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Original Research Paper

# Phytoremediation of Domestic Wastewater by Using a Free Floating Aquatic Angiosperm, *Lemna minor*

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## ABSTRACT

Phytoremediation is a novel, efficient, ecofriendly, low priced and an emerging method of biotechnology for environmental pollution management. In this technology, plants are used to improve the status of environment. In this work, an attempt has been made to remove organic and inorganic pollution load of domestic wastewater. A culture of aquatic plant, *Lemna minor* was grown in the pond water. Water from the same pond was filled in a cement tank and *Lemna* was grown for a stipulated interval of seven days. The domestic wastewater quality was evaluated before and after the culture by analysing its physicochemical properties in order to know the improvement in quality of water. The results of analysis show that phytoremediation of wastewater occurs more rapidly in tank water as compared to the pond water. The increase in biomass of *Lemna minor* and the physicochemical analysis have proved that *Lemna minor* is a suitable aquatic plant for phytoremediation of domestic wastewater, which improved the quality of domestic wastewater by absorbing organic and inorganic pollutants.

## INTRODUCTION

In recent years the pollution of water has become one of the most significant environmental problems in the world. Normally water is never pure in chemical sense. It contains impurities of various kinds dissolved as well as suspended matter. When toxic substances enter lakes, streams, rivers, oceans and other water bodies, they get dissolved or lie suspended in water and get deposited . This results in the deterioration of water quality, which affects the aquatic ecosystems. Pollutants can also seep down and affect the groundwaters. Polluted waters are turbid, unpleasant, bad smelling, and unfit for drinking, bathing, washing and other purposes.

Sources of water pollutants are of two types, point sources and nonpoint sources. Point sources of pollution occur when harmful substances are emitted directly into a body of water. A nonpoint source delivers pollutants indirectly through environmental changes. The control of water pollution is one of the most important aspects of environmental protection. Most of the growing cities in India hardly have any treatment facility and are simply diverting the untreated domestic wastewater into aquatic bodies like rivers, ponds and lakes posing problem of eutrophication. In this context phytoremediation may prove to be a better solution.

Phytoremediation describes the treatment of environment pollution by use of plants. This word, in general, is used to describe any system where the plants can be introduced into an environment and allowed to absorb contaminants into its parts. Several workers have carried out studies to check potential of various plant species to treat diverse wastewaters and removal of heavy metals and other toxicants (Al Hamdani & Blair 2004, Asma & Tahiro 2005, Bennicelli & Stepniewska 2004, Ciria & Solano 2005, Jaij et al. 1989, Noraho & Gaur 1996, Osmolavaskaya 2005).

In phytoremediation, plants could do that same job as a group of engineers for one tenth of the cost both *in situ* and *ex situ*. The plants used for the treatment can easily be monitored, and the possibility of recovery and reuse of valuable metals can be screened and diagnosed. The main drawback of this technology is that it is not good for all sites. If the contamination runs too deep or is too much, the plants alone can not handle it. Studies have been carried out where the groundwater is pumped out and then treated. Phytoremediation is done by the methods like phytoextraction, phytostabilizaiton, phytotransformation, phytostimulation, phytovolatilization, and rhizofiltration etc.

Phytoremediation is limited to the surface area and depth occupied by the roots, slow growth and low biomass require a long term commitment. With plant based systems of remediation, it is not possible completely to prevent the leaching of contaminants into groundwater. The survival of the plants is affected by toxicity of contaminated land and general condition of the soil. Plant based bioremediation technologies have received attention as strategies to cleanup contaminated soil and water. Diverse plant species show great promise as phytoremediation agents. These plants include grasses, trees and several other monocots and dicots.

The present study deals with the phytoremediation of domestic wastewater by using an aquatic angiosperm *Lemna minor*, also known as common duck weed, which is a free floating aquatic plant belonging to the family Lemnaceae. Duck weeds are among the world's smallest flowering plants. The plants reproduce vegetatively and sexually. Asexual reproduction allows rapid colonization of water. The rapid growth of duck weeds finds their application in bioremediation of polluted waters and as test organisms for environmental studies. Dried duckweeds are used as a good cattle feed.

A culture of the aquatic plant *Lemna minor* was grown in the domestic wastewater in Thrissur district. The domestic wastewater quality was evaluated before and after the treatment by analysing physicochemical properties of water. In order to know the improvement in quality of wastewater, different physicochemical parameters were analysed both *in vivo* and *in vitro* conditions.

## MATERIALS AND METHODS

Phytoremediation of domestic wastewater was done by using a free floating aquatic plant, *Lemna minor*. Domestic wastewater was taken from a pond situated in Chentrappinni. The work was done during the month of April, May, June and July, 2008. Fresh weight of 200g of *Lemna minor* was grown in cement tank of 145 cm breadth, 195 cm length and 75cm depth, containing domestic wastewater. Physicochemical parameters were assessed before and after the treatment (APHA 1989). Increase in biomass of aquatic plants in seven days culture was determined by harvest method. The parameters taken for assessment were pH, temperature, turbidity, salinity, electrical conductivity, total dissolved solids, total alkalinity, free $CO_2$, chloride, dissolved oxygen, COD, total hardness, calcium, magnesium, nitrate, BOD, acidity, fluoride, iron.

## RESULTS AND DISCUSSION

Phytoremediation of wastewater was done by using aquatic plant *Lemna minor*. The results of the study are given in Table 1, 2 and 3. Different parameters show gradual decrease after the treatment. pH in water gives a straight picture of its acidic or alkaline nature and considered to be a significant parameter in water quality assessment. In the present study slight variations were observed in pH values. pH value after the treatment was increased slightly both in tank and pond.

In tank, turbidity before the treatment was recorded higher in the month of April, due to the excessive evaporation. After seven days treatment it was drastically reduced. But in the month of May the turbidity value before and after the treatment almost remains the same. In June it was in-

Table.1 Results of physicochemical analysis of domestic wastewater before (Bp) and after (Ap) phytoremediation with *Lemna minor* in tank water.

| Parameters | April | | May | | June | | July | |
|---|---|---|---|---|---|---|---|---|
| | Bp | Ap | Bp | Ap | Bp | Ap | Bp | Ap |
| pH | 6.56 | 7.05 | 7.21 | 7.61 | 7.23 | 7.57 | 7.67 | 7.6 |
| Turbidity (NTU) | 13.8 | 1.1 | 0.2 | 0.2 | 0.2 | 1.2 | 4.1 | 1.1 |
| Temperature (°C) | 27.8 | 28 | 28.7 | 28 | 26.9 | 28.7 | 26 | 28 |
| EC (micromhos/cm) | 232 | 213 | 298 | 310 | 216 | 232 | 125 | 82 |
| TDS (mg/L) | 92.8 | 85.2 | 119.2 | 124 | 86.4 | 92.8 | 82.4 | 75 |
| Total Alkalinity (mg/L) | 68 | 76 | 106 | 104 | 68 | 76 | 40 | 33 |
| Free $CO_2$ (mg/L) | 17.6 | 8.8 | 6.16 | 5.2 | 5.28 | 4.64 | 3.54 | 1.76 |
| Chloride (mg/L) | 16 | 30 | 22 | 24 | 26 | 32 | 14 | 12 |
| Dissolved $O_2$ (mg/L) | 3.2 | 6.3 | 7.11 | 7.11 | 8.13 | 10.16 | 11.06 | 11.17 |
| COD (mg/L) | 15 | 10 | 10 | 8.0 | 8 | 7.0 | 12 | 7 |
| Total Hardness (mg/L) | 74 | 88 | 108 | 100 | 80 | 70 | 44 | 38 |
| Calcium (mg/L) | 24 | 32 | 29.6 | 20.8 | 30.4 | 16.8 | 15.2 | 12.4 |
| Magnesium (mg/L) | 3.40 | 1.94 | 8.26 | 11.6 | 6.97 | 6.80 | 1.45 | 1 |
| Nitrate (mg/L) | 15.51 | 9.30 | 6.20 | 4.43 | 3.98 | 3.98 | 1.77 | 1.0 |
| BOD (mg/L) | 6.0 | 4.0 | 4.0 | 3.0 | 2.0 | 3.2 | 4.8 | 2.0 |
| Acidity (mg/L) | 6.0 | 4.0 | 4.0 | 2.0 | 4.0 | 4.0 | 2.0 | 2 |
| Fluoride (mg/L) | 0.38 | 0.30 | 0.20 | 0.14 | 0.17 | 0.16 | 0.16 | 0.16 |
| Iron (mg/L) | 2.09 | 1.02 | 0.81 | 0.43 | 1.04 | 1.0 | 1.76 | 1 |
| Sulphate (mg/L) | 1.0 | 2.1 | 12.2 | 6.0 | 1.0 | 10.3 | 1.9 | 0.9 |
| Phosphate (mg/L) | 0.073 | 0.651 | 0.03 | 0.04 | 0.01 | 0.026 | 0.03 | 0.02 |
| Manganese (mg/L) | 0.02 | 0.01 | Nil | 0.01 | 0.01 | Nil | 0.01 | Nil |
| Productivity (gcal/cm$^2$/year) | 1.01 | 0.68 | 0.68 | 1.36 | 0.67 | 1.69 | 0.34 | 0.68 |
| No.of coliforms/100mL | 1100$^+$ | 1100$^+$ | 1100$^+$ | 1100$^+$ | 1100$^+$ | 1100$^+$ | 1100$^+$ | 1100$^+$ |

creased after the treatment but in July turbidity was reduced after treatment. In pond, the turbidity before the treatment was high, which reduced after the treatment in the month of June and July. Reduction in turbidity was associated with reduction in suspended growth and microbial growth.

Temperature plays a vital role in the chemical and biological activities of water bodies. It always gets influenced by external environment, hence temperature was increased after the treatment in tank, but in pond it was decreased in July. Salinity is the amount of salts in water. In tank it shows a gradual increase up to June, and then suddenly decreased in the month of July. In the case of pond water salinity was gradually increased. In tank, electrical conductivity in the month of April before the treatment was high, but after the treatment with *Lemna* it was reduced. In the month of May and June, conductivity was increased after treatment, but in the month of July it was drastically reduced. In pond, electrical conductivity of water before the treatment was recorded higher, but after the treatment, there was significant decrease in its values. Electrical conductivity of water depends upon concentration of dissolved ions and water temperature. As the concentration of dissolved ions increases, the ability of water to conduct electric current also increases. With the increase in water temperature in the present study conductivity was increased in the month of May and June. TDS value is an important parameter in drinking water and other water quality standards. In the present study, both in tank and pond, TDS values exhibited decrease after the treatment.

Acidity is the quantitative capacity of aqueous media to react with $OH^-$ ions or to accept electrons. Water attains acidity from industrial effluents, acid mine drainage, pickling liquors and from humic acid. In tank, acidity value decreased after treatment in the month of April and May, but in

Table 2:Results of physicochemical analysis of domestic wastewater before (Bp) and after (Ap) phytoremediation with *Lemna minor* in pond water.

| S. No. | Parameter | Unit | Pond | | |
|---|---|---|---|---|---|
| | | | April | June | July |
| 1 | pH | - | 6. 01 | 6.50 | 6.58 |
| 2 | Turbidity | NTU | 13.8 | 2 | 1.3 |
| 3 | Temperature | °C | 27.8 | 28.7 | 24.6 |
| 4 | Electrical Conductivity | micro mhos/cm | 232 | 192 | 110 |
| 5 | Total Dissolved Solids | mg/L | 92.8 | 76 | 35 |
| 6 | Total Alkalinity | mg/L | 68 | 48 | 32 |
| 7 | Free $CO_2$ | mg/L | 17.6 | 15.6 | 7.7.2 |
| 8 | Chloride | mg/L | 16 | 26 | 24 |
| 9 | Dissolved $O_2$ | mg/L | 3.2 | 3.04 | 6.6 |
| 10 | COD | mg/L | 15 | 10 | 10 |
| 11 | Total Hardness | mg/L | 74 | 60 | 48 |
| 12 | Calcium | mg/L | 24.0 | 15.2 | 13.6 |
| 13 | Magnesium | mg/L | 3.4 | 5.34 | 3.40 |
| 14 | Nitrate | mg/L | 15.51 | 3.10 | 4.45 |
| 15 | BOD | mg/L | 6.0 | 4.0 | 4.0 |
| 16 | Acidity | mg/L | 6.0 | 2.0 | 8.0 |
| 17 | Fluoride | mg/L | 0.38 | 0.15 | 0.17 |
| 18 | Iron | mg/L | 2.09 | 1.70 | 1.92 |
| 19 | Sulphate | mg/L | 1.0 | 5.6 | 6.0 |
| 20 | Phosphate | mg/L | 0.073 | 0.037 | 0.01 |
| 21 | Manganese | mg/L | 0.02 | 0.01 | 0.01 |
| 22 | Productivity | $gCal/cm^2/year$ | 1.01 | 0.68 | 1.36 |
| 23 | Bacteriological Analysis | No.of coliforms/100mL | 1100+ | 1100+ | 1100+ |

June and July it remains constant after and before the treatment. In pond acidity value was decreased in the month of June, but increased above the initial value in the month of July. Total alkalinity is a measure of the buffer capacity of water. In general, alkalinity should not be less than 30mg/L and values higher than 400 to 500 mg/L are considered too high. Alkalinity in wastewaters results from the presence of hydroxides, carbonates and bicarbonates. Total alkalinity after the treatment was reduced both in tank and pond due to the absorption of dissolved solids.

Free $CO_2$ values were lowered both in tank and pond as a result of treatment of wastes by *Lemna minor* and the decrease was due to absorption of $CO_2$ by plants for photosynthesis. Dissolved oxygen is one of the important parameters to measure pollution in aquatic systems. The dissolved oxygen levels in natural as well as wastewaters depend on physical, chemical and biological activities. Normal DO content in the pure water should vary from 3 to 6 mg/L. After treatment with *Lemna*, dissolved $O_2$ content in tank and pond was increased. It shows that *Lemna* plays an important role in oxygen transfer in water system. Increase in DO also indicates reduction in microorganisms.

COD is widely used for measuring organic strength of domestic and industrial wastes. COD was recorded higher before the treatment. But after the treatment COD values were decreased both in tank and the pond. The reduction in COD after the treatment was due to more availability of oxygen in water for oxidation of organic matter. BOD is the quantity of oxygen required for oxidation of organic matter by bacterial action in the presence of oxygen. It is, in fact, a measure of the strength of organic matter in terms of ifs ability to decrease oxygen in water. In tank BOD values were decreased after treatment in the month of April, May and July, but in June BOD was increased after the treat-

Table 3: Biomass of *Lemna* before and after the treatment in tank water.

| Month | Initial | Final |
|---|---|---|
| April | 200g | 300g |
| May | 200g | 280g |
| June | 200g | 260g |
| July | 200g | 240g |

ment. In pond, BOD values were decreased after treatment.

Total hardness is caused due to bivalent cations such as $Ca^{++}$, $Mg^{++}$, $Sr^{++}$, etc. The estimation of hardness is of vital significance. Potable water should be moderately soft and total hardness should not exceed 600 mg/L. After the treatment, at first, in tank, total hardness value was gradually increased but finally decreased. In pond water total hardness decreased after the treatment. Calcium occurs in water mainly due to presence of limestone, gypsum, dolomite and gypsiferrous materials. Calcium and magnesium are the major scale forming constituents in raw water. High calcium content in water is undesirable for washing, bathing and laundering. At high levels, magnesium salts have laxative effect. According to WHO desirable limit of Ca is 75 mg /L and desirable limit of Mg is 30mg/L. In tank after the treatment Ca value was first increased and then decreased, but in pond, it gradually decreased. After the treatment with *Lemna* Mg values were first increased and then decreased in tank, but in pond they increased after treatment in the month of June but return to the initial value in the month of July, i.e., in pond, Mg value neither increased nor decreased.

According to WHO, desirable chloride concentration in water is up to 200 mg/L. In the present study, in tank, at first, chloride value show gradual increase, but finally decreased. In pond, chloride value was increased after treatment from the initial value. According to WHO sulphate concentration should not exceed more than 150 mg/L. In tank, after treatment, sulphate value showed an increase in the initial months and finally decreased. But in pond sulphate content was increased after the treatment. Fluorides, if present in small concentration up to 1ppm, are generally considered to be beneficial in water. Excessive fluorides in drinking water may cause dental fluorosis. After the treatment, the fluoride value was decreased both in tank and pond. Presence of nitrates indicates the most stable form of nitrogenous matter in the water sample. According to WHO, desirable limit of nitrate is 45 mg/L. In tank, after the treatment nitrate value was gradually decreased, but in pond it drastically decreased after the treatment. Nitrate form of nitrogen is highly absorbed by plants for growth.

Phosphate and manganese are seen as pollutants in wastewaters. Manganese can be leached from soils and occur in groundwater by the action of anaerobic bacteria. According to WHO desirable limit of manganese in water is 0.1 mg/L and the permissible limit is 0.3mg/L. After treatment with *Lemna*, both in tank and pond, phosphate and manganese values were decreased. Iron in water may be present in dissolved, colloidal or suspended form. Generally, the ferric form is predominant in natural waters. According to WHO desirable limit of iron in water is 0.3 mg/L. After the treatment with *Lemna* iron content was decreased both in tank and pond.

Primary productivity is the basis of whole metabolic cycle in natural ecosystems. Productivity studies are of paramount interest in understanding the effect of pollution on an aquatic ecosystems. In tank, productivity decreased after the treatment in the month of April, but in May, June and July it increased after the treatment. In pond, productivity shows a decrease in June, but increase in July. The biomass of *Lemna minor* was also increased after treatment. In pond, it covers the entire surface of water after treatment. Natural water contains bacteria, which may be harmful or harmless. Before and after the treatment bacterial content remains unchanged both in tank and pond.

The work done by Alkhateeb & Asker (2005) showed that *Lemna minor* is very effective in phytoremediation of industrial wastewater. Carvalho & Martin (2001) in their study reveal that four aquatic plants *Typha domogenasis,* duckweed (*Lemna obscura), Hydrilla verticillata* and swamp lily can be used as phytoremoval agents for selenium in aqueous solutions. Van Steveninck et al. (1992) revealed that fronds of Zn-tolerant clone of *Lemna minor*, exposed to a high level of Zn, showed the presence of cellular deposits consisting of Zn, Mg, K and P. The same Zn tolerant clone of *L. minor*, when exposed to a high level of Cd, showed the presence of globular deposits consisting of Cd, K, and P in mature fronds.

Obek & Hasar (2002) analysed the role of duck weed (*Lemna minor*) harvesting in biological phosphate removal from secondarily treated effluents. Orthophosphate can be efficiently removed if duck weed is frequently harvested. The initial phosphate concentration decreased from 15 to 0.5 mg/L at the end of an 8-day period. Allinson et al. (2000) during the treatment of alkaline industrial wastewater by *Azolla filiculoides* and *Lemna minor* observed that alkalinity and fluoride concentration was decreased. This result also agrees with the present study.

## CONCLUSION

Phytoremediation, the use of plants for environmental restoration is an emerging cleanup technology for remediation of contaminated water. In the present work an attempt has been made to remove organic and inorganic pollution load of domestic wastewater by using this technology. The recommended limits for water quality were exceeded in a few parameters. However, most of the water quality parameters do not exceeded the WHO standards for drinking water quality. The increase in biomass of *Lemna minor* and results of physicochemical analysis have proved that *Lemna minor* is suitable for phytoremediation.

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