J. Mater. Environ. Sci. 5 (3) (2014) 859-864
ISSN : 2028-2508
CODEN: JMESCN

A study on the removal efficiency of organic load and some nutrients from sewage by *Ceratophyllum Demersum-L*

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Received 8 Oct 2013, Revised 2 Feb 2014, Accepted 3 Feb 2014
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Abstract
Phytoremediation is a low cost and safe alternative to conventional methods of wastewater treatment. In the present study, we used a macrophyte to treat the sewage water. *Ceratophyllum Demersum-L* known as coon tail is a submerged macrophyte commonly seen in freshwater ponds in temperate climates. This water plant was experimented for direct purification of sewage water. The aim of our research is to study the removal efficiency of organic load (as Biochemical Oxygen Demand and Chemical Oxygen Demand) and some nutrients like phosphate and ammonia from sewage water. This study was conducted without any conventional pre-chemical or pre-biological treatments. The productivity of the plant was moderate. Initially acclimatization was very difficult but its use in sewage treatment was highly encouraging. The physiochemical properties such as turbidity, ammonia, phosphate, Chemical Oxygen Demand and Biological Oxygen Demand showed a significant decrease in values due to bio-digestion of organic nutrients during phytoremediation. The quantitative reduction of nutrients in sewage water suggests *C. Demersum-L* as an efficient aquatic plant for the phytoremediation of organics and nutrients from sewage water.

Keywords: *Ceratophyllum demersum*, BOD, COD, turbidity, ammonia, phosphate, organic load, acclimatization, phytoremediation, sewage purification, wastewater purification

Introduction
Stabilization ponds have been used for treating domestic sewage and certain industrial liquid wastes for centuries. The ponds do not employ any equipment and rely purely on the energy naturally available from the sun [1]. Certain drawbacks in treating sewage by stabilization pond method have been highlighted from time to time. Algae laden effluent is the foremost disadvantage in employing a stabilization pond [2]. Subsequent polishing lagoons and tertiary treatment units to get the effluent at required standard is generally recommended [3]. A simple treatment for removal of organic load from sewage or wastewater will be therefore very useful particularly for adopting in small communities and rural areas.

Macrophyte in Waste treatment

Aquatic weeds, by nature, are reported to be maintaining the water quality in many surface waters [4]. Aquatic plants generally help in denitrification and removal of BOD in treatment of wastewater [5]. Reports have been made on the cultivation of Pistia Stratoes-L and its use for purification of sewage waters [6]. In a modeling of duckweed, biomass production for water quality improvement and removal of BOD has been reported [7]. Water hyacinth is reported to remove nutrients from domestic wastewater and its role in denitrification is established [8]. Phytoremediation studies have been conducted using Water hyacinth (Eichornia crassipes) and Ryegrass (Lobicon perenne-L) for restoration of Waigang River, a major tributary of the Quinhuai River system in China [9]. Studies have been conducted by construction of wetlands for wastewater treatment using submerged and floating plants for conservation of Lake Biwa [10]. Aquatic plants are known to accumulate heavy metals [11]. Aquatic macrophytes grown on an industrial effluent channel have shown the tendency to accumulate metals [12]. The concentration of Cd, Cu, Pb and Zn in sediments, water, and different plant organs of aquatic plant species like *C. demersum-L*, Echinochloa pyramidalis hitchc, Eichhornia crassipes, Myrophyllum spicatum-L have been investigated by Manal Ahmed Fawzy and et al [13]. Xiangiang et al have attempted to evolve Ecological techniques for nutrient reduction and eutrophication control [14]. Jatin Srivatsa et al have studied how to manage water quality with aquatic macrophytes [15]. The duckweed-covered sewage lagoons are helpful for oxygen balancing and COD removal. Water lettuce (Pistia stratiotes) has been found to play a role in removal of nutrients [16]. The potential of macrophytes to grow in mesocosm and to mitigate the nutrient ions and metals from water and wastewaters has been studied by Deaver et al [17]. Removal of phosphorus from agricultural run off by submerged aquatic vegetation-based treatment wetlands has been studied by Dierberg et al [18]. It has been observed that temperature and salinity are influencing heavy metal uptake by submerged plants [19]. Accumulation of heavy metals in Water Spinach (Ipomoea aquatica) has been reported in a study conducted in the Bangkok region, Thailand [20]. Industrial wastewater has also been treated by growth of macrophyte in a pilot-scale constructed wetland [21].

The application of *Ceratophyllum Demersum, Eichhornia Crassipes and Pistia Stratiotes* in tertiary wastewater treatment is well established [22]. Direct purification of sewage by *Ceratophyllum Demersum-L* has been reported by the first author [23]. Parameswaran Aravind et al have comprehensively reviewed Cd-Zn interactions in a hydroponic system using *Ceratophyllum demersum-L* [24]. *Ceratophyllum demersum-L* has been found to uptake nitrate [25].

Comparative ecological studies have been reported on two species of *Ceratophyllum* viz. *Ceratophyllum demersum-L* and *Ceratophyllum Murica* [26]. *Ceratophyllum L* is known to survive extended periods of stress [27]. *Ceratophyllum Demersum-L* is a submerged species of still waters mostly in the plains away from the coast. The species of the family are distributed in all temperate and tropical countries. In India, it occurs in shallow ponds, tanks, lakes and other stagnant waters [28]. This paper presents the results from a study of organic load removal by *C. demersum* from sewage water.

2. Materials and methods

C. demersum plants were collected from a lake from Avadi near Chennai in Tamilnadu in 2010. When the aquatic plant was collected from its parent body, it was collected and transported along with adequate quantity of water from the source. Acclimatization of the plant in the new environment was found to be a major problem. Water with low Total dissolved solids (TDS) was a requirement for initial filling of the experimental tanks. In the initial stages, growth of algae was another problem. To overcome this problem, shading was provided for a few days till the plant was considered to be safe in the new environment. By shading, direct sunlight was avoided. Copper sulphate (0.05 mg/L) was also added in one lot. Once the plant got acclimatized, the water from local source was added to compensate the evaporation loss. The process was continued over a period of one month to adequately acclimatize the plant for the new environment. Initial acclimatization was carried out in a 20L plastic tub.

2.1. Experimental setup

In the actual experimental setup a masonry tank of 2m L x 0.5m W x 0.75m H which was filled with raw water from the local site having a TDS of 1,000 mg/L. Copper sulphate at 0.05 mg/L was added. Live *Ceratophyllum Demersum-L* plants previously acclimatized to the source water was introduced to satisfactorily cover the tank both by submersion and floating.

At one end raw sewage was fed and at another end, after treatment, it was withdrawn. Initially diluted sewage was fed. When the system got stabilized, the detention time was maintained at 15 days. The tank effluent was withdrawn daily. The samples were periodically tested for biochemical oxygen demand (BOD) and chemical oxygen demand (COD) tests.

The experiment was performed in open air under natural daylight. Samples were collected for thirteen periods with two months intervals and compared with reference sewage water treated without *Ceratophyllum demersum-L.*

2.2. Sampling and analysis

The experiment was carried out from 10th Dec, 2010 to 20th Dec, 2012. All analyses were conducted according to the Standard Methods of Examination of Water and Wastewater (APHA, 19th edition, 1995).

3. Results and discussion

The quality of Sewage water before and after the phytoremediation with *Ceratophyllum Demersum L* was evaluated by the results of physiochemical properties**.**

3.1. Turbidity: In the study period, the turbidity of raw sewage ranged from 46.9 to 66.9 NTU. The turbidity after treatment by *Ceratophyllum demersum-L* was in the range 0.9-2.9 NTU. The values obtained from us was good compared to the reported values [29].The turbidity reduction by this treatment was 93.8 to 98.7%. In the oxidation process (background sample) the turbidity level was reduced to the range 23.8-45.7 NTU. The % reduction by oxidation process ranged from 26.8 to 55.3 only (Table 1). The % turbidity reduction by *Ceratophyllum* treatment was high in the month of June indicating that the phytoremediation efficiency was high in this period. Contrary to this the % turbidity reduction by oxidation process was low in this period. In summer the photosynthetic process will be at its maximum level and production of more algae increased the turbidity.

Table1: Turbidity (NTU) values for different periods**:**

Date	Dec 2010	Feb 2011	Apr 2011	Jun 2011	Aug 2011	Oct 2011	Dec 2011	Feb 2012	Apr 2012	Jun 2012	Aug 2012	Oct 2012	Dec 2012
Raw Sewage	47.0	53.2	57.9	62.4	65.6	56.9	46.8	50.3	58.3	66.9	57.2	53.5	49.1
Sewage treated by natural oxidation	25.0	23.8	30.6	45.7	43.5	31.8	28.0	28.2	31.4	38.5	37.2	30.9	27.6
Sewage treated by Ceratophyllum	2.6	1.8	1.9	1.1	1.3	1.5	2.9	2.4	2.2	0.9	1.7	1.8	2.2
% removal by Ceratophyllum	94.5	96.6	96.7	98.2	98.0	97.4	93.8	95.2	96.2	98.7	97.0	96.6	95.5

3.2. Nitrogen: Of the three forms of nitrogen viz. ammonia, nitrite and nitrate, the ammonia form of nitrogen will be high in sewage due to high amounts of oxygen demanding wastes in it. Reduction of ammonia is not high in the oxidation process taking place naturally in oxidation ponds. The ammonia in raw sewage ranged from 25.5 to 33.6 mg/L. In the oxidation treatment it ranged from 16.8 to 21.6 mg/L indicating that the reduction is not significant. This is only 28.2 to 45.2% reduction. But the phyto remediation method resulted in 97.2-99.2% reduction of ammonia. Compared to the reported macrophytes such as *Hydrilla verticillata, Eichhornia crassipes, Solms-Laub. (Water hyacinth), Pistia stratiotes L. (Water lettuce) and Lemna minor L. (Duckweed)*[30]. Our macrophyte showed excellent activity.The seasonal variations in ammonia reduction efficiency were not noteworthy (Table 2).

Table 2: Ammonia (as NH_3, mg/L) values for different periods**:**

Date	Dec 2010	Feb 2011	Apr 2011	Jun 2011	Aug 2011	Oct 2011	Dec 2011	Feb 2012	Apr 2012	Jun 2012	Aug 2012	Oct 2012	Dec 2012
Raw Sewage	29.8	25.5	31.9	33.6	36.0	30.7	26.5	29.7	31.5	32.3	33.6	29.3	25.9
Sewage treated by oxidation pond	20.6	18.3	19.7	20.4	21.6	19.9	17.4	16.8	17.9	18.5	18.4	17.6	16.7
Sewage treated by *Ceratophyllum*	0.8	0.7	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.5	0.5	0.3	0.2
% removal by *Ceratophyllum*	97.3	97.3	97.2	97.6	98.1	98	98.1	98.7	98.7	98.5	98.5	99	99.2

3.3. Phosphate: The removal of phosphate from sewage is not a simple process. In biological treatment some amount of phosphate goes to sediments. Otherwise PO_4^{3-} cannot go out of the system. Even in chemical treatment, PO_4^{3-} is only sedimented. In the present study, the amount of phosphate in raw sewage ranged from 15.6 to 22.8 mg/L. In the treated sewage it was 0.3-1.4 mg/L. Patel also observed similar results[29]. A reduction of 93.5-98.3% in the PO_4^{3-} level was observed. By oxidation process the phosphate was reduced to the range 6.8 to 9.7 mg/L. The reduction was only 51.5 to 61.7% (Table 3).

Table 3: Phosphate (as PO_4, mg/L) values for different periods**:**

Date	Dec 2010	Feb 2011	Apr 2011	Jun 2011	Aug 2011	Oct 2011	Dec 2011	Feb 2012	Apr 2012	Jun 2012	Aug 2012	Oct 2012	Dec 2012
Raw Sewage	17.3	22.8	16.7	18.9	20.6	21.7	18.3	17.2	19.5	21.1	20.6	15.6	16.8
Sewage treated by oxidation pond	8.3	9.7	8.1	8.5	9.1	9.6	8.4	7.9	8.5	8.8	7.9	6.8	7.6
Sewage treated by *Ceratophyllum*	0.8	1.2	0.7	0.8	1.2	1.4	0.4	0.3	0.6	0.5	0.7	0.3	0.5
% removal by *Ceratophyllum*	95.4	94.7	95.8	95.8	94.2	93.5	97.8	98.3	96.9	97.6	96.6	98.1	97.0

3.4. Chemical oxygen demand: The chemical oxygen demand (COD) of raw sewage ranged from 825 to 1,260 mg/L. The COD of sewage treated by *Ceratophyllum demersum-L* ranged from 30 to 55 mg/L. The percentage reduction was between 93.3 and 96.8 (Table 4). The average reduction by oxidation was only 74.5%. There is remarkable efficiency in reduction of COD when *Ceratophyllum demersum-L* is used. Minimum value of COD in sewage was recorded in the month of December due to dilution of sewage by rain water. When the system stabilized the COD removal was maintained at a level of 95.1 to 96.6%. Seasonal variation was not significant for the COD removal by *Ceratophyllum*.

Table.4. COD (mg/L) values for different periods**:**

Date	Dec 2010	Feb 2011	Apr 2011	Jun 2011	Aug 2011	Oct 2011	Dec 2011	Feb 2012	Apr 2012	Jun 2012	Aug 2012	Oct 2012	Dec 2012
Raw Sewage	845	885	920	1165	1180	1034	885	915	1080	1260	1280	1030	895
Sewage treated by oxidation pond	230	240	280	305	290	255	200	220	280	310	300	285	230
Sewage treated by *Ceratophyllum*	55	50	45	40	40	35	30	40	45	50	55	45	40
% removal by *Ceratophyllum*	93.3	94.4	95.1	96.6	96.6	96.6	96.8	95.8	95.8	96	95.2	95.6	96.0

3.5. Biological oxygen demand: The BOD values in raw sewage ranged from 320 to 440 mg/L in the study period. The BOD after treatment by *Ceratophyllum demersum-L* was from 10 to 20 mg/L. The percentage reduction was from 94.6 to 97.5 mg/L. The percentage reduction by oxidation process was 78.3 to 83.8 (Table.5). Juwarkar et al reported in his paper 78 to 91% removal of BOD by *Typha latiofolia* and *Phragmites Carka* [31]. The organic load in sewage is estimated by the parameters BOD and COD. The BOD represents the biologically oxidizable matter and COD represents the chemically oxidizable matter. The average BOD and COD reductions were 95.7% and 96.0% respectively indicating a close correlation between B.O.D and C.O.D reduction values (Fig.1). The correlation coefficient between BOD and COD removal percentages is 0.85 indicating a good level of correlation between COD reduction and BOD reduction.

Table. 5. BOD (mg/L) values for different periods**:**

Date	Dec 2010	Feb 2011	Apr 2011	Jun 2011	Aug 2011	Oct 2011	Dec 2011	Feb 2012	Apr 2012	Jun 2012	Aug 2012	Oct 2012	Dec 2012
Raw Sewage	420	400	440	320	380	380	390	370	390	300	300	320	372
Sewage treated by oxidation pond	70	65	75	70	65	65	65	70	70	60	65	65	70
Sewage treated by *Ceratophyllum*	15	10	15	10	10	15	20	20	15	10	15	15	20
% removal by *Ceratophyllum*	96.4	97.5	96.6	96.9	97.4	96.1	94.9	94.6	96.2	96.7	95	95.3	94.6

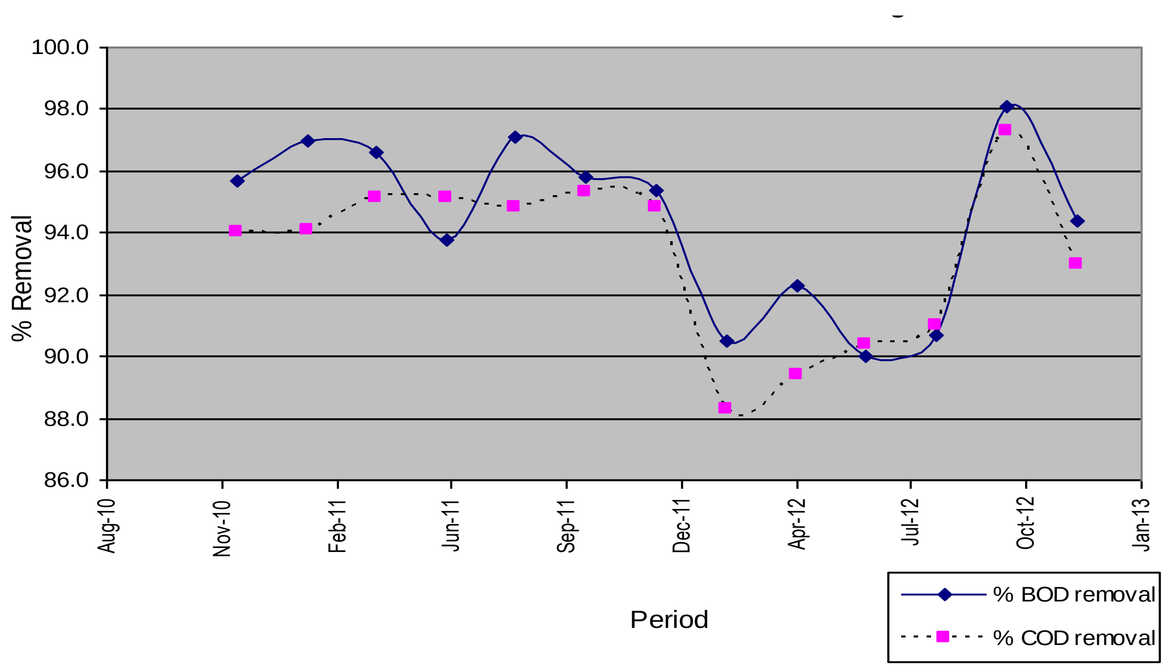

Figure.1. Percentage removal of BOD and COD

On the basis of present findings, it can be concluded that *Ceratophyllum demersum-L* is an effective plant for the phytoremediation of sewage water.

Conclusion

It is observed that *Ceratophyllum demersum-L* after proper acclimatization helps to reduce the organic load in sewage to a significant level as indicated by the removal efficiency of BOD and COD. An advantage in treating the sewage by *Ceratophyllum demersum-L* is the simultaneous removal of ammonia and phosphate from it. Further there is no requirement for any pretreatment in this method. When the sewage treated with *Ceratophyllum Demersum-L* is discharged into water bodies the dissolved oxygen level will not be depleted significantly to affect the aquatic life. There is a good scope to study the control of microorganisms, other nutrients and some toxic substances by this treatment. The study can be extended to other types of wastes also. The mechanism of removal is still to be explored. Finally it could be concluded that *C. demersum* can be successfully used for removing organic pollutants from wastewater.

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