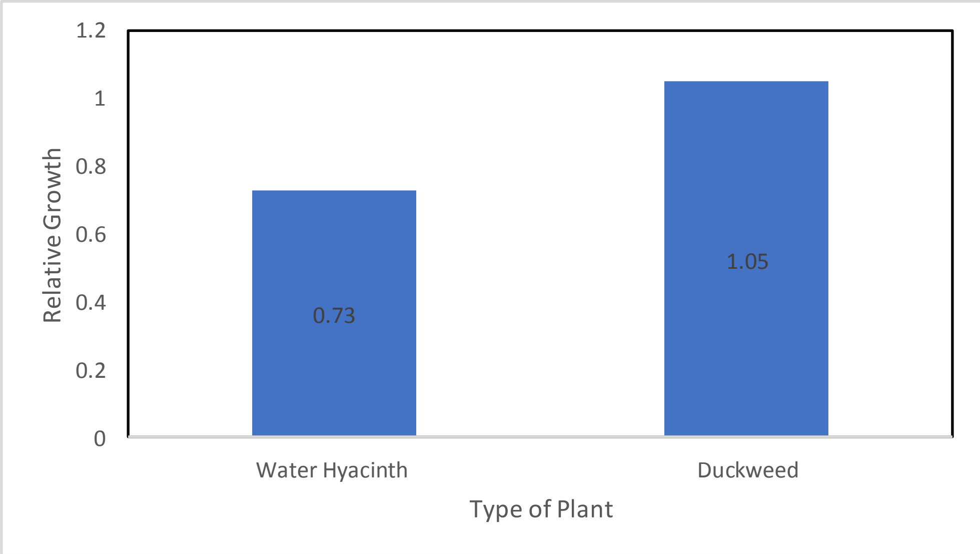

Figure 3. Relative growth of water hyacinth and duckweed.

Results show that there is an increment in relative growth of both of water hyacinth and duckweed after 10 days of treatment. This indicates that Zn and Fe are essential micronutrients for the plant's growth (Bartosova *et al.,* 2015). According to Pandey and Sinha (1995), Zn can be classified as the components of enzymes such as alkaline phosphatase, glutamic dehydrogenase and carboxypeptidase. The enzymes are necessary for the synthesis of RNA and metabolism process of carbohydrate and phosphorus in plants. Meanwhile, Fe is a component of many enzymes that related with energy transfer, nitrogen reduction and fixation, and lignin formation.

In this study, the relative growth recorded by duckweed and water hyacinth is 1.05 and 0.73, respectively which the relative growth of duckweed is higher compared to water hyacinth. Khellaf and Zerdoui (2009) reported that Zn had shown a reduction of growth rate of duckweed for the concentration between 0.5 to 15 mg/L. This occurred because of the inhibitor effect imposed by Zn. Vaillant et al. (2005) supported the reason and mentioned that Zn can reduce the growth of plant, photosynthesis and production of chlorophyll. This is proved when the nitrogenase enzymes activity in water fern was entirely inhibited because of the presence of Zn (Sela *et al.,* 1989). However, the duckweed growth in this study was seemed not affected by the Zn concentration in the wastewater since it grows better than the water hyacinth.

Although there is the difference in relative growth of both plants, still the relative growth of water hyacinth and duckweed can be considered as normal. This is because, Ingole and Bhole (2003) had mentioned that at low concentration of heavy metals (below than 5 mg/L), the plant growth is normal and the removal efficiency was greater.

3.3 Bioconcentration Factor (BCF)

Bioconcentration Factor (BCF) can be calculated to determine the amount of heavy metal absorbed by plants from the water (Ndimele *et al.,* 2014). It is a measure to determine the ability of the plants in accumulating metal with respect to its concentration in surrounding water medium (Ghosh and Singh, 2005).

Figure 4 illustrates the BFC values of Zn and Fe in both of water hyacinth and duckweed. It shows that the BCF value for Zn in duckweed is slightly higher compared to the water hyacinth. The BCF value recorded by duckweed is 100 while for water hyacinth is 98. Similarly, the BCF value of Fe recorded in duckweed is also slightly higher compared to the water hyacinth. The BCF values for duckweed and water hyacinth are 98 and 97, respectively.

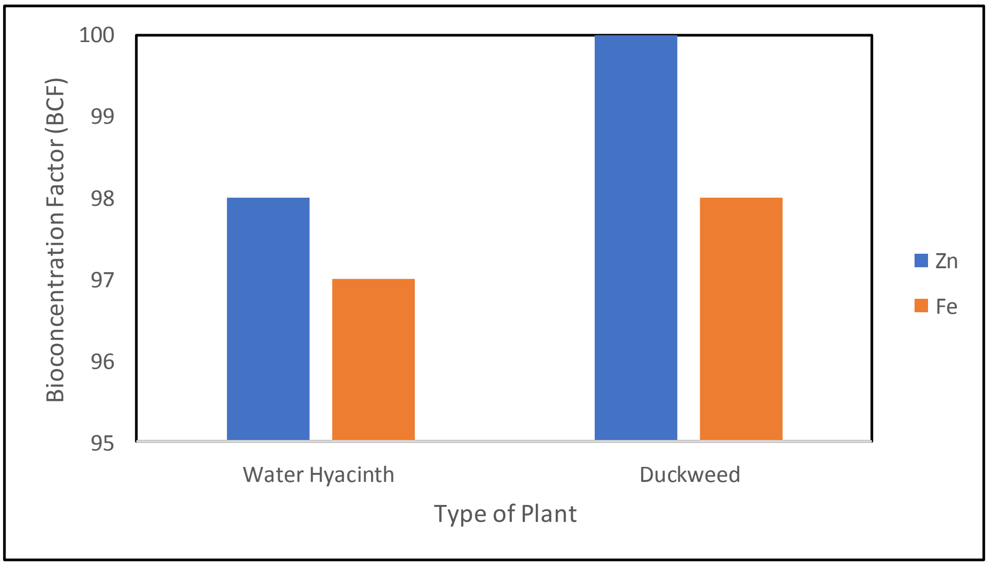

Figure 4. Bioconcentration Factor of Zn and Fe in water hyacinth and duckweed.

In general, the BCF values for water hyacinth and duckweed are range from 97 to 100, which is less than 1000. This is obvious that both of water hyacinth and duckweed in this study are not a hyperaccumulator plant. A hyperaccumulator plant refers to the plant having a BCF value of 1000 or more (Rascio and Navari-Izzo, 2011). Besides that, according to Hoffmann and Poorter (2002), a hyperaccumulator plant can be defined as the plant with capability to grow in very high concentration of metal and accumulates high levels of heavy metals in its tissues.

The BFC values in this study was inconsistent with Soltan and Rashed, (2003) and Farrel (2011) which indicated water hyacinth and duckweed as hyperaccumulator plants for various metals. This inconsistent result may be caused by the length of treatment time. Mokhtar et al. (2011) performed the experiment for longer treatment time (21 days) compared to this study (10 days). Another reason that can contribute to the difference was due to high biomass of plants used, which cause high accumulation rate (Liao and Chang, 2004).

3.4 Translocation Factor (TF)

Translocation factor (TF) refers to the trace metal translocation in the plants from shoot to roots (Abdul and Bivin, 2009). According to Mellem *et al.,* (2009), TF values less than 1 indicates the metal are accumulated by plants and largely stored in the roots of the plants. Meanwhile, TF values greater than 1 indicates the plant translocate metals effectively from root to leaves. Figure 5 presents the Translocation Factor of Zn and Fe in water hyacinth and duckweed, respectively.

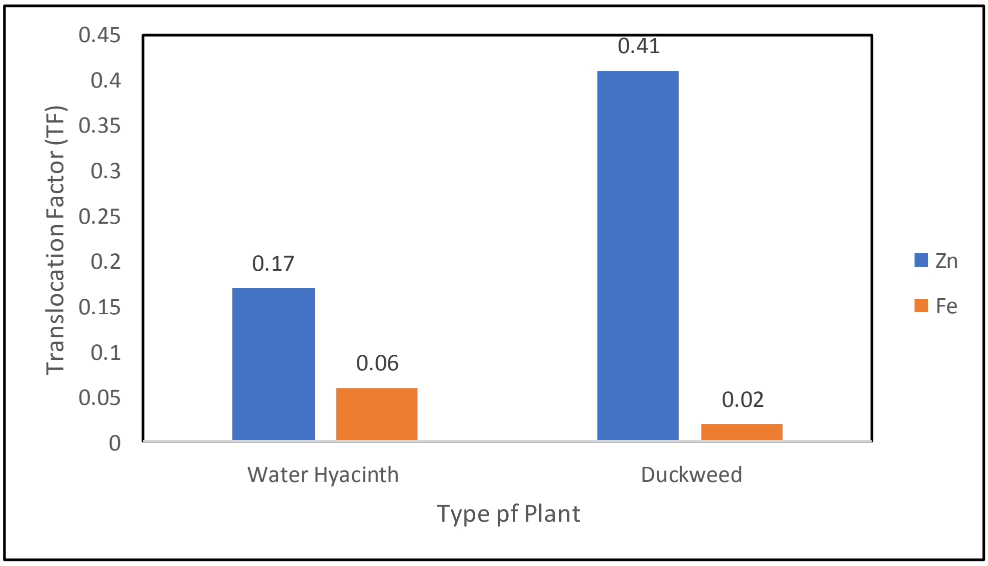

Figure 5. Translocation Factor of Zn and Fe in water hyacinth and duckweed.

Results show that the TF values of Zn and Fe in duckweed recorded are 0.06 and 0.02, respectively. Meanwhile, for water hyacinth, the TF values of Zn and Fe in the plant are 0.17 and 0.41, respectively. The lower TF values of Zn and Fe in duckweed indicated that the plant has a poor translocation ability compared to the water hyacinth.

Apart from that, the TF values in this study are in range of 0.02 to 0.41, which is lower than 1. This means that most of the Zn and Fe were accumulated in the roots of both plants. The inability of duckweed and water hyacinth to translocate metal may be due to some physiological barriers against metal transport to the aerial parts such as stem and leaf (Lu *et al.,* 2004). Besides that, translocation of metals in plants from roots to shoots can also be affected by two processes, which are root pressure and leaf transpiration (Lasat, 2000).

4. CONCLUSION

In this study, both duckweed and water hyacinth has demonstrated their capability in removing nearly 100% Zn and Fe from the wet market wastewater. This indicates that both floating plants were suitable to be a phytoremediation in removing metals from the solution. Although both plants may remove the metals from the solutions, it is appeared that the duckweed is as a better floating plant in removing Zn and Fe from wet market wastewater as compared to water hyacinth due to the higher percentage removal of Zn and Fe which are 99.57% and 97.91%, respectively. This might be due to the higher relative growth and bioconcentration factor (BCF) recorded by duckweed as compared to water hyacinth. Similar findings were recorded for Translocation Factor (TF) of duckweed and water hyacinth which is less than 1 indicating Zn and Fe were accumulated in the roots of both plants.

ACKNOWLEDGEMENTS

The authors would like to thank all individuals who have involved directly and indirectly throughout this study.

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