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Duckweed Plant: A Better Future Option for Phytoremediation

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Abstract-Preservation of the environment quality is one of the major concerns of this century. The biosphere is getting degraded by the release of natural and synthetic substances which can cause deleterious effects on living organisms. Among all the pollutants, heavy metals are easily transported and accumulated in the environment. Several industries such as textile, steel, electroplating, metal producing etc. release heavy metals (cadmium, copper, chromium, nickel, lead etc.) in the wastewater. Most of the heavy metals are toxic or carcinogenic in nature and may pose a threat to human health and the environment at higher concentrations. Several conventional methods are used for the removal of heavy metals from wastewater include chemical precipitation, ion exchange, reverse osmosis etc. but major limitations of such treatments are production of large quantities of sludge and may be ineffective or economically expensive processes. . So, the search for a new, simple, effective and eco-friendly technologies for the removal of heavy metals from wastewater has directed attention towards phytoremediation. Many plants has been used for treating wastewater but duckweeds (family Lemnaceae) appear to be the better alternative and have been recommended for wastewater treatment as they are more tolerant to cold than water hyacinth as well as more easily harvested than algae, and capable of rapid growth.

Key Words: Heavy Metals, Duckweed, wastewater treatment, Phytoremediation.

I. INTRODUCTION

The ideal plants for phytoremediation should possess the ability to tolerate and accumulate high levels of heavy metals in their harvestable parts, while producing high biomass. Several species of aquatic plants have been used for phytoremediation of wastewater (Khellaf and Zerdaoui 2009).). A list of some aquatic plants used for phytoremediation in recent past is given in Table 1. (V.P. Dushenkov et al.,1995, Prasad et al.,2003).

A list of some aquatic plants used for phytoremediation	
Eichhornia crassipes	Water hyacinth
Hydrocotyle umbellata L.	Pennywort
Typha latifolia L.	Cattail
Lemna minor L.	Duckweed

Duckweeds (family Lemnaceae) appear to be the better alternative and have been recommended for wastewater treatment as they are (i) more tolerant to cold than water hyacinth, (ii) more easily harvested than algae, and (iii) capable of rapid growth (Shanti S. Sharma , J.P. Gaur.1994). The small size, simple structure and rapid growth make duckweed very suitable for toxicity tests (OECD, 2002), able to remove and accumulate large amounts of heavy metals, principally through the fronds (Zayed et al. 1998). Duckweeds are aquatic plants which often form dense floating mats in eutrophic ditches and ponds (Driever et al., 2005). A literature survey has indicated that duckweed has very good potential as a phyto-remediating plant. Duckweeds belong to four genea; Lemna, Spirodela, Wolfia and Wolffiella. About 40 species are known worldwide (Iqbal, 1999). All of the species have flattened minute, leaf like oval to round "fronds" from about 1mm to less than 1cm across. Some species develop root-like structures in open water which either stabilise the plant or assist it to obtain nutrients where these are in dilute concentrations. Duckweed appear to be better alternative and have been recommended for wastewater treatment because it has capability of rapid growth on wide range of pH and cold tolerable to grow throughout the year but aquatic plants, such as water hyacinth, can only grow in summer (PRISM 1990) . Duckweed produces biomass faster than any other aquatic plant and has clear potential as an alternative for accumulation of heavy metals. The Lemna gibba L. and the Lemna minor L. are the most studied species of Lemnaceae family in phytoremediation and ecotoxicology (Mkandawire et al., 2004; Mkandawire and Dudel, 2005). Most members of the Lemna genus are used as model plants for Eco toxicological assessment, phytoremediation, nutrient and metal uptake studies, and bioassays (Sandra Redic et al.,2009, Ensley et al., 1995).

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II. REVIEW WORK

There are several studies that supported the fact that most Lemna spp. Show an exceptional capability and potential for the uptake and accumulation of heavy metals as well as metalloids, surpassing that of algae and other aquatic macrophytes. Many studies support Lemnaceae (duckweed) for its greatest capacity in heavy metal removal as well as organic matter removal. Axtell et al. (2003) have reported that duckweed (Lemna minor) can remove 82% nickel and 76% of lead that make it a potential plant for phytoremediation. Toxicity of metal in Lemna tissue was found to be in decreasing order of damage: Zn > Ni > Fe > Cu > Cr >Pd (Horvat et al. 2007) when Lemna minor was exposed to electroplating wastewater. Water and all the pollutant contents are removed through the leafy fronds (Naumann et al. 2007). Leela Kaur et al. (2012) show the effect of pH in the range from 4-10 on duckweed for the removal of Pd and Ni. The author found that the maximum removal was 99.99% for Pb at pH 5-6 and 99.3% for Ni at pH 6 after 28 days exposure. The highest bio concentration potential of Pb was 0.900 at pH 6 when L. minor is treated with 10 mg/l of Pb for 10 days by Divya et al. (2012) clearly indicate that L.minor has the potential for removing Pb from industrial wastewater. Jafari et al. (2011), Lahive et al. (2011), investigated the capacity of three Lemna species namely L. minuta, L. minor, and L. trisulca to purify waters polluted with Zn. Percentage removal by Lemna spp. for 1, 5, 10, 15, and 20 mg/l Zn treatment for 10 day incubation was found to be highest by L. trisulca (97%) as compared to L. minuta (89%) and L. minor (83%). Another studies conducted with Lemna minor to treat water polluted with cadmium shows that lemna minor is a good cadmium accumulator and able to remediate cadmium polluted water, especially at 13 and 22µM concentration (Bianconi et al. 2013). Lemna polyrrhiza was also found to be very good bio accumulator of heavy metals. When this plant was exposed to 10 mg/l of the Zn, Pd and Ni for four days accumulated 27.0, 10.0 and 5.5 µg/mg of Zn, Pd and Ni respectively (Sharma et al, 1994). Lemna minor effectively remediate copper from the municipal wastewater. The addition of Lemna minor to the municipal wastewater polluted with copper can lower down the copper concentration up to 55% (MR Apelt, (2010). According to the research conducted by Donganlar BZ, Seher C, Telat Y (2012), Lemna gibba can effectively remove Mn from the polluted aquatic environment by phytoremediation. Lemna gibba accumulated up to 15.15 mg/g of D.W. when exposed to 16 mg/l of Mn concentration. Duckweed pond can be well suited for post-treatment for textile wastewater specially for Cr (Roger P. Staves, Ronald M. Knaus. 1985) and Zn removal at lower concentration (Christian et al. 2012). N. Khellaf, M. Zerdaoui (2009) have reported that duckweed can tolerate various heavy metal, viz., Cu, Ni, Cd and Zn at concentrations of 0.4, 3.0, 0.4 and 15.0 mg/L respectively without any toxicity (chlorosis, frond disconnection and necrosis). Uysal (2013) demonstrated with pilot system consisting of ponds with continuous water flow, like a natural and constructed wetland, that duckweed, Lemna minor L. could efficiently reduce chromium contents of water. It can accumulate chromium concentration up to 4.423mgCr/g when the pond operated at pH 4.0 and 5.0 mg Cr/L. Several other studies have concluded that Duckweed (Lemna minor L.) can be used as a test organism to monitor heavy metals and other aquatic pollutants, because duckweed may selectively accumulate such chemicals. As compared to algal test, Lemna test is considered as most suitable one to detect genotoxicity or toxicity (Stefan Gartiser et al. 2010). The plants possess physiological properties (small size, rapid growth between pH 5 and 9, and vegetative propagation) as well as detect inhibition of photosynthesis and also not get disturbed by waste water colouration, which make them an ideal test system for ecotoxicological testing (Redic et al. 2009, K.-J. Appenroth. 2009). Wafaa abou el-kheir et al, (2007) studied the efficiency of duckweed (Lemna gibba L.) as the biological tool for wastewater treatment. The results shows that total suspended solids, biochemical oxygen demand, chemical oxygen demand, nitrate, ammonia, ortho-phosphate, Cu, Pb, Zn and Cd decreased by: 96.3%, 90.6%, 89.0%, 100%, 82.0%, 64.4%, 100%, 100%, 93.6% and 66.7%, respectively. Loveson et al. (2013) reported the heavy metal removal efficiency of duckweed. This study involved a laboratory experiment of eight days with Spirodela polyrrhiza duckweed in improving the quality of two polluted wetlands. The highest rates of reduction after 8 days of treatment were for heavy metals, accounting 95%, 79%, and 66% for Lead, Copper and Zinc, respectively, followed by 53% for Chromium, 45% for Mercury, 26% for Cobalt, 20% for manganese and 7% for Nickel. Hegazy et al (2009) studied the bioaccumulation of four metals (Cr, Cu, Pb and Zn) by Lemna gibba. Heavy metals were ranked according to the preference for bioaccumulation by L. gibba, Zn came in the first place followed by Cr, Pb and Cu with bioaccumulation factors 13.9, 6.3, 5.5 and 2.5 respectively. Smain Megateli et al. (2009) confirmed the capacity of accumulation of copper, cadmium and zinc by Lemna. Phytoremediation by this plant was attributed to precipitation of metal salt, adsorption on the plants and absorption and sequestration inside the plant. Abd El-Mageed et al. (2010) recommended the treatment of sewage water with duckweed before use in agricultural practices specially fish farming. Lemna species accumulate the heavy metal like Pd, Cd, Cu and Fe in their tissues and reduced the bioavailability of these metals in reared fishes. Experiment conducted by Wenhua Hou et al (2006) shows that duckweed can effectively tolerate Cu^{2+} <10 mg/l andCd^{2+}< 0.5 mg /l concentrations, So can be recommended to bio remediate water body polluted with low level Cu and Cd. The S. polyrhiza L. can be a good option for phytofiltration of arsenic by physico-chemical adsorption and through phosphate uptake pathway when treated with arsenate and dimethylarsinic acid (DMAA) with 1.0, 2.0 and 4.0 µM concentration. Bioaccumulation of various trace element by Lemna gibba was well documented (Jain et al., 1988; Ernst et al., 1992; Hasar and Öbek, 2001; Kara et al., 2003). Lemna gibba can also accumulate arsenic, uranium and boron from secondary effluent and the preferential sequence is As > B > U (AhmetSasmaz & ErdalObek . 2009). Nayyef M. Azeez & Amal A. Sabbar.(2012) tested the efficiency of duckweed in improving the quality of effluent from oil refinery. The heavy metal removal efficiency was found to be 99.8%, 99.6%, 98.7% and 72% for Copper, Cadmium, Lead and Zinc, respectively. Zayed (1998) provided the result under experimental conditions that duckweed found to be a good accumulator of Cd, Se, and Cu, a moderate accumulator of Cr, and a poor accumulator of Ni and Pb. The author shows the toxicity effect of each trace element on plant growth was in the order: Cu > Se > Pb > Cd > Ni > Cr. Teixeira et al. (2013) also support the potential of L. minor for the bioaccumulation of iron which make it an ideal plant for the bioremediation of mine effluent.

III. CONCLUSION

Water contamination caused by heavy metals is a major problem worldwide. Both wastewater and un-sufficiently treated industrial water contribute continuously to degrade the environment. In contrast to organic contaminants, heavy metals persist and are likely to accumulate in the environment. Conventional remediation technologies like chemical precipitation, reverse osmosis, ion exchange and solvent extraction have disadvantages including incomplete metal removal, quite expensive and generation of toxic sludge which requires disposal. Phytoremediation technology has proved to be a viable option to purify water contaminated with trace elements since it is cost-effective and has a positive impact on the environment. This is an alternate technology in which small scale wastewater treatment can be achieved. It has been used recently in Bangladesh for wastewater treatment as well as this technology has been implemented at village level under UNDP project. More research through pilot projects is needed in order to refine the sizing of the ponds used and to determine the correct innocculum of plant material to achieve a predetermined effluent quality.

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