Duckweed as Ecofriendly Tool for Phytoremediation

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Abstract: ***Wastewater treatment remains a problem in most developing countries. This is a review paper illustrating the use of duckweed-based wastewater treatment systems that provide genuine solutions to these problems. 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. This review paper illustrating the efficiency of duckweed (lemna minor, Lemna gibba, S. polyrhiza) for heavy metal removal. Any aquatic plant that is capable of recovering or extracting nutrients or pollutants and has a fast growth rate coupled with high nutritive value is an excellent candidate for bio-remediation of waste waters. Therefore, this review paper is oriented towards cost-effective and eco- friendly technology for waste water purification, which will be beneficial for community. This paper discusses the utilization of duckweed plants in purifying water and waste. They are functionally simple, yet easy to maintain; and they can provide tertiary treatment performance equal or superior to conventional wastewater treatment systems now recommended for large scale operation.***

Keywords: Duckweed, Phytoremediation, wastewater Treatment, Heavymetal, Bioremediation

1. 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).).). Duckweed is a small, free–floating aquatic plant belonging to the Lemnaceae family (Landolt, 1998). Various duckweed species have been used for the treatment of municipal and industrial wastewaters in many countries, including Bangladesh, Israel, and the U.S. (Alaerts et al., 1996; Culley et al., 1981; Oron, 1994; Oron et al., 1988; van der Steen et al., 1998). 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). 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. This review paper addresses the utilization of some eco-friendly and low cost technologies for sustainable *crassipes* at low metal concentration The removal percentages were 100%, 100% and 95% for 1, 3 and 6 mg l-1 respectively for *L. minor* at the end of the experiment. These results were found to be similar to those found by development, with special reference to duckweed technology. Studying the economics of different wastewater a treatment is an essential pre-requisite to the identification of cost-effective solutions. Duckweed can be found world-wide on the surface of nutrient rich fresh and brackish waters (Zimmo, 2003). The nutrients taken up by duckweed are assimilated into plant protein. Under ideal growth conditions more than 40% protein content on dry weight basis may be achieved (Skillikorn et al., 1993).

2. 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.). According to Khellaf et al .2009, L. minor can tolerate heavy metal concentration at 0.4, 0.4, 3 and 15 mg/L of metals Cd, Cu, Ni and Zn respectively. It proved that the aquatic macrophytes could survive in a medium containing 3 mg Ni/L or 15 mg Zn/L. Although the level of heavy metal can affect the growth. The result shows that aquatic species could be a good candidate for cleaning up wastewater polluted with Zinc and Nickel (industrial and residential effluents). BRES at al 2012 conducted a comparative study for heavy metal removal efficiency for *lemna minor* and *Eichhornia crassipes* for the removal of ni metal. The results clearly states that *lemna minor* can more effectively remove Ni metal as compared to the *Eichhornia* Axtell et al. (2003), who studied the removal of Ni in L. minor with different concentrations of Pb and they found similar removal. The results showed that this plant removed an 80 % and 87 % of Ni to 2.5 and 5 mg l-1 respectively. As aforementioned, Lemnaceae can tolerate and accumulate high concentrations of heavy metals and organic compounds. Abou el- Kheir et al. (2007) conducted an experiment to study the efficiency of duckweed (*Lemna gibba L.*) as an alternative cost effective natural biological tool in wastewater treatment in general and eliminating concentrations of both nutrients and soluble primary treated sewage water systems (from the collector tank) for aquatic treatment over eight days retention time period under local outdoor natural conditions. Samples were taken below duckweed cover after every two days to assess the plant's efficiency in purifying sewage water from different pollutants and to examine its effect on both phytoplankton and total and fecal coli form bacteria. 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. Phytoplankton standing crop decreased by 94.8%. Total and fecal coliform bacteria decreased by 99.8%. Dry and wet weights and protein content of *Lemna gibba* increased with increasing treatment period. 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). At different pH values in the range of 4-10, the removal of Pb and Ni in solution with *Lemna minor* was studied by Leela at el 2012. The maximum removal was found to be 99.99% for Pb at pH 5-6 and 99.3% for Ni at pH 6 after 28 days exposure. The study found that Pb removal was lowest (95.94%) at pH 10 after 7 days exposure treatments. In the same way the lowest Ni removal was achieved at pH 10 for 7 days treatments (73.78%). This states that alterations of the physiochemical conditions of the environment like pH can strongly influence the relative proportions of the metal ions that can be taken up by the respective plant. So, the study confirm the capacities of accumulation of lead and nickel by *Lemna minor* plant and its good potential for phyto remediation. The reason behind the removal from the medium was attributed to precipitation of metal salts, adsorption on the plants and absorption and sequestration inside the plant. *L. minor* could be used as an effective bio accumulator for the treatment of Pb and Ni containing wastewater. The capacity of aquatic plant such as duckweed (Lemna sp.) to remove toxic heavy metals from water are well documented and plays an important role in extraction and accumulation of metals from wastewater. *L.minor* can remove up to 90% of soluble Pb from wastewater. Some characteristics e.g. *L.minor* can grow well in pH from 6 to 9 while the lowest value of pH it can tolerate in between pH 5-6 make it a suitable plant for phytoremediation. However, nitrate had few inhibitory on the growth (Chong et al., 2003). Mark R. Apelt 2010 also recommend *Lemna minor* plant for removal of copper from the wastewater as lemna minor plant can effectively decrease copper upto 55% of the total in only 9 days. *Lemna minor* was shown to be effective at remediating copper from an aqueous solution of municipally generated waste water. *Lemna minor* can be used as suitable flora species for phytoremediation of copper contaminated waste water. Duckweed (*Lemna minor*) found to remove effectively iron and copper at low concentrations in laboratory experiments (Jain et al., 1989) as well as cadmium (Wang et al., 2002). Common duckweed *(L. minor*) is a worldwide species which is commercially used in ecotoxicological laboratories and research (Vladimír DVOŘÁK et al 2012, Sandra Radic at al 2009). 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 elements 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. In the experiment of Shammout et al, (2008), duckweed (Lemna sp.) has been used to upgrade the quality of wastewater at Khirbet As-Samra wastewater treatment plant, which is the largest in Jordan. It was originally designed to receive 68,000 m?/day but it is currently receiving 160,000 m^3/day. Laboratory experiments showed that the average percentage removal efficiency of Total Coliform (TC) was 68%, Faecal Coliform (FC) 69%, Total Viable Count (TVC) 75%, BOD5 51%, NO_3^- 56%, TN 48%, organic nitrogen 46%, PO_4^{3-} 56% and total phosphorus 50%. At the experimental site of Khirbet As-Samra, the results were 57, 59, 50, 44, 30, 26, 25, 28 and 26%, respectively, and the removal efficiency of NH_4^+ was 27%. Experimental results showed that *Lemna gibba* could be used to upgrade the quality of the pond effluent with respect to pathogens, biological oxygen demand, nitrogen and phosphorus.

3. Conclusion and Future Scope of the Study

Natural systems, such as duckweed systems are yielding good effluent quality, in many situations at reduced costs and it is believed also at reduced environmental impact. Duckweed based systems fit into the new concept of recycling and cost recovery. It is an affordable technology utilizing plants as environmental cleansers in wastewater management. On one hand manure and fertilizers are getting costlier day by day and on the other hand we have resources like village ponds where the much needed nutrients are lying free of cost. 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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