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PHYTOREMEDIATION OF NUTRIENTS FROM THE COIR RETTING WASTEWATER BY WATER HYACINTH, *EICHHORNIA CRASSIPES*

REENA MOL S. AND A.G.MURUGESAN[2]

[1]Research and Development Centre, Bharathiar University, Coimbatore 641 046, T.N., India
Sree Narayana Arts and Science College, Kumarakom, Kottayam 686 563, Kerala, India
[2]Sri Paramakalyani Centre of Environmental Sciences Manonmaniam Sundaranar University, Alwarkurichi, Tirunelveli 627 412, T.N., India

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ABSTRACT

Macrophytes are widely used to remove pollutants from the wastewater. These macrophytes showed special mechanisms to remove pollutants and translocate elements into plant tissue. The main aim of the study is to improve coir retting wastewater quality discharged from the retting pond using a macrophyte, *Eichhornia crassipes*. Phytoremediation treatment of coir retting wastewater using showed decreased TSS level. The mean initial TSS level was 19760 ± 400 mg/l before treatment and the removal of TSS was 58.4% after 10 days and 95.4% after 20 days ($p<0.001$). The percentage removal of nitrite was 41% after 6 days and increased significantly after 20 days of treatment (98%) ($p<0.001$). The mean initial sulphate level was 82.4 ± 8.3 mg/l and decreased more than 90% after 20 days of treatment. The chemical oxygen demand of the raw effluent was 10184 ± 263.2 mg/L and it decreased as 2092 ± 138.4 mg/l after 10 days and the percentage of chemical oxygen demand decreased after 20 days of treatment ($p<0.001$) (96.1%). The mean initial biological oxygen demand was 5028.2 ± 409.4 mg/l before treatment and 89.9% reduction was achieved after 10 days. Biological oxygen demand removal increased after 20 days of treatment (95.15%) ($p<0.001$).

KEY WORDS : Phytoremediation, Eichhornia crassipes, wastewater, coir retting, chemical oxygen demand

INTRODUCTION

Aquatic phytoremediation is a novel method used for the removal of various pollutants from the surface wastewater and restoration of contaminated water bodies. In the surface water, water plants can be grown to remove number of pollutants from the sediment and the water column (Axtell *et al.,* 2003). Among the water plants, macrophytes are widely used to remove and degrade pollutants within aquatic eco-system. Macrophtes are emergent, submerged, and floating type. Floating macrophytes lives in the water surface include *Nymphaea* (water lilies), *Hydrocharis* (frogbit) and *Lemna* (duckweeds) and are rooted or free floating. Submerged macrophtes grow below the surface water level of the water column and emergent macrophtes are rooted into the surface and occupy the margin of water bodies. These macrophytes have a potential for uptake of various nutrients for their growth and can thus reduce the pollutants of an eco-system. Macrophytes used unique mechanisms to remove pollutants and degradation is based on the location of the pollutants and the type of pollutant within the surface water body (Bhaskaran *et al.,* 2013). The efficiency of phytoremediation is based upon the metabolic rate of macrophytes and translocation of elements into plant tissue (Ekperusi *et al.,* 2019).

Rhizodegradation and phytometabolism in the sediment and within the water column are integral remediation processes in the phytoremediation of various organic matters. Macrophytes uptake nitrogen in the form of ammonia and nitrate and P is consumed as phosphate. Most of these macrophytes have fastest growth rate and have effective nutrient absorbing ability. *E. crassipes* has very rapid growth rate (60–110 t/ha/year) than *Typha latifolia* (8–61 t/ha/year), and *Lemna* sp. (6–26 t/ha/year). The floating macrophytes such as *Pistia stratiotes*, *Lemna gibba*, and *E. crassipes* showed maximum nutrients removal rate from the water. However, submerged plants have lower nutrient removal ability. The phytoremediation ability of a specific macrophyte is greatly influence by various biotic factors such as predation, competition, and abiotic factors such as light availability, pH, and temperature of the water column (Ceschin et al., 2020). *E. crassipes* removed nitrate at optimum nitrate concentration in the water (100 – 300 mg/L) and removal efficiency declined at higher concentrations of nitrate (400 and 500 mg/L) (Leal-Alvarado et al., 2018).

Macrophytes are considered as hyperaccumulators and *E. crassipes* can concentrate >10 g Zn from the water (Moyo et al., 2013). These plants have detoxifying mechanism to avoid toxicity within the cells. Polyculture of macrophytes improved heavy metal removal and significantly reduced chemical oxygen demand than monoculture. Water hyacinth has the potential to remove various pollutants from the wastewater environment. Previous studies revealed that it effectively removed nutrients, phosphorus and nitrogen from the wastewater. Water hyacinth has the ability to convert wastewater into relatively clean water. It has the potential to remove suspended solids and biological oxygen demand. The aims of the present study are reduction in the contamination of coir retting industry effluent though water hyacinth plant and to make coir retting wastewater beneficial for irrigation.

MATERIALS AND METHODS

Coir retting effluent

Coir retting wastewater was collected from the discharged point of the open coir retting plant at Kerala State (India).

Aquatic macrophytes

Aquatic macrophytes were collected from the pond near to the coir retting unit. The extensive field study was performed for a period of six months and macrophytes were collected. The field trips were performed once in a month for a period of six months in order to determine macrophytes in this pond. Macrophytes were directly collected from the pond by hand, or using a long handled hook nets and washed several times with tap water. The washed macrophytes were dried under filter paper and identification was performed. Morphological characters were analyzed and the macrophytes were identified as described previously by Cook (1990).

Phytoremediation using *E. crassipes* (Mart)

Experiment was performed in a rectangular tank (50 cm length × 20 cm depth × 20 cm width). It was performed in the controlled environmental conditions with 12 h light and 12 h dark photoperiod and the relative humidity was 60%. *E. crassipes* plants were grown in the tank containing sufficient level of water. The age of the plant (*E. crassipes*) was approximately 5 – 6 weeks and equal weight plant was slected for this study. Triplicate experiment was performed and the mean value was taken for consideration. Throughout the experiment, constant pollution pattern was maintained and no new water was added to the experimental or control tanks.

Analytical experiments

The efficacy of removing ammonia nitrogen (NH_3-N), total suspended solids (TSS), phosphate, total dissolved solids, total hardness, sulphate, chloride, fluoride, and ammonia from the retting effluent. The selection of macrophyte was based on rapid growth rate. Toxic heavy metals such as, nickel, zinc, lead, chromium and mercury were analyzed by atomic absorption spectroscopy.

Statistical analysis

Mean values registered for the three different experiments. Analysis of variance was used to determine the significant differences between the available excess nutrients in the tank and water hyacinth removed pollutant level. Experiment was performed for 20 days and the significant level was calculated at 5% level and the p value < 0.05 was considered as statistically significant.

RESULTS

Physicochemical analysis of coir retting effluent

The physico-chemical factors of retting wastewater used for bioremediation were analyzed and the mean ± standard deviation was used for analysis. Total suspended solid value was 19760 ± 400 mg/L and increased level of nitrate was observed (5.82 ± 0.42 mg/L). Elevated level of sulphate, phosphate, calcium, iron and phenol was detected. Alkaline pH was observed and increased magnesium level (187.5 ± 10.4 mg/L) was observed (Table 1).

Table 1. Physicochemical analysis of coir retting effluent collected near the outlet of the open coir retting unit.

Sl. No	Parameters	Result
1	Total dissolved solids	1438 ± 120
2	Total suspended solids	19760 ±400
3	Nitrite	2.41 ± 0.05
4	Nitrate	5.82 ±0.42
5	Sulphate	82.4 ±8.3
6	Chloride	348 ± 10.3
7	Chemical oxygen demand	10184 ±263.2
8	Biological oxygen demand	5028.2 ±409.4
9	Calcium	492.4 ±24.2
10	Magnesium	187.5 ± 10.4
11	Sulphate	138.4 ±5.5
12	Iron	3.19 ± 0.32
13	Phenol	450 ± 10.2
14	pH	9.72 ± 0.1

Removal of total suspended solids

Phytoremediation treatment of coir retting wastewater using *E. crassipes* showed decreased TSS level. The mean initial TSS level was 19760 ± 400 mg/L before treatment. On the second day of treatment, the TSS value was significantly reduced (12100 ± 150 mg/L) ($p<0.001$). On day 20, the TSS value was 603 ± 10 mg/L and the reduction of TSS was mainly due to the fibrous root system of macrophyte. The percentage of removal of TSS was 49% after 4 days and the percentage of TSS removal increased after 20 days of treatment (3.02%) ($p<0.001$) (Fig. 1).

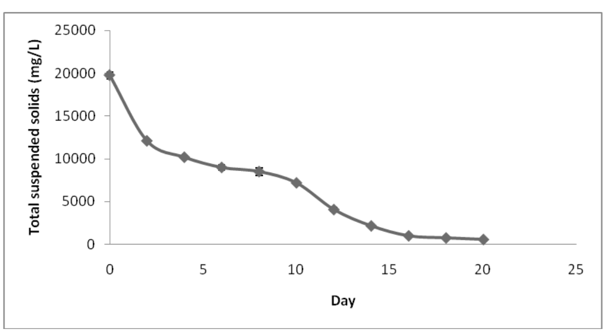

Fig. 1. Phytoremediation of total suspended solid values in the water hyacinth treatment systems (n=3). TSS value represents an average value for 20 days.

Removal of total dissolved solids

Phytoremediation treatment of coir retting wastewater using *E. crassipes* showed decreased TDS level. The mean initial TDS level was 1438 ± 120 mg/L. On Day 4 of treatment, the TDS value was significantly reduced (1092 ± 22 mg/L). On day 20, the TDS value was 95.2 ± 1.52 mg/L and the reduction of TSS. The percentage of removal of TSS was 58.4% after 10 days and the percentage of TDS removal increased significantly after 20 days of treatment (95.4%) ($p<0.001$) (Fig 2).

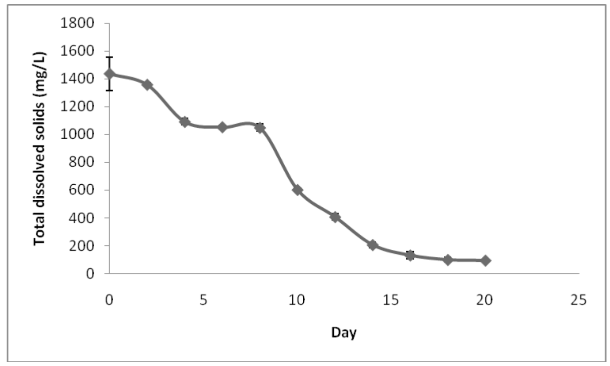

Fig. 2. Phytoremediation of total dissolved solids values in the water hyacinth treatment systems (n=3). TDS value represents an average value for 20 days.

Removal of nitrite

Phytoremediation treatment of coir retting wastewater using *E. crassipes* showed decreased nitrite level. The mean initial nitrite level was 2.41 ± 0.05 mg/L before treatment. On the second day of treatment, the nitrate value was reduced marginally (2.34 ± 0.14 mg/L). On day 20, the nitrite value was 0.14 ± 0.09 mg/L. The percentage of removal of nitrite was 41% after 6 days and the percentage of nitrite removal increased significantly after 20 days of treatment (98%) ($p<0.001$) (Fig. 3)

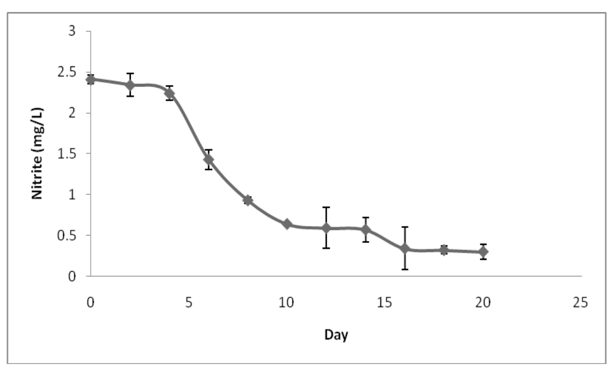

Fig. 3. Phytoremediation of nitrite in the water hyacinth treatment systems (n=3). Nitrite value represents an average value for 20 days.

Removal of nitrate

Phytoremediation treatment of coir retting wastewater using *E. crassipes* showed decreased nitrate level. The mean initial nitrate level was 5.82 ± 0.42 mg/L before treatment. On the second day of treatment, the nitrate value was significantly reduced (3.29 ± 0.17 mg/L). On day 10, the nitrate value was 0.87 ± 0.014 mg/L and the reduction of nitrate. The percentage removal of nitrate was 85% after 10 days and the percentage of nitrate removal significantly increased after 16 days of treatment (93.3%) ($p<0.001$) (Fig. 4).

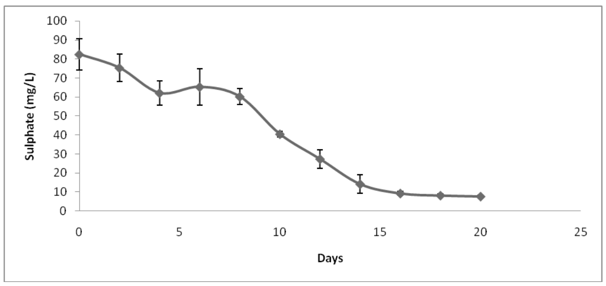

Fig. 4. Phytoremediation of nitrate in the water hyacinth treatment systems (n=3). Nitrate value represents an average value for 20 days.

Removal of sulphate

Phytoremediation treatment of coir retting wastewater using *E. crassipes* showed decreased sulphate level. The mean initial sulphate level was 82.4 ± 8.3 mg/L before treatment. On the second day of treatment, the sulphate value was significantly reduced (75.3 ± 7.2 mg/L). On day 10, the sulphate value was 40.5 ± 1.5 mg/L and the reduction of sulphate content. The percentage of removal of sulphate was 51% after 10 days and the percentage of sulphate removal significantly increased after 20 days of treatment (90.7%) ($p<0.001$) (Fig. 5).

Removal of chemical oxygen demand

Phytoremediation treatment of coir retting wastewater using *E. crassipes* showed decreased chemical oxygen demand. The mean initial chemical oxygen demand was 10184 ± 263.2 mg/L before treatment. On the second day of treatment, the chemical oxygen demand was 9108 ± 402 mg/L. On day 10, the chemical oxygen demand value was 2092 ± 138.4 mg/L. The percentage of removal of chemical oxygen demand was 79.5% after 10 days ($p<0.001$) and the percentage of chemical oxygen demand decreased after 20 days of treatment ($p<0.001$) (96.1%) (Fig. 6)

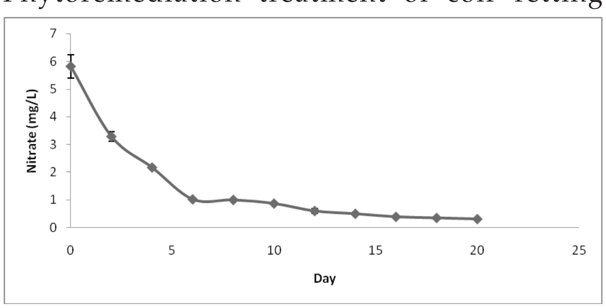

Fig. 5. Phytoremediation of sulphate in the water hyacinth treatment systems (n=3). Sulphate level represents an average value for 20 days.

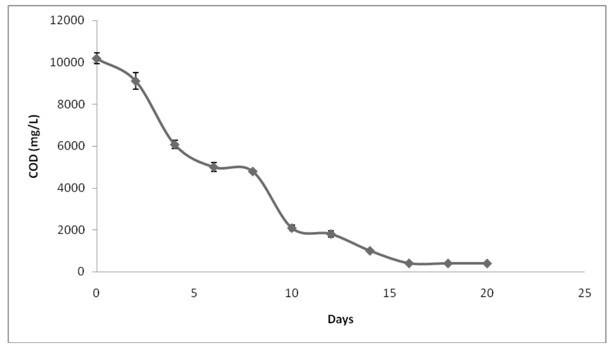

Fig. 6. Phytoremediation of chemical oxygen demand in the water hyacinth treatment systems (n=3). Chemical oxygen demand value represents an average value for 20 days.

Removal of biological oxygen demand

Phytoremediation treatment of coir retting wastewater using *E. crassipes* showed decreased biological oxygen demand. The mean initial biological oxygen demand was 5028.2 ± 409.4 mg/L before treatment. On the second day of treatment, the biological oxygen demand was 5021 ± 308.2 mg/L. On day 10, the biological oxygen demand value was 502 ± 12.5 mg/L ($p<0.001$). The percentage of removal of biological oxygen demand was 89.9% after 10 days and the percentage of biological

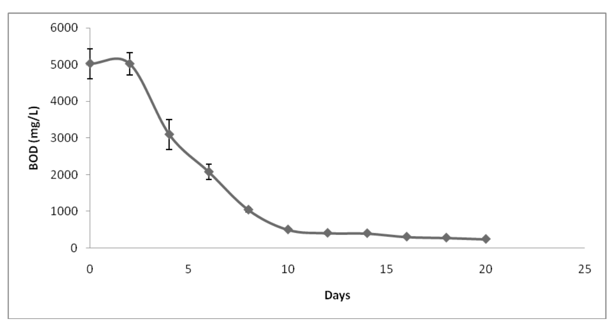

Fig. 7. Phytoremediation of biological oxygen demand in the water hyacinth treatment systems (n=3). Biological oxygen demand represents an average value for 20 days.

oxygen demand removal increased after 20 days of treatment (95.15%) ($p<0.001$) (Fig. 7).

DISCUSSION

Freshwater macrophytes play a major ecological role in the aquatic environment, regulating in the stabilization and management of mineral cycling. The present study revealed that the shallow water pond with very large bottom sediments showed favourable environment for macrophyte growth and reproduction. In this study, *E. crassipes* was used for the removal of inorganic and organic contaminants. The amont of pollutants removal of macrophytes depends on the macrophyte species, physico-chemical characteristics of the contaminant and the biochemical composition of the plant species. The metabolic pathways for the removal of contaminants from the environment by aquatic macrophytes have been reported (Wang *et al.*, 2019). The continuous exposure of macrophytes to various inorganic or organic matter results in sequestration or rapid uptake followed by degradation or transformation, which can be oxidative, revealing in the development of metabolites, which get assimilated by covalent binding to macrophytes (Valadi *et al.*, 2019). Macrophytes present in constructed and natural wetlands also show the potential to remove inorganic matters such as phosphorus and nitrogen from effluent (Uysal, 2013). Aquatic plant species such as, *Potamogeton crispus*, *Ceratophyllum demersum*, *Elodea nuttallii*, *Elodea canadensis* and *Eichhornia crassipes* were used to remove excessive phosphorus, nitrogen from the wastewater from hydroponic systems. In macrophytes, nitrogen removal ability occurs mainly in the form of nitrate and ammonia (Umar *et al.*, 2015). Aquatic macrophytes possess hardiness, ease of handling, maximum productivity, tolerance to survive adverse climatic conditions, rapid growth and bioaccumulation ability establish them as unavoidable source in the field of phytoremediation. In plants, the biological removal of pollutants from natural environment by plants through interactions with functional groups presents cell wall such as, carbohydrates, lipids and proteins (Mahamadi and Nharingo, 2010). Priya and Selvan (2014) reported that aquatic macrophytes showed lot of potential to remove nutrients from the contaminated environment. Sung *et al.* (2015) reported the ability of *Ceratophyllum demersum* and *E. crassipes* for organic matter removal on both water and wet soil environments and amount of phosphorus and nitrogen reduced considerably in the wastewater treated with *E. crassipes* than other macrophytes. *E. crassipes*-is a good candidate for the removal of organic matters from the water (Jin *et al.*, 2020).

Phytoremediation treatment of coir retting wastewater using *E. crassipes* showed decreased chemical oxygen demand. The mean initial chemical oxygen demand was 10184 ± 263.2 mg/L and the percentage removal of chemical oxygen demand was 79.5% after 10 days of treatment. The BOD of raw retting effluent was 5028.2 ± 409.4 mg/L and decreased continuously after treatment. In the present study, *E. crassipes* effectively remove COD from the wastewater. Rezania *et al.* (2016) reported that the bacteria associated with the root system of plants greatly contributed the removal of COD. These associated bacteria transform the available organic matter in the retting effluent into absorbable mineral compounds which are beneficial for the development of macrophytes. The beneficial role of *E. crassipes* has been reported. The root associated bacteria degrade various organic compounds and promoted the growth of macrophytes (Pang *et al.*, 2016). According to Wang *et al.* (2019) macrophytes synthesize exudates using the root system. Bacteria utilized these exudates and involved in denitrification process. These microbial processes involved leaching of various organic substances leading in the removal of COD from the environment. The bioreduction of COD was achieved because water plants undergo photosynthesis process. The available oxygen supported the proliferation and development of aerobic bacterial consortia to reduce COD and BOD content (Singh *et al.*, 2012). This clearly revealed that wastewater would have a smaller impact on the water eco-system treated with water hyacinth.

CONCLUSION

The present results revealed that the selected macrophyte able to reduce nitrite, nitrate, COD and TSS contents in retting wastewater with various treatment times. A one-way ANOVA test revealed that there was a significant reduction of nutrients from the wastewater. Phytoremediation could be the alternative to current methods for wastewater treatment. It is cost effective, eco-friendly and involves the application of macrophytes, including *E. crassipes*.

Conflict of Interest

None declarded

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