

Application of Aquatic Plants Phytoremediators as Green Technology Treatment in Polluted Urban Lakes Ecology

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Abstract—The aim of this research is to determine the species of aquatic plant for water quality remediation in polluted urban lake ecology. The removal rate of pollutants such as Chemical Oxygen Demand (COD), Copper (Cu), Zinc (Zn), Plumbum (Pb), and Iron (Fe) will be examined through a model system. These water quality parameters were chosen due to their high concentrations and may cause contamination to microorganism and aquatic urban lake ecology. Urban lake wastewater samples will be taken from 3 study areas which are Tasik Aman, Petaling Jaya, Tasik Ayer Keroh Melaka and Tasik Taman Pelangi Indah, Johor, which according to National Hydraulic Research Institute of Malaysia (NAHRIM) in 2010 to be the most polluted lake in Malaysia. Plants will be selected based on its availability, landscape value and highest pollution reduction. Batch treatment in a model system method will be adopted. Plants will be placed in a tank filled with the urban lake wastewater to be treated. The wastewater qualities and the plant growth will be monitored for 14 days on daily basis. The effectiveness of these plants to be used as phytoremediation for urban lake wastewater pollution and the best retention time will be identified.

Keywords—Green Technology; Phytoremediation; Removal Rate; Urban Lakes Ecology; Water Quality Parameters.

Abbreviations—Atomic Absorption Spectrophotometer (AAS); Chemical Oxygen Demand (COD); Copper (Cu); Iron (Fe); Indah Water Konsortium (IWK); National Hydraulic Research Institute of Malaysia (NAHRIM); Plumbum (Pb); Zinc (Zn).

I. INTRODUCTION

A major environmental concern due to dispersal of industrial and urban wastes generated by human activities is the contamination of urban lakes. Siti Zubaidah and Nik Ismail Azlan in their paper titled Aquatic Plant Based Green Technology as Phytoremediator for Polluted Urban Lakes Ecology, presented at International Congress on Natural Sciences and Engineering 2013 stated that controlled and uncontrolled disposal of waste, accidental and process spillage, mining and smelting of metalliferous ores, sewage sludge application to urban lakes are responsible for the migration of contaminants into non-contaminated sites as dust or leachate and contribute towards contamination of our urban aquatic ecosystem. Metal hyperaccumulation is a characteristic present in over 500 plant species and approximately in 0.2% of all angiosperms [Sarma, 2011].

At least 20 metals are classified as toxic with half of them emitted into the environment that poses great risks to

human health [Akpor & Muchie, 2010]. The common heavy metals like Cd, Pb, Co, Zn and Cr are phytotoxic at both low concentration as well as very high concentration are detected in waste water especially the urban lakes water ecology [Divya et al., 2012]. Recently, there has been an increasing interest in using biological indicators and remediators such as plants for soil, air and water pollution [Ruiz & Velasco, 2010]. Aquatic macrophytes are widely distributed in various wet environments, from fresh to salt water [Bonanno & Guidice, 2010] and they play an important role in heavy metals cycling in the wetlands due to uptake, storage, and release processes. Phytoremediation is a cost effective, environmental friendly, aesthetically pleasing approach most suitable for developing countries [Ghosh & Singh, 2005]. It consists of mitigating pollutant concentrations in contaminated soils, water, or air, with plants able to contain, degrade, or eliminate metals, pesticides, solvents, explosives, crude oil and its derivatives, and various other contaminants from the media that contain them.

With the ecological problems in view, therefore the motivation of this research is to determine the species of aquatic plant for water quality remediation in polluted urban lakes ecology. Phytoremediation using aquatic plants is evolving as a cost-effective alternative to high-energy, high-cost conventional method, thus considered to be a “Green Revolution” in the clean-up technologies. The objectives of the research are:

- To identify aquatic plant species suitable for pollution reduction
- To examine the effectiveness and the potential of aquatic plant species as remediator for unhealthy urban lake ecology
- To develop a model system for plant-based green technology water purification

The research focuses on the aquatic ecosystem of urban lakes in Malaysia which also applicable to other tropical countries. The watershed of this urban lake ecosystem is part of the urban issue and thus they tend to stress out the environmental problems affecting the urban areas by collecting and accumulating large amounts of nutrients and pollutants contaminants. Faecal contamination and toxic cyanobacteria blooms may worsen the ecological value of these environments and transform them into a potential risk of human health, which may require costly management and restoration plans. Therefore, the contribution of this manuscript is to come out with aquatic plant species list with the highest heavy metal accumulation rate. Thus, a recommendation of phytoremediator aquatic plants with significant landscape design value usage in the urban lake landscape design will be addressed to the landscape architects, urban lake managers and to all of its stakeholders.

II. REVIEW OF LITERATURE

Urban lakes are known to be the ecological barometers for the health of cities [Dalwani et al., 2008]. They regulate the microclimate of any urban center (Junior et al., 2008). The presence of urban lake, greatly influence the life of people living surrounding them. Since the olden days, urban lakes had been created to store rainwater and ensure supply for domestic use and for agriculture purposes [Dalwani et al., 2008]. Urban lakes are usually shallow, have many different demands made on them, and as a result they are vulnerable to changes in water quality through nutrient enrichment. Nevertheless the conception of city has deeply changed in time, especially in the last century, and the well-known features of the modern urban areas such as infrastructure development, housing and factories activities and encroachments of lakebeds itself has significantly contribute to threaten the quality of urban lakes aquatic ecosystems [Rao, 2006].

Due to the extreme consequences, heavy metal contamination in the urban lakes is a concern. A cost-effective means of remediation related to the contaminated areas must be provided. There is a number of conventional

remediation technologies such as solidification, soil washing and permeable barriers, but a majority of these technologies are costly to implement and cause further disturbance to the already damaged environment. Moreover, lack of understanding of the functioning of lakes among those responsible for their management is a major contributory factor in the decline of healthy urban lakes. There is a need to make current ecological knowledge about lakes and the way they function, available to lake managers, so that they can make informed decisions about the management of their urban lakes.

Contamination with heavy metals is one of the most pressing threats to water and soil resources, as well as human health [Lorestani et al., 2012]. Phytoremediation might potentially be used to remediate metal-contaminated sites. A major advance in the development of phytoremediation for heavy metal affected soils was the discovery of heavy metal hyperaccumulation in plants. This study applied several established criteria to identify hyperaccumulator plants. A case study was conducted at a mining area in the Hamedan province in the west central region of Iran. The results indicated that plant metal accumulation differed among species and plant parts. Plant species grown in substrata with elevated metal levels contained significantly higher metal levels. Using the most common criteria, *Euphorbia macroclada* and *Centaurea virgata* can be classified as hyperaccumulators of specific heavy metals measured in this study and they might potentially be used for the phytoremediation of contaminated soils.

Zhang et al., (2012) experimented with *Scirpus triquetus* (Triangular club-rush), a typical wetland species, to study the response characteristics to pyrene. A pot experiment was conducted to investigate the growth parameters (height, diameter, shoot number, total volume, underground biomass, above-ground biomass and total biomass), and enzymes (catalase and superoxide dismutase) of *S. triquetus*. The characteristics of soil enzymes (catalase and polyphenol oxidase) and microorganisms (bacteria and fungi) were also assessed after pyrene treatment. Elevated pyrene concentration (80 mg/kg(-1)) in the soil reduced the shoot number and biomass significantly, especially at the early growth stage. In root tissue, the enzyme catalase was activated at 80 mg/kg(-1) of pyrene. Compared to roots, shoots had higher enzyme activities. Catalase activities in the rhizosphere increased throughout the growth period of *S. triquetus*. Polyphenol oxidase activities in the rhizosphere were higher than those in the bulk soil and unplanted soil. The populations of bacteria (total bacteria, pyrene-tolerant bacteria, and actinomyces) and fungi decreased under the stress of high pyrene concentration, while that of pyrene-tolerant bacteria increased with the increasing pyrene concentration. The presence of pyrene did not benefit the growth of *S. triquetus*. *S. triquetus* and soil enzymes varied within the growth stages. The presence of *S. triquetus* could improve the activity of soil enzymes and facilitate the propagation of microorganisms which could help eliminate pyrene contamination.

III. PROBLEM STATEMENT

The aim of this research is to study the potential of aquatic plants as phytoremediator for excess nutrients.

Concerned with pollutant contaminants issues, this research attempts to discover the potential of aquatic plants as a remediator of unhealthy urban lake ecology. Aquatic plants have been widely used to treat wastewaters or increasingly used to remediate eutrophic waters in forms of constructed wetlands or retention ponds. This is a low-cost treatment with low land requirements, which is attractive to urban areas with high land prices. Thus, the research on how aquatic plants species can affect the life of aquatic ecosystem is going to be concluded. The focus of this research is on the phytoremediation technology, the current remediation technique for cleaning up contaminated lake using aquatic plants, which is cost-effective and has aesthetic advantages and long term applicability [Siti & Nik, 2013]. Besides that, phytoremediation also has been perceived to be a more environmentally-friendly “green” and low-tech alternative to more active and invasive remedial method. The aim of this research is to study the potential of aquatic plants as phytoremediator for excess nutrients. From literature review that have been made, the abundance of certain aquatic plants such as *Nelumbonucifera* (Water Lily), *Eichhorniacrassipes* (Water Lettuce) and *Hydrillaverticillata* (Common Hydrilla) were found to be substantially the best phytoindicator and phytoremediator species for unhealthy environment. Meanwhile *Nelumbonucifera* (Water Lily) was found to be useful remediator of low level environmental contamination that might otherwise be difficult to detect. Therefore, it can be concluded that all categories of aquatic plants (emerged, submerged and floater) can be manipulated as a tools to trace environmental contaminants of inorganic and organic pollutants.

Identifying and assessing the potential of aquatic plants species as a tool to trace pollutant contaminants is hoped to provide a guide that will help site cleanup managers and increase awareness on technical information and specialized recourses related to phytoremediation technologies. According to Russell et al., (2005), phytoremediation has become not only an interest of universities and major research centers, but also created a new business for contractors and consulting firms. The stakeholder will be advised by the phytoremediation consultants about whether phytoremediation would be the best cleanup method for their sites, and contractors are able to install the selected remediation system. However, there is still having limitations and disadvantages of phytoremediation that may not be applicable to each mechanism of phytoremediation. Although phytoremediation has proven to be an effective method, it is a site-specific technology.

Based on the success stories on the implementation of phytoremediation in some of the developed countries, the research relating to this emerging technology should be encouraged, deepened and applied in order to serve an economically feasible approach to pollutant removal

[Erakhumen & Andrew, 2007]. Various studies have shown that aquatic plants can improved the ecosystem of urban lakes and has been discovered to contribute to water quality maintenance. Therefore, the purpose of this study is to propose aquatic plant based green technology as phytoremediator for polluted urban lakes ecology.

IV. MATERIALS AND METHOD

The materials and methods of the research are divided into four sections. The first section described the study area selected for the research in order to identify the aquatic plant species that are suitable for Malaysian urban lakes pollution reduction. The second section described the plant sample collection and handling procedures. In the third section, lab based experiments have been conducted to examine the effectiveness of these aquatic plant species as pollution remediator for unhealthy urban lakes. The last section is the establishment of a pilot model system in the laboratory which uses samples from the study area. The heavy metal accumulation percentage will be monitored and recorded at 1day interval for 2 weeks. The data collected from the laboratory experiment and pilot model system had determined the most suitable aquatic plant species for water quality remediation in Malaysian urban lakes.

V. STUDY AREAS

Three lakes in Malaysia were selected for this research. These three areas were selected based on Indah Water Consortium report in 2010 being the most polluted lakes in Malaysia. Tasik Taman Jaya, Petaling Jaya in Selangor was reported to have the highest number of pollution from a total of 1,850 sources. This is followed by Tasik Taman Pelangi Indah, Johor with a total of 1,774 sources and Tasik Ayer Keroh, Melaka with 1,355 sources. Each lake represented different water pollution source with different types of heavy metals pollution.

5.1. Taman Tasik Jaya, Petaling Jaya, Selangor, Malaysia

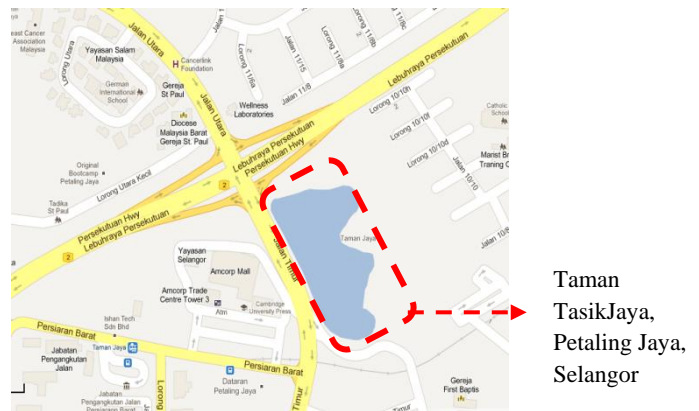


Figure 1: Location Plan of Taman Tasik Jaya, Petaling Jaya

Located at the heart of Petaling Jaya city (3°6'18"N 101°38'54"E), Tasik Taman Jaya, Petaling Jaya was reported to have the highest lake pollution percentage in Malaysia which had also been categorized as an endangered lake (IWK, 2010). According to Lake Maintenance Department, MajlisBandarayaPetaling Jaya, almost 80% of point sources that flows into the lake were from the residential and commercial area surrounding the lake. 10% is from manufacturing industry while another 10% is from rain water. Increasing industrialization and urbanization activities within the Petaling Jaya City, has led to the degradation of Tasik Taman Jaya ecology.

5.2. Tasik Taman Pelangi Indah, Johor Bahru, Malaysia

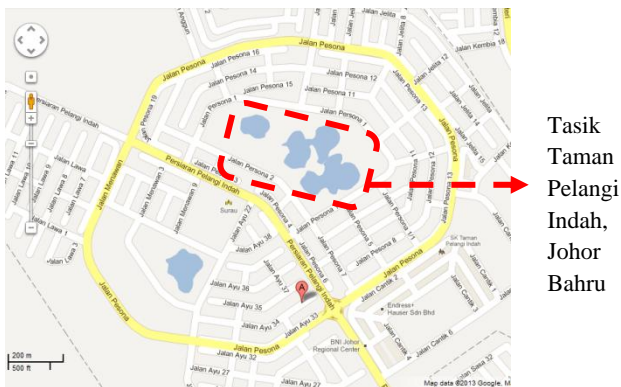


Figure 2: Location Plan of Taman Tasikpelangi Indah, Johor Bahru

Tasik Taman Pelangi Indah, Johor Bahru was reported to have the second highest lake pollution percentage in Malaysia by Indah Water Consortium (IWK) in 2010. According to Lake Maintenance Department, MajlisBandaraya Johor Timur, almost 65% of point sources that flows into the lake were from the residential and commercial area surrounding the lake. 25% is from manufacturing industry, 5% from rain water and another 5% in from various sources.

5.3. Taman Tasik Ayer Keroh, Melaka, Malaysia



Figure 3: Location plan of Taman Tasik Ayer Keroh, Melaka

Tasik Ayer Keroh, Melaka was ranked the third highest lake pollution percentage in Malaysia which had also been categorized as an endangered lake (IWK, 2010). According to BahagianKejuruteraan Sungai Negeri Melaka, in January 2011 a team named River Range Melaka lead by Haji Farnoh Bin Salam was formed to access and audit the lake water quality of Tasik Ayer Keroh. The outcome of the lake water quality audit clearly stated that Tasik Ayer Keroh was polluted with fertilizers, detergent, organic waste and sewage which in total decrease the amount of oxygen in water. The pollution affects the amount of oxygen present in the lake water compound which in long term will destruct the aquatic ecosystem of Taman Tasik Ayer Keroh, Melaka. According to MajlisBandaraya Melaka Bersejarah, almost 65% of point sources that flows into the lake were from the recreational area surrounding the lake. 20% is from manufacturing industry at Ayer Keroh Industrial Area. Another 10% is from surrounding residential area and 5% from various sources.

VI. DATA COLLECTION

6.1. Plant and Water Sampling

The samples were collected from stagnant lake water of the three study areas, in places where aquatic species could be observed. At these sites, samples of the water and emergent plant species were taken. The plant species collected were submerged, free-floating and rooted emergent plants. Each plant material was washed thoroughly with fresh water to remove sediment and other foreign objects and then briefly cleaned with distilled water. The preparation of plant material included, when appropriate, the separation into roots and aerial tissues of the aquatic plants. The sampling was accomplished within 6 months (January to June, 2013), and 13 species from different families were identified (Table 1). A total of 30 plant collection points were sampled at those 3 study areas. These points were marked on each lake site plan together with the water and soil sample for lab experiment usage. The pH of the water was determined using a pH meter in the field. The plant sampling procedure may took six months' due to the documentation works that needs to be done for Municipal Council of each lake in order to get approval to collect the aquatic plants, water and soil samples.

Table 1: Aquatic Plant Species List Collected at Study Areas

No.	Name	Family	Category	Collection Point
1	<i>Acrostachiumaureum</i> (Pokok Pakis)	Pteridaceae	Emergent	Lake bank, Tasik Taman Pelangi Indah, Johor Bahru
2	<i>Centellaasiatica</i> (PucukPegaga)	Apiaceae	Emergent	Lake bank, Tasik Taman Jaya, Petaling Jaya
3	<i>Colocasiaesculanta</i> (KeladiTelor)	Araceae	Emergent	Lake bank, Tasik Taman Pelangi Indah, Johor Bahru
4	<i>Cyperusculantus</i> (RumputSegiTiga)	Cyperaceae	Emergent	Lake bank, Tasik Taman Jaya, Petaling Jaya
5	<i>Eichorniacrassipes</i> (Water Hyacinth)	Pontederiaceae	Floaters	Lake edges, Tasik Taman Pelangi Indah, Johor Bahru
6	<i>Fimbristylismiliaceae</i> (RumputSegiTiga)	Cyperaceae	Emergent	Lake bank, Tasik Taman Pelangi Indah, Johor Bahru
7	<i>Hanguanamalayana</i> (Bakong)	Hanguanaceae	Emergent	Lake bank, Tasik Taman Jaya, Petaling Jaya
8	<i>Ipomeaaquatica</i> (Kangkung)	Convolvulaceae	Emergent	Lake bank, Tasik Taman Jaya, Petaling Jaya
9	<i>Nymphaea alba</i> (Water Lily)	Nymphaeaceae	Floaters	Lake edges, Tasik Taman Pelangi Indah, Johor Bahru
10	<i>Pandanusamaryllifolius</i> (Pandan Wangi)	Pandanaceae	Emergent	Lake bank, Taman Tasik Ayer Keroh, Melaka
11	<i>Pandanusanderi</i> (MengkuangKuning)	Pandanaceae	Emergent	Lake bank, Taman Tasik Ayer Keroh, Melaka
12	<i>Pandanusstectorius</i> (Mengkuang)	Pandanaceae	Emergent	Lake bank, Taman Tasik Ayer Keroh, Melaka
13	<i>Wedeliatrilobata</i> (WedeliaKuning)	Asteraceae	Emergent	Lake bank, Taman Tasik Ayer Keroh, Melaka

Three replicate water samples were taken in 1 litre bottle at each site to be examine in the laboratory. Each particular site will have 3 bottles of water sample. These samples were taken at different points of each lake. These points were based on the macrophytes subgroup locations which were the emergent, submergent and floaters. On site, YSI 556 MPS (Multi Probe System) equipment had been calibrated to identify the parameter of pH and D.O. (dissolved oxygen) of the respective water bodies. This equipment is an auto detect for the cited parameters. Those physiochemical parameters were measured randomly and triplicate on different spots at each sampling site. Abiotic factors such as temperature, light, pH will determine the aquatic plant distribution and nutrient concentrations [Bronmark & Hansson, 2007].

The samples were carefully labelled and transported to the laboratory in an icebox and then stored at 4°C in the laboratory where sample analysis was done. Those samples were tested using HACH spectrophotometer [HACH, 1989], in order to detect different nutrients, which are ammonium (NH₄), nitrite (NO₂), nitrate (NO₃) and phosphate (PO₄). Water samples were collected between January to June 2013 (6 months).

6.2. Laboratory Testing

6.2.1. Sample Processing of Heavy Metal

Ten samples were collected in triplicate in plastic containers at selected sites using standard methods of collection. Water samples were brought to the laboratory at 40C and preservation of samples has been done by the addition of 2.5ml chloroform in 500 ml of water. The sample processing

and analytical procedures for Atomic Absorption Spectrometer (AAS) analysis were as follows:

- Water samples was filtered through No 40 filter paper to remove gelatinous precipitates
- Water samples was filled into test tube
- A multistandard and an acid nitric is prepared and placed in front of line of test tubes. This multistandard is needed because each heavy metal has its own chemical standard. These 2 acid nitric needs to be added regularly throughout the process because it acts as blank.

6.2.2. Sample Analysis by Atomic Absorption Spectrometer

Heavy metal concentration in different water samples were determined by flame atomic absorption spectrometer using the Perkin-Elmer Atomic Absorption Spectrometer. Operational conditions were adjusted in accordance with the manufacturer guidelines to yield optimal determination. Quantification of heavy metals was based upon calibration curves of standard solutions of respective heavy metals. These calibration curves were determined several times during the metal analysis and controlled by including triplicate samples in analytical batches and blanks. The relative standard deviation of the mean of triplicate measurements was <5.

6.2.3. Sample Processing of Nutrient

Ten water samples were collected in triplicate in plastic containers at selected sites using standard methods of collection. Water samples then were brought to the laboratory at 40C and preservation of samples were done by the addition

of 2.5ml chloroform in 500 ml of water for further analysis. Nitrogen and phosphorus were analyzed by using HACH DR 3800 Spectrophotometer.

6.2.4. Sample Analysis by HACH DR 3800 Spectrophotometer

A sample cell was filled with 10 mL of sample.

- Prepared Sample: The content of one NitraVer 5 Nitrate Reagent Powder Pillow will be added. A stopper was inserted into the cell. The cell was swirled to dissolve. A pink color will develop if

nitrite is present (Figure 4). The instrument timer was started. A 20-minute reaction period has begun.

- Blank Preparation: When the timer expires, a second sample cell was filled with 10 mL of sample. The blank was wiped and inserted into the cell holder. The instrument was zero. The display showed: 0.0 mg/L NO₃ —N. Within two minutes after the timer expires, the prepared sample was wiped and inserted into the cell holder. The results was read in mg/L 0.0 mg/L NO₃ —N.



Figure 4: Sample Analysis Result of each Pollution Nutrient

6.3. Laboratory Testing

Six experiments cells will be perform in identical containers (0.39 0.56m² floor area), in order to simulate the level of circulation (Figure 1.6). The working volume of the containers was set at 46 L. The tests were performed using 30 min/h of artificial light at 4600–4700 lux. In five containers, water and soil from study area was used to support different macrophytes (15 pieces in each), and one container (sixth) (without plants) was used as the control (for pollution reduction percentage bar). In these experiments, the circulation conditions were as follows:

Table 2: Sewage Water Circulation Flow Rate [Zimmels, 2006]

Test Number	Circulation	Flow Rate (L h ⁻¹)
1		10
2		20
3		30
4		40
5		0
6		Control

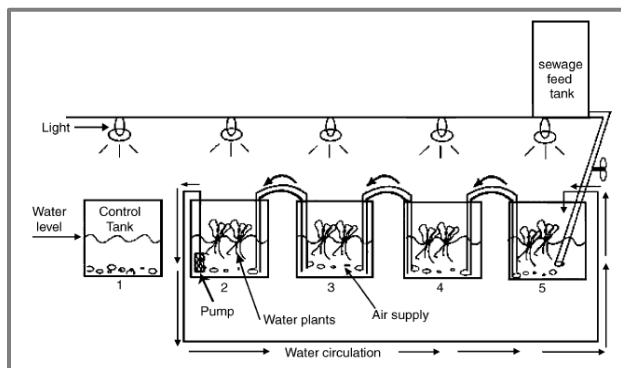


Figure 5: Schematic Layout of Laboratory Pilot Model System Setup

5 tanks will be filled with sewage water from taken from the site study area. Tank 1 will be the controller. Tank 2-5 will be filled with selected aquatic plants for heavy metal absorption readings. Each tank will be filled with 5-10 numbers of each species. The pollution reduction readings in each cell will be recorded in 1 week intervals. After 2 weeks, each cell plant sample will be replaced with other set of macrophytes. Table 2 is the water circulation flow rate standard used in this model system according to Zimmels, 2006.



Figure 6: An Example of Pilot Model System of Aquatic Plants Phytoremediation Process done by Sayali Joshi from Shrishti Eco-Research Institute [Sengupta et al., 2008]

VII. ANALYSIS AND DISCUSSION

The concentrations of metals in aquatic plants can be more than 100,000 times greater than the associated water [Clayton et al., 2000]. Thus, certain aquatic plants can be used as remediators of metal contamination that might be difficult to detect. Bioaccumulation of heavy metals varies significantly among species growing in the same area [Brekken & Steinnes, 2004]. Consequently, heavy metal accumulation rate may also show differ during seasonal variation [Eid, 2009]. According to Al-Yemni in 2003, the major industrial heavy metal contaminants, that is, Cd, Hg, Pb, Cr, Cu and Zn, remain as dissolved phase in water and soil.

The experiment will concentrate on seven potential remediator aquatic plants species listed in table 3 below as the research limitation. The laboratory experiment and pilot model system data analysis will determine heavy metal accumulation and toxic concentration of each species. In this research, not only the phytoremediation ability is being measured but those aquatic plants also being valued by the landscape design merit. Table 3 below shows the aquatic plant species list with highest phytoremediation ability that earned highest landscape design merit. Each of these aquatic species can trace and remediate different types of heavy metals. Figure 7 shows that those aquatic species consist of submerge and floaters aquatic subgroups. Based on their pollutants remediation ability and landscape design values, a recommendation of the usage and planting location of these aquatic plants will be made to the landscape architects and lake managers of the Malaysian urban lakes stakeholders.

Table 3: Aquatic Plants for Phytoremediation of Toxic Trace Elements in a Wide Range of Toxicity Bioassays

No.	Plant Species	Metals remediated
1	Azollafiliculoides	Cr, Ni, Zn, Fe, Cu, Pb
2	Hydrillaverticillata	Hg, Fe, Ni, Pb
3	Lemna Minor	Mn, Pb, Ba, B, Cd, Cu, Cr, Ni, Se, Zn, Fe
4	Pistiastratoites	Cu, Al, Cr, P, Hg
5	Salvinianatans	Pb, Cr
6	Spirodelapolyrhiza	Cr
7	Wolffiaglobosa	Cd, Cr

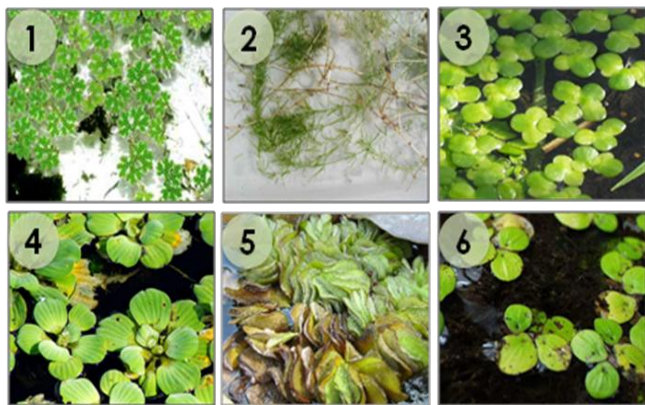


Figure 7: Aquatic Plant Species with Phytoremediation Ability [Dalwani et al., 2008]

VIII. CONCLUSION

Phytoremediation of metals is a cost-effective green technology based on the use of specially selected metal-accumulating plants to remove toxic metals from soils and water. Phytoremediation is widely accepted as a cost-effective environmental restoration technology. Phytoremediation is an alternative to engineering procedures that are usually more destructive to the soil. It can be concluded that treatment for urban lakes wastewater by aquatic plants is beneficial in improving water quality by high efficiency in removing nutrients especially nitrogen and phosphorous and approximately removing heavy metals.

Over the past 20 years, this technology has become increasingly popular and has been employed at sites with soils contaminated with lead, uranium, and arsenic. While it has the advantage that environmental concerns may be treated in situ. One major disadvantage of phytoremediation is that it requires a long-term commitment, as the process is dependent on a plant's ability to grow and thrive in an environment that is not ideal for normal plant growth.

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