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Use of Duckweed in Wastewater Treatment

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ABSTRACT: Treatment of domestic wastewater, at both the village and urban level, 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. They are inexpensive to install as well as to operate and maintain. They do not require expensive technologies. 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: Ammonium, Duckweed, Lemna minor, Nitrogen, Nutrient removal, Phosphorus, Swine wastewater treatment.

I. INTRODUCTION

Waste-water is the combination of liquid or water-carried wastes originated from the sanitary conveniences of dwellings, commercial or industrial facilities and institutions, in addition to any ground water, surface water and storm water that may be present. Untreated wastewater generally contains high levels of organic material, numerous pathogenic microorganisms, as well as nutrients and toxic compounds. It thus entails environmental and health hazards and, consequently, must immediately be conveyed away from its generation sources and treated appropriately before final disposal. The ultimate goal of wastewater management is the protection of the environment in a manner commensurate with public health and socioeconomic concerns. Wastewater treatment is becoming even more critical due to diminishing water resources, increasing wastewater disposal costs. The municipal sector consumes significant volumes of water, and consequently generates considerable amounts of wastewater discharge. This review paper addresses the utilization of some eco-friendly and low cost technologies for sustainable development, with special reference to duckweed technology. Studying the economics of different wastewater treatments is an essential pre-requisite to the identification of cost-effective solutions.

II. REVIEW WORK

The Lemnaceae family consists of four genera (Lemna, Spirodela, Wolffia&Wolffiella) and 37 species have been identified so far. Compared to most other plants, duckweed has low fiber content (about 5%), since it does not require structural tissue to support leaves and stems. Applications of Lemnagibba L (duckweed) in wastewater treatment was found to be very effective in the removal of nutrients, soluble salts, organic matter, heavy metals and in eliminating suspended solids, algal abundance and total and fecal coliform densities. Duckweed is a floating aquatic macrophyte belonging to the botanical family Lemnaceae, which 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). According to SaschaIqbal(1999) two basic principles for pond design and operation are used for duckweed treatment, namely plug-flow and batch systems. Duckweed plug flow design seems to be the

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more suitable treatment option for larger wastewater flows originating from communities and (peri-)urban areas, as it ensures an improved and more continuous distribution of the nutrients. A plug-flow design also enhances the contact surface between wastewater and floating plants, thereby, minimizing shortcircuiting. To ensure plug-flow conditions, a high plug-flow length to width ratio of 10:1 or more is necessary (Hammer 1990). Alaerts et al. (1996) reported excellent treatment results with a length to width ratio of 38:1. Moreover, a narrow, channel-like design allows easier access to the water surface for operation and maintenance work. Batch-operated ponds are a feasible option for introduction of duckweed aquaculture in villages where already existing ponds can often be used and, thus, save capital costs for extra earth work. The HRT is dependent on the organic, nutrient and hydraulic loading rate, depth of the system and harvesting rate (Metcalf and Eddy 1991). To ensure acceptable pathogen removal and treatment efficiency, comparatively long retention times in the range of 20 to 25 days are postulated for duckweed (plug-flow) systems (Metcalf and Eddy 1991). Reported pond depths range from 0.3 to 2.7 m up to even 5 m (Lemna Corp. 1994). Average organic loading rates expressed in terms of BOD5 for plant systems without artificial aeration should not exceed 100 to 160 kg/ha•d in order to obtain an effluent quality of 30 mg BOD/l or less (Metcalf and Eddy 1991, Gijzen and Khondker 1997). The choice of harvesting technique is dictated by system design and by labour and equipment costs. For shallow ponds, the most simple harvesting techniques include manual skimming of the plants from the pond. Two people were reported to require 3.5 hours for manual harvesting of duckweed from a 0.3 ha pond in Taiwan. Large-scale harvesting in industrialized countries is carried out with mechanical harvesting machines requiring, however, deep ponds. Duckweed growth rapidly declines at temperatures above 31 °C to 35 °C (Iqbal 1999). TSS are removed mainly by sedimentation and biodegradation of organic particles in the pre-treatment and duckweed pond system. A minor fraction is absorbed by the roots of the duckweed fronds, where organic particles undergo aerobic biodegradation by microorganisms, and part of the degraded products is assimilated by the plants (Iqbal 1999). Landolt and Kandeler (1987) reported the direct uptake of small hydrocarbons by duckweed, however, heterotrophic growth probably plays a minor role in total BOD removal. Existing results suggest that approx. 50 % (± 20 %) of the total nitrogen load is assimilated by duckweed, while the remaining nitrogen is removed by indirect processes other than plant uptake of which nitrogen loss to the atmosphere by denitrification and volatilisation of ammonia are suggested to play a major role (Alaerts et al. 1996, Gijzen and Khondker 1997, Koerner and Vermaat 1997). In a duckweed treatment system, phosphorous is normally removed by the following mechanisms: plant uptake, adsorption to clay particles and organic matter, chemical precipitation with Ca^{2+}, Fe^{3+}, Al^{3+}, and microbial uptake (Iqbal 1999). 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 (Lemnagibba 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 Lemnagibba increased with increasing treatment period. Ozengin N, Elmaci A.(2007) performed the studies in which growth of duckweed was assessed in laboratory scale experiments. They were fed with municipal and industrial wastewater at constant temprature. COD, total nitrogen (TN), total phosphorus (TP) and ortho-phosphate (OP) removal efficiencies of the reactors were monitored by sampling influent and effluent of the system. Removal efficiency in this study reflects optimal results: 73-84% COD removal, 83-87% TN removal, 70-85% TP removal and 83-95% OP removal.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 m³/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%, NO3− 56%, TN 48%, organic nitrogen 46%, PO43− 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 NH4+ was 27%. Experimental results showed that Lemnagibba could be used to upgrade the quality of the pond effluent with respect to pathogens,

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biological oxygen demand, nitrogen and phosphorus. The results of this project will be the first of its kind in Jordan and it will establish a baseline for future research on the use of duckweed for wastewater treatment. 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). Lemnapolyrrhiza 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).Bioaccumulation of various trace element by Lemnagibba was well documented (Jain et al., 1988; Ernst et al., 1992; Hasar and Öbek, 2001; Kara et al., 2003). Lemnagibba 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.

III. CONCLUSION

Although polluted, village ponds are rich source of nutrients like nitrate and phosphate which can be recovered by phyto-remedition. 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. Therefore, recovering this valuable nutrient resource and recycling into some productive system makes sense both ecologically and economically.

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