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Phytoremediation of metals by aquatic plants at natural wetlands in major lakes (industrial city) Hosur, Krishnagiri district, India

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ABSTRACT

An important feature of India's wetland development programme is that it combines the task of securing out a strategy for wetland development alternatives with the task of lending similar support to implement the projects. Such a unified programme ensures reduction of gap between expected benefit and actual outcome – a gap that has been a matter of serious consent in many of the lofty endeavors all over the world. Toxic metal pollution of water and soil is a major environmental problem, and most conventional remediation approaches do not provide acceptable solutions. Wetland plants are being used successfully for the phytoremediation of trace elements in natural and constructed wetlands. This study demonstrates the phytoremediation potential of three different water hyacinths (*Eichornia crassipes, Ipomea spp, Stachytarpheta jamaicensis*) in three different lake system (*Ramanaickan Lake, Basthi Lake Dharga Lake*) of Hosur district. Our results shows *Eichornia crassipes* is a potent metal (Ca, Mg, Cl) accumulator and tolerant species collected from Rama Naicken Lake, Hosur. *Ipomeas spp* is a moderate accumulator (Fe, SO_4, PO_4) and sensitive species collected from Dharga lake whereas *Stachytarpheta jamaicensis* is non accumulator and tolerant species. *Eichornia crassipes* is a promising candidate for phytoremediation of wastewater polluted with different metals and can be used for natural wetland cultivation.

Introduction

'Wetlands' are those areas inundated or saturated by surface or ground water at a frequency and duration sufficient to support and that, under normal circumstances, do support a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas. In general, wetlands are areas of land that remain waterlogged for a substantial period of the year.

Natural bodies of water are not absolutely pure. Various organic compounds and inorganic elements remain in dissolved form. Silt and clay remain suspended in the water for a considerable period. Many kinds of microscopic and a good number of macroscopic flora and fauna grow in different types of aquatic habitats. Most of the industries and factories are situated on the banks of the rivers or very close to a lake system and the effluents and wastes are mostly thrown directly into the river or lake water without any treatment to make the effluent 'safe' from the biological standpoint. As a result, the depletion of the biotic components near the sources is observed.

The wetland ecosystems have two complementary phases – aquatic and terrestrial (during dry season). During the latter phase it may be used for agriculture or for grazing and both benefit the fishery by enriching the aquatic phase during flood. The former may, however, lead to cultural eutrophication.

An important feature of India's wetland development programme is that it combines the task of securing out a strategy for wetland development alternatives with the task of lending similar support to implement the projects. Such a unified programme ensures reduction of gap between expected benefit and actual outcome – a gap that has been a matter of serious consent in many of the lofty endeavors all over the world.

Water hyacinths *Eichornia crassipes, Ipomea spp, Stachytarpheta jamaicensis,* is a floating macrophyte whose appetite for nutrients and explosive growth rate has been put to use in cleaning up municipal and agriculture wastewater. It has been discovered that water hyacinth's quest for nutrients can be turned in a more useful direction. The plant has been shown to accumulate trace metals such as Ca, Mg, Cl, Fe, SO_4, PO_4. The focus on water hyacinth as a key step in wastewater recycling is due to the fact that it forms the central unit of a recycling engine driven by photosynthesis and therefore the process is sustainable, energy efficient and cost efficient under a wide variety of rural and urban conditions.

The present investigation was to demonstrate the phytoremediation potential of water hyacinths, *Eichornia crassipes, Ipomea spp, Stachytarpheta jamaicensis,* for the removal of metals.

Materials and Methods

Description of Study Region

Hosur is a town and a municipality in Krishnagiri district in the Indian state of Tamil Nadu. It is a taluk of Krishnagiri district. It is located about 40 kilometres south-east of Bangalore and 38 kilometres from Krishnagiri. Hosur experiences a tropical savanna climate with distinct wet and dry seasons. Due to its high elevation, Hosur usually enjoys a more moderate climate throughout the year, with occasional heat waves. The coolest month is January with an average low temperature of 17.1 °C and the hottest month is April with an average high temperature of 33.6 °C. Winter temperatures rarely

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drop below 12 °C, and summer temperatures seldom exceed 36 °C. Hosur receives rainfall from both the northeast and the southwest monsoons and the wettest months are September, October and August, in that order. The summer heat is moderated by fairly frequent thunderstorms but no flooding. Humidity is 31% and average rainfall is 84 cm.

Hosur is known for its expanding manufacturing industries and its pleasant climate.After 1970, the area become a wetland and a habitat for many aquatic species. Domestic and industrial wastewaters, and sewage water from landfills, have caused serious pollution problems. Water inflow of the study site includes the Ram Naickan Lake, Dharga Lake and Basthi Lake. The incoming wastewater with conductivities that range from 572 to 17,790 µs/cm. Sixty to seventy percent of the free water surface of the above said lakes is covered by water hyacinth plants.

Water, Sediment, and Plant Sampling

The main area of interest was along the Ram Naickan Lake, Dharga Lake and Basthi Lake, located in the southern part of the Hosur wetlands. A set of samples was taken during the Month April 2011. Surface water, Soil sediment, and water plants were sampled and studied.

Analytical Methods

Water samples were collected in plastic bottles that had been previously soaked in 10% nitric acid for 48 hours and thoroughly rinsed with deionized-distilled water. All samples were filtered using 0.45 µm cellulose acetate filters, and acidified to pH 2 with nitric acid in the laboratory. Sediment samples were air-dried at 30 C and pounded to pass a 2-mm sieve. Using a 1:1 soil-water extraction ratio, the sediment was digested as described elsewhere (Goncalves and Boaventura 1991). The concentrations of Calcium, Magnesium, Chloride, Iron, Sulphate, Phosphate were analyzed. The minimum detection limits were found to be 1.3, 1.2, 2.4, 3.2, and 1.3, µg/kg, respectively.

At least three separate water hyacinth plants were collected at each sampling station. The plants were collected into clean plastic bags, previously soaked in dilute nitric acid and thoroughly rinsed with deionized-distilled water. In the laboratory, the plants were carefully washed with distilled water and then divided into tops and roots, and dried for 12 hours at 120 C in a forced air oven (Brower et al. 1997). The samples were then ground to a fine powder using a silica pestle and mortar, and the heavy metals were digested and analyzed.

Physical Examination

Physical Examination Such as Appearance, Odour, Turbidity, Total Dissoved Solids and Electrical Conductivity were calculated.

Chemical Examination

The series of chemical examination such as pH, Alkalinity, Total Hardness, Calcium, Magnesium, Sodium, Potassium, Iron, Manganese, Free Ammonia, Nitrite, Nitrate, Chloride, Flouride, Sulphate, Phosphate, Tidy's Test, Silica, BOD were calculated.

Results and Discussions

Toxic heavy metal pollution of water and soil is a major environmental problem, and most conventional remediation approaches do not provide acceptable solutions. Wetland plants are being used successfully for the phytoremediation of trace elements in natural and constructed wetlands.

Hosur valley consists of three sub-tropical lakes, with high diversity of flora and fauna. These lakes are used for irrigation, drinking water, fishery and eco-tourism purpose. But the water quality of these lakes is degrading gradually by the intense human activities and their impacts. These lakes are plagued with multiple problems: sedimentation, eutrophication, pollution, encroachment and fish poisoning. The upstream catchments of these lakes have many degraded areas, which serve as sources of sediments in the water body.

1. Physical Examination

Initially water samples from three different lakes were collected and examined of their physical characteristics such as appearance, odour, turbidity, Total Dissolved Solids and electrical conductivity.

Out of these 3 samples Rama naicken lake water samples are slightly turbid and odourless. Whereas Dharga lake water is clear and Basthi lake is slight greenish yellow. There is no specific odour observed in these three lakes. Turbidity range is higher in Rama naicken lake than Dharga and Basthi lake. Interestingly the Total dissolved solid and electrical conductivity high in Dharga lake when compared to other lakes which represented in Table. 1

2. Chemical Examination

Water samples of three different lakes were examined for series chemical examination such as pH, alkalinity, Total hardness, Calcium, Magnesium, Sodium, Potassium, Iron, Manganese, Free Ammonia, Nitrite, Nitrate, Chloride, Flouride, Sulphate, Phosphate, Tidy's test and Silica.

Obviously the results shows that Dharga lake shows high pH about 7.63 due to increased effluent discharge whereas other two lakes shows moderate pH. Water samples of Dharga lake shows increased Total hardness, Calcium, Magnesium, Sodium, Sulphate, Potassium, Chloride, Silica when compared to Rama naicken and Basthi lake, but less in Iron, Manganese, Free Ammonia, Fluoride, Phosphate.

The composition of Rama naicken lake water shows increased percentage of free ammonia, nitrate, nitrite, phosphate but other elements like Calcium, Magnesium, Sodium, Potassium, Chloride, Sulphate, Silica present in decreased amount.

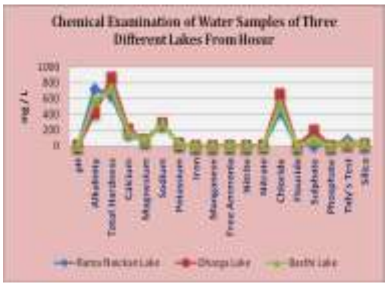
Whereas the Basthi lake shows minimal element concentration than other two lakes. The overall composition of three lakes shown in Table. 2 and their graphical representation shown.

3. BOD / COD Examination

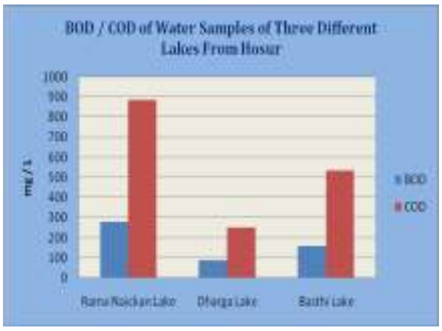
The Biological and Chemical oxygen demand of three lakes were analysed. Of these Rama naicken lake showed higher BOD about 280 mg/L whereas other two lakes showed less BOD level. The higher COD were noticed in Rama naicken lake which indicates the effluents discharge is more from industries and tanneries. However the other two lakes showed less BOD / COD levels which replies less effluent disposal. The BOD/COD level were reported in Table. 3 and represent in graph.

4. Metal Distribution of Soil Sample

The soil sediment of three different lakes were analysed for metal composition such as Calcium, Magnesium, Chloride, Iron, Sulphate, Phosphate. The sedimented soil of Dharga lake have total hardness of about 3.121 whereas Rama naicken lake was 3.044 and Basthi lake was 3.087. Dharga lake soil have rich amount of calcium, magnesium and phosphate whereas chloride and sulphate concentration were low. Rama naicken lake showed increased amount magnesium, chloride, sulphate and low in Iron and calcium whereas Basthi lake showed poor metal concentration. Table No. 4 showed the Metals Distribution of Soil sample of three different lakes and graphical representation shown.



Chemical Examination Of Water Samples Of Three Different Lakes



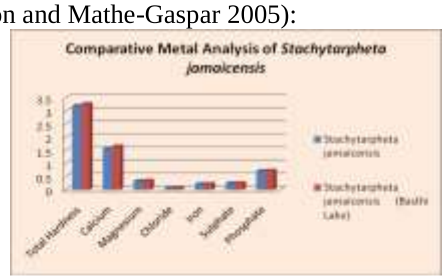
BOD/COD of Water Samples of Three Different Lakes from Hosur.

5. Metals Distribution of Three Different Plant Extract

Eichornia crassipes, Ipomea spp and *Stachytarpheta jamaicensis* were dominant in these three different lakes of Hosur. These plants were collected enormously for metal analysis. The overall distribution of metal of three different plant species are tabulated in Table No. 5 and graphically represented.

6. Metals uptake of *Eichornia crassipes, Ipomea spp* and *Stachytarpheta jamaicensis*

The tested plant species were grouped by their capability of heavy metal uptake and sensitivity to high metal pollution, which characters were determined in the present and a previous work (Anton and Mathe-Gaspar 2005):



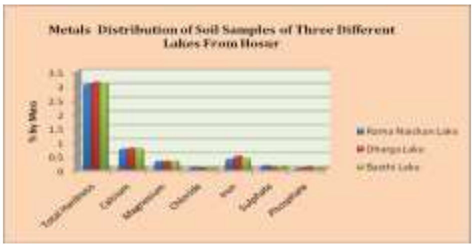
Comparative Metal Analysis of *Stachytarpheta jamaicensis*

1. Accumulator and tolerant species: e.g. *Eichornia crassipes* (Ca, Mg, Cl) is act as a good accumulator and tolerance species of many toxic metals discharged from industrial effluents in Rama naicken lake which is shown in the Table 6.

2. Moderately accumulator and tolerant species: e.g. *Ipomeas spp* moderately accumulate (Fe, SO_4, PO_4) and moderately sensitive species from Dharga lake represented in Table 7.

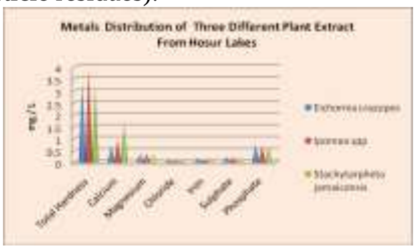
3. Non-accumulator and tolerant species: e.g. *Stachytarpheta jamaicensis*. Element content of normal and polluted lake plant are almost similar not much differentiated in uptake of metals, hence this act as good tolerant species but non accumulator, which shown in Table 8.

Natural and constructed wetlands have been very effective in reducing the amounts of contaminats in runoff from both agricultural and industrial lands. The use of wetlands for the removal of pollutants involves a complex variety of biological processes, involving microbiological transformations and physio-chemical processes such as adsorption, precipitation or sedimentation.



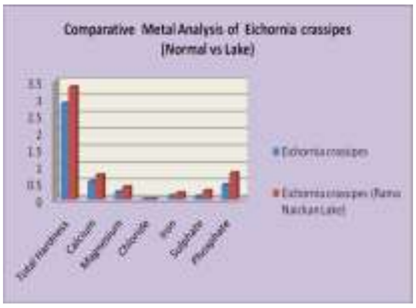
Metals Distribution of Soil Samples of Three Different Lakes From Hosur

Hosur is eminently suitable for use as a wetland plant species due to the following morphological and physiological features (Cull *et al.*, 2000), such as its ability to tolerate flooded soil conditions making it ideal for use in epimeral or permanent wetlands and increase detention time and enhance deposition of sediment and sediment bound contaminants (Eg. Heavy metals and some particle residues).



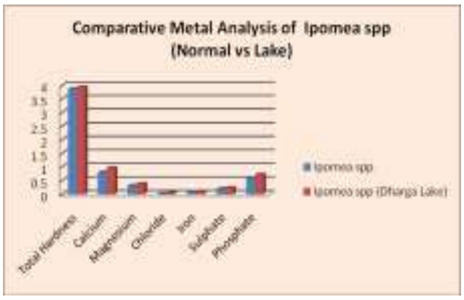
Metals Distribution of Three Different Plant Extract From Hosur Lakes

Based on the three plants species, the average values for the raw sewage characteristics in the lake of (Hosur) are shown in Table. 1. These average results of the analysis of waste water samples can reflect the waste water characteristics for the rural areas of the Hosur.



Comparative Metal Analysis of *Eichornia crassipes*

Obviously, the data show a COD value of 176 mg.L and ammonia content of 157 mg / L, a TDS 1448 mg/L and TSS value of 156 mg/L. The data compared with the corresponding data of the other lake wastewater indicates that lower COD and higher TSS content. In comparision with Table 1 the wastewater of the Hosur lake should COD of 2088mg/L and TSS of 897mg/L.



Comparative Metal Analysis of *Ipomea Spp*

The metal uptake by plants in this lake is very high, compared with that of other near by aquatic plant. Because of this, the values of some parameters such as COD, NH_4 and TSS are comparatively higher than the typical values. The results reveals that the values of EC, TS, TSS, TDS are highest. This could be attributed to that the wastewater availble currently at Hosur may be very useful for bioremediation process or these consortia would act as an efficient bioremeidal package in agriculture.

Conclusion

Our study proves that *Eichornia crassipes* from Rama Naicken lake accumulate metals (Ca, Mg, Cl, Fe, SO_4, PO_4). Thus, they can be recommended as indicators for determination of pollution levels of the environment. The metal concentrations in soils of the measured area (Rama Naicken, Dharga and Basthi lake) did not exceed the limited values recommended by the Indian Standards for agricultural soils. Lower amounts of heavy metals in soil samples taken in spring were observed. The contents of metals in examined plants (*Eichornia crassipes, Ipomeas spp* and *Stachytarpheta jamaicensis*) were higher than the normal plants grow in natural lakes. Generally, the concentration of metals decreased with increasing distance from the pollutant emission sources. *Eichornia crassipes* do absorb the contaminants during their relatively short vegetation period, i.e. Spring-autumn. The concentrations of metals in *Eichornia crassipes* were proportional to those in soil. For that reason they are very good instruments - biosensors - for observation of the trends in soil composition of pollutants. This study shows water Hyacinth to be promising candidate for phytoremediation of wastewater polluted with different industrial effluents. This result will serve as a study for further investigation of plant species in bioindication of environmental pollution. We will continue this trend of investigations in our future work.

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Tables and Graphical Representations

Table No : 1 Physical Examination of Water Samples of Three Different Lakes FromHosur

Parameters	Rama Naickan Lake	Dharga Lake	Basthi Lake
Appearance	Slightly Turbid	Colourless & Clear	Slightly greenish Yellow
Odour	None	None	None
Turbidity NTU	10.06	9.2	9.8
Total Dissolved Solids mg/L	1760	2108	1987
Electrical Conductivity	2546	3044	2723

Table No : 2 Chemical Examination of Water Samples of Three Different Lakes From Hosur

Parameters	Rama Naickan Lake (mg / L)	Dharga Lake (mg / L)	Basthi Lake mg / L)
pH	7.13	7.63	7.28
Alkalinity	720	420	580
Total Hardness	640	860	720
Calcium	154	212	179
Magnesium	61	79	68
Sodium	280	290	282
Potassium	30	30	30
Iron	01	0.7	0.85
Manganese	00	00	00
Free Ammonia	14.75	0.56	7.43
Nitrite	0.48	0.44	0.43
Nitrate	14	10	11
Chloride	431	653	527
Flouride	0.03	00	0.01
Sulphate	07	192	86
Phosphate	4.69	0.32	2.22
Tidy's Test	80	27	45
Silica	17.93	21.24	19.79

Table No : 3 BOD / COD of Water Samples of Three Different Lakes From Hosur

Parameters	Rama Naickan Lake (mg / L)	Dharga Lake (mg / L)	Basthi Lake (mg / L)
BOD	280	90	160
COD	884	252	534

Table No 4 : Metals Distribution of Soil Samples of Three Different Lakes From Hosur

Parameters	Rama Naickan Lake (% by Mass)	Dharga Lake (% by Mass)	Basthi Lake (% by Mass)
Total Hardness	3.044	3.121	3.087
Calcium	0.730	0.761	0.742
Magnesium	0.292	0.292	0.291
Chloride	0.090	0.043	0.068
Iron	0.368	0.468	0.393
Sulphate	0.145	0.093	0.132
Phosphate	0.005	0.099	0.078

Table No 5 : Metals Distribution of Three Different Plant Extract From Hosur Lakes

Parameters	Eichornia crassipes (% by Mass)	Ipomea spp (% by Mass)	Stachytarpheta jamaicensis (% by Mass)
Total Hardness	3.325	3.938	3.272
Calcium	0.718	0.959	1.654
Magnesium	0.367	0.380	0.342
Chloride	0.006	0.041	0.058
Iron	0.187	0.097	0.211
Sulphate	0.251	0.230	0.243
Phosphate	0.778	0.715	0.721

Table 6: Comparative Metal Analysis of Eichornia crassipes (Normal vs Lake)

Parameters	Eichornia crassipes (% by Mass)	Eichornia crassipes (Rama Naickan Lake) (% by Mass)
Total Hardness	2.840	3.325
Calcium	0.525	0.718
Magnesium	0.216	0.367
Chloride	0.001	0.006
Iron	0.106	0.187
Sulphate	0.089	0.251
Phosphate	0.431	0.778

Table 7: Comparative Metal Analysis of Ipomea spp (Normal vs Lake)

Parameters	Ipomea spp (% by Mass)	Ipomea spp (Dharga Lake) (% by Mass)
Total Hardness	3.874	3.938
Calcium	0.802	0.959
Magnesium	0.312	0.380
Chloride	0.009	0.041
Iron	0.078	0.097
Sulphate	0.202	0.230
Phosphate	0.586	0.715

Table 8: Comparative Metal Analysis of Stachytarpheta jamaicensis (Normal vs Lake)

Parameters	Stachytarpheta jamaicensis (% by Mass)	Stachytarpheta jamaicensis (Basthi Lake) (% by Mass)
Total Hardness	3.203	3.272
Calcium	1.563	1.654
Magnesium	0.324	0.342
Chloride	0.050	0.058
Iron	0.209	0.211
Sulphate	0.241	0.243
Phosphate	0.712	0.721