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Efficacy of an Integrated System Incorporated with *Eichhornia crassipes* in Phytoremediation of Calcium from Inland Saline Water

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ABSTRACT

In the present study, free floating plant *Eichhornia crassipes* was used for the phytoremediation of calcium from inland saline water by using water having salinity of 2.5, 5 and 7.5 ppt for one week each. Water samples were collected on 0^{th}, 4^{th} and 6^{th} day and plant sample was at end of the experiment for calcium estimation and for other water quality parameters i.e., total hardness (TH), total alkalinity (TA), dissolved oxygen (DO), carbon dioxide (CO_2), potassium (K) and pH on 0^{th} and 6^{th} day of the experiment. There was a significant difference in the calcium uptake ($P<0.05$) by the plants compared to the 0^{th} day samples. The higher percentage removal of calcium was noted at 2.5 ppt salinity (47.7%) followed by 5 and 7.5 ppt salinity (36.04 and 23.13%) respectively. There was significant improvement in the water quality characteristics. In first cycle at 2.5 ppt salinity, the initial concentration of TH, TA, K and CO_2 was 833.33, 166.66, 2.7 and 2.6 mg.L^{-1} which decreased to 813.33, 144.66, 1.7 and 0 mg.L^{-1} respectively, at the end of experiment. Similarly, there was a decrease in the concentration of pH noted from 8.5 to 8.2. An increase was obtained in the concentration of DO i.e., from 6.3 to 7.1 mg.L^{-1}. The trend of decreasing was observed for other cycles also. The used integrated system (sand filter + charcoal filter + coconut coir bed filter incorporated with *E. crassipes*) was efficient for calcium removal and higher percentage removal was obtained at 2.5 ppt salinity followed by 5 and 7.7 ppt. At 2.5 ppt, higher percentage removal was obtained in second cycle i.e. 47.7% compared to first and third cycle i.e. 45 and 46.22% respectively. Similar trend of percentage removal was obtained at 5 and 7.5 ppt i.e., 36.04 and 23.13% respectively than other two cycles. The overall results suggest that finding of this study will serve as a baseline for treatment of inland saline water to make it useful for various agricultural and aquaculture applications.

INTRODUCTION

Groundwater is a natural and renewable resource for day-to-day human activity. It is estimated that approximately one third of the world's population use groundwater only for drinking purpose (United Nations Environment Program 1999). Due to intensive use of natural resources and increased human activities, it pushed the groundwater quality under great threat and deterioration (Foster 1995, Mor et al. 2006). According to the FAO Land and Plant Nutrition Management Service (2008) salt affected (saline and sodic) land area cover over 400 million hectares, which is over 6% of the world land area. While comparing with Indian scenario, nearly 8.68 million ha of land area is seriously affected with soil salinity problem and 1.93 million square kilometre area is underladen with ground saline water (Pathak et al. 2013). According to the Central Soil Salinity Research Institute Annual Report (CSSRI 2010-11), an estimated salt affected area is 6.73 million ha of which 3.77 and 2.95 million ha is sodic and saline, respectively. All over India, Gujarat has maximum salt affected soil of 2.2 million ha followed by Uttar Pradesh, Maharashtra and Haryana with 1.3, 0.6 and 0.2 million ha respectively.

Salinity mainly caused either through natural or human-induced processes which result in the accumulation of dissolved salts in the soil water up to an extent that may inhibit plant growth. Water hardness is one of the major problems of inland saline water. In simple terms, it is the capacity of water to react with soap and is a very important property of any groundwater from its utility point of view. The calcium (Ca^{2+}) and magnesium (Mg^{2+}) are the two important ions responsible for the total hardness of water. There is difference in calcium concentration in different places of Haryana as reported by various researchers, viz. in Hisar city 38.5-

225.7 mg.L^{-1} (Khaiwal & Vinod 2007), in Ambala district 47.8-460 mg.L^{-1} (Prem Singh et al. 2010), and in Rohtak district 12-600 mg.L^{-1} (Mukul Bisnoi et al. 2007). According to the ICMR and BIS standards, the permissible limit for total hardness is 300 ppm of $CaCO_3$. According to Jana et al. (2004), the salinity of the inland saline water in the State Haryana ranges from 10-35 ppt with high Ca^{2+} and Mg^{2+}, which has resulted in high water hardness.

Phytoremediation is the process where the use of plants is promoted for environmental clean-up and is very good approach to the cost-effective treatment of wastewater, groundwater and soils contaminated by organic xenobiotics, heavy metals, and radionuclides (Gardea-Torresdey 2003). There are numerous descriptions and definition of the term phytoremediation, but according to the Gardea-Torresdey (2003) one clear definition is "the use of plants for the removal of pollutants from the environment". According to Khan et al. (2004), phytoremediation has been applied to a number of contaminants including heavy metals, radionuclides, chlorinated solvents, petroleum hydrocarbons, PCBs, PAHs, organophosphate, insecticides, explosives and surfactants in small-scale field and/or laboratory studies. In case of higher plants, certain species having capability to accumulate very high concentrations of metals in their tissues without-showing any toxicity effect (Klassen et al. 2000, Bennett et al. 2003). These plants can be used successfully for environmental clean-up (viz. heavy metal polluted soils) if metal content is less, and their biomass is large enough to complete remediation process within a reasonable period (Ebbs & Kochian 1998).

Common desalination methods are either physical or electrochemical. These techniques are mainly based on the principle of ion exchange, filtration or separation and adsorption, which are energy consuming and costly. The use of phytoremediation was considered to be a non-polluting and cost effective way of removing or stabilizing toxic chemicals that might otherwise be leached out of the soil by rain to contaminate nearby watercourses (Meagher 2000). Calcium removal from inland saline water using macrophytes, is not attempted by researchers earlier.

In the light of above facts, the present study has been conducted for achieving the objective of to study the calcium removal efficiency of an integrated system including *Eichhornia crassipes* as a component.

MATERIALS AND METHODS

In this study, the free-floating perennial aquatic plant *Eichhornia crassipes* (water hyacinth) was used for phytoremediation of calcium from inland saline water. This particular work was carried out in field condition of the CIFE, Rohtak centre (Haryana). Integrated system was consisted of two filtration tanks followed by third tank with macrophyte, *E. crassipes* (Fig. 1). The first filtration tank was kept at the height of 177.5 cm from the base on a stand, second filtration tank at the height of 125.5 cm and third tank with plants on the base. First two tanks were similar cylindero-conical shaped (inner diameter 47 cm, height 59 cm) base fitted with outlet pipe and third one circular FRP tank (500 L capacity). First filtration tank has a sand bed of 30 cm with its bottom having a sponge acting as a screen to prevent passing of sand particles.

The second filtration tank has a coconut coir bed of 15 cm and charcoal bed of 5 cm followed by a sponge screen. For this experiment, inland saline water with three different

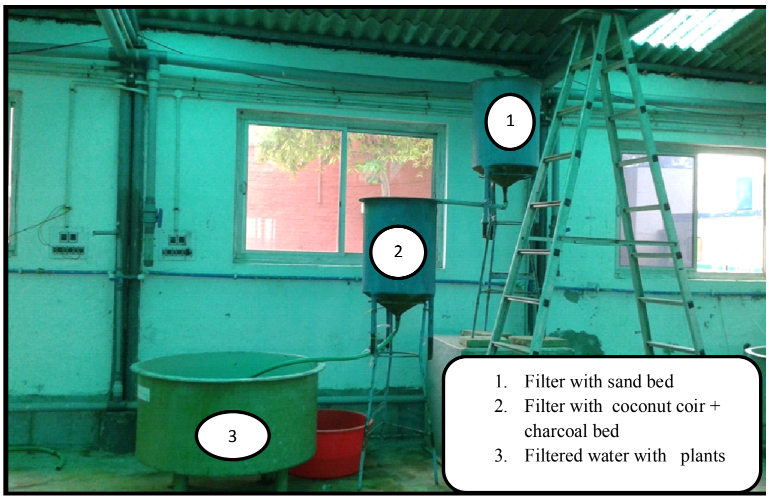

Fig. 1: Experimental set-up for the experiment.

salinities of 2.5, 5.0 and 7.5 ppt were used. Desired salinity was obtained by adding freshwater to hatchery groundwater having salinity of 10 ppt. All the FRP tanks were properly washed, cleaned and dried before use for the experiment. The water with different salinities was passed through a filter system and desired quantity (300 L) was collected in the last circular FRP tank, with water level of 22 cm. *E. crassipes* was collected from Saini pond (Rohtak) and washed and cleaned properly, and 5 kg introduced in respective tanks. For each salinity, three cycles of 7 days were run at the same time.

Sample Collection and Preparation

Water: The water samples of 50 mL each were collected at alternate day in polypropylene bottles from each tank in triplicates for calcium removal study. All the bottles were cleaned by soaking in dilute hydrochloric acid for 7-8 hours, and washed with distilled water and dried before use. Water samples were filtered through Whatman filter paper No.1 to avoid chocking of the nebulizer of flame photometer and then used for calcium analysis by the same equipment. For water quality parameters (TH, TA, DO, free CO_2, K, pH) analysis, water samples were collected in different sample bottles separately, which were carried out on the day of sample collection.

Plant: *Eichhornia crassipes* plants were collected randomly from each FRP tank at the end of experiment. All the samples were air-dried at room temperature for 2-3 days, then dried in hot air oven at temperature 105°C for 3-5 hours to attain a constant weight and ground to powder using glass mortar and pestle. The powder (finely ground material) was stored in sealed polyethylene bags and marked properly and kept at room temperature. The plant sample digestion and estimation of calcium was done at the Aquatic Environment and Health Management Division Laboratory of the Central Institute of Fisheries Education (CIFE), Mumbai.

Estimation of Moisture Content in Macrophyte

The moisture content analysis of the macrophyte was carried out separately before starting of the experiments. It was determined by drying a known quantity of the plants in air for three to four days and then in a hot-air oven at 105°C till attaining a constant weight. The difference in weight of the samples represented the moisture content, which was calculated using the following formula:

$$\%\ \text{Moisture} = \frac{\text{Fresh Weight} - \text{Dry Weight}}{\text{Fresh Weight}} \times 100$$

Calcium Analysis of Water and Plant Samples

Water: Water samples were collected and filtered by using Whatman filter paper No. 1 and stored in polypropylene bottles. Filtration was done to get rid of any suspended solids. The samples were subjected to calcium analysis by using a flame photometer and results were expressed in mg.L^{-1}.

Plant: The replicates of dried powdered plant samples were

Table 1. Mean and percentage removal efficiency of the integrated system incorporating *E.crassipes* with different salinities.

Integrated system	First cycle		Second cycle		Third cycle	
	Mean value (in mg.L^{-1})	% removal	Mean value (in mg.L^{-1})	% removal	Mean value (in mg.L^{-1})	% removal
			2.5 ppt			
ITW (0^{th}day)	141.33	-	141.33	-	141.33	-
SF (0^{th}day)	105.33	25	102.66	29.36	104	23.52
SF+Ch+CBF(0^{th} day)	86.66	38	98.66	32.11	93.33	31.61
SF+Ch+CBF+E (4^{th} day)	82.66	41.51	81.33	42.45	78.66	44.34
SF+Ch+CBF+E (6^{th}day)	77.33	45	76	47.7	76	46.22
			5 ppt			
ITW (0^{th} day)	172	-	172	-	172	-
SF (0^{th} day)	140	18.60	144	16.27	146	15.11
SF+Ch+CBF(0^{th}day)	131.33	23.64	130.66	24.03	133.33	22.48
SF+Ch+CBF+E (4^{th} day)	125.66	26.94	124.34	27.52	121.64	29.27
SF+Ch+CBF+E (6^{th}day)	118.28	31.23	110.31	36.04	115.52	32.83
			7.5 ppt			
ITW (0^{th}day)	250.66	-	250.66	-	250.66	-
SF (0^{th} day)	225.33	10.10	228	9.04	221	11.83
SF+Ch+CBF (0^{th}day)	212.28	15.31	215.33	14.09	213.65	14.76
SF+Ch+CBF+E (4^{th}day)	205.22	18.21	200.31	20.08	203.32	18.88
SF+Ch+CBF+E (6^{th}day)	198.61	20.76	192.66	23.13	195.61	21.96

ITW-Initial Tap Water, SF- Sand Filter, Ch- Charcoal, CBF- Coconut Bed Filter, E- *E.crassipes*.

Table 2: Percentage of calcium removal by the integrated system incorporating *E. crassipes* (Mean ± SE).

Treatment/salinity	2.5 ppt	5 ppt	7.5 ppt
SF (0^{th} day)	25.96_c ± 1.75	16.66_d ± 1.02	10.32_d ± 0.81
SFCFCBF (0^{th} day)	33.90_b ± 2.05	23.38_c ± 0.46	14.72_c ± 0.35
SFCFCBFE (4^{th} day)	47.76_a ± 0.83	27.91_b ± 0.70	19.05_b ± 0.54
SFCFCBFE (6^{th} day)	46.30_a ± 0.78	33.36_a ± 1.41	21.95_a ± 0.68

Mean values in a column under each category bearing different superscripts vary significantly (P<0.05)

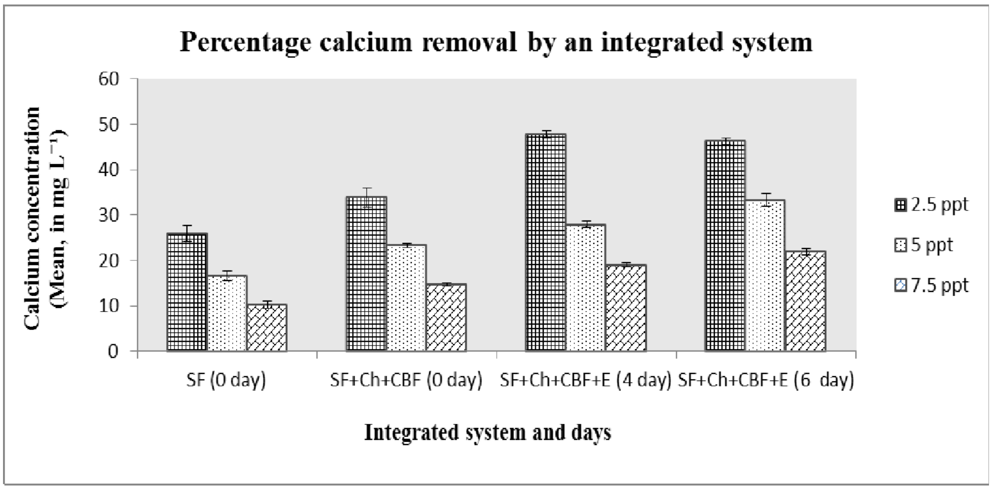

Fig. 1: Percentage of calcium removal from the integrated system incorporating *E. crassipes* (Mean ± SE).

digested by using open digestion method on hot plate by using concentrated nitric acid and hydrogen peroxide acid till colourless solution was obtained. Finally, the sample was subjected to calcium analysis by using a flame photometer at 422.7 nm wavelength. The results were expressed in mgCa/g dry wt. on dry weight basis.

Statistical analysis: For all the above experiments, the data were analysed by using SPSS 16.0 software. One-way ANOVA was carried out for each experiment to find out the significant difference between treatments with selected macrophytes (< 0.05).

RESULTS

The calcium removal efficiency of an integrated system including *E. crassipes* was carried out for salinity i.e., 2.5, 5 and 7.5 ppt for one week duration. The percentage removal efficiency and mean of calcium concentration is given in Table 1. Higher percentage removal was obtained in 2.5 ppt salinity followed by 5 and 7.7 ppt. At 2.5 ppt, higher percentage removal was obtained in second cycle i.e. 47.7% compared to the first and third cycle i.e., 45 and 46.22% respectively. Similar trend of percentage removal was obtained in 5 and 7.5 ppt i.e., 36.04 and 23.13% respectively than the other two cycles.

There was a significant difference in calcium removal efficiency of integrated system incorporating *E. crassipes* than other system (SF+CF+CBF) at lower salinity (2.5 ppt), and there was no significant difference in calcium removal on 4^{th} and 6^{th} day of the experiment (Table 2, Fig. 1.), but at higher salinities (5 and 7.5 ppt), a significant difference was observed. At 5 ppt salinity, calcium removal on 4th day and 6th day was 27.91± 0.7 and 33.36 ± 1.41 $mg.L^{-1}$ (mean ± SE) and at 7.5 ppt salinity, removal was 19.05 ± 0.54 and 21.95 ± 0.68$mg.L^{-1}$ respectively.

The calcium uptake on dry weight basis is presented in Table 3 for 4th and 6th day It was similar for different salinities (2.5, 5 and 7.5 ppt) and maximum was observed on 6th day There was significant uptake of calcium on 4th and 6th day by *E. crassipes* on 4^{th} and 6^{th} day of the experiment for all the salinities (Fig. 2).

Changes in water quality parameters of an integrated system incorporating *E. crassipes*: Changes in water quality parameters were also checked on first day and at the end of experiment, and the observed mean reduction is given in Table 4. There was significant reduction in mean value of observed parameters viz., TH, TA, K and free CO, in all salinity and all cycles. Similarly there was a decrease in the

Table 3: Calcium uptake by *E. crassipes* with the integrated system on 4th and 6th day of experiment at different salinities (Mean ± SE).

Salinity (in ppt)	Calcium uptake by *E. crassipes* with the integrated system (in mg Ca/g dry wt.) First cycle		Second cycle	
	4th day	6th day	4th day	6th day
2.5	$21.59_b \pm 1.19$	$26.69_a \pm 0.74$	$23.48_b \pm 1.19$	$27.30_a \pm 0.60$
5	$17.69_b \pm 1.27$	$23.23_a \pm 0.82$	$18.89_b \pm 0.87$	$25.87_a \pm 0.57$
7.5	$18.20_b \pm 0.85$	$20.77_a \pm 0.86$	$20.20_b \pm 0.58$	$23.64_a \pm 0.89$

Mean values in a column under each category bearing different superscripts varysignificantly (P<0.05)

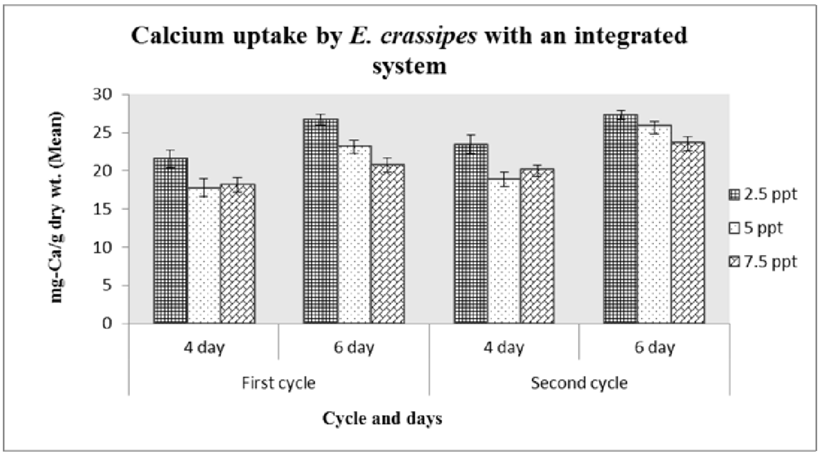

Fig. 2: Calcium uptake by *E. crassipes* with the integrated system on 4th and 6th day of experiment at different salinity (Mean ± SE).

value of pH, but there was significant increase in concentration of DO.

In the first cycle at 2.5 ppt salinity, the initial concentration of TH, TA, K, pH and CO_2 was 833.33, 166.66, 2.7, 8.5 and 2.6 mg.L^{-1} which decreased to 813.33, 144.66, 1.7, 8.2 and 0 mg.L^{-1} respectively at the end of experiment. But an increase in concentration was obtained for DO i.e., 6.3 to 7.1 mg.L^{-1}. At 5 ppt of first cycle, the initial concentration of TH, TA, K and CO_2 was 1353.33, 189.33, 4.4 and 2.6 mg.L^{-1} was decreased to 1146.66, 162, 3.4 and 0 mg.L^{-1} respectively at the end of experiment. While there was an increase in concentration for DO and pH i.e., 6.3 to 7.2 mg.L^{-1} and 8.3 to 8.7 respectively. Similarly, at 7.5 ppt salinity of first cycle, the initial concentration of TH, TA, K and CO_2 was 1936.66, 246.66, 5.6 and 3.3 mg.L^{-1} which got decreased to 1933.33, 205.33, 5.1 and 0 mg.L^{-1} respectively. An increase in concentration was obtained for DO and pH from 5.8 to 6.8 mg.L^{-1} and 8.3 to 8.6 respectively, at the end of experiment.

DISCUSSION

Calcium removal efficiency of an integrated system incorporating *E. crassipes* was studied for salinity 2.5, 5 and 7.5 ppt and in three cycles of one week. At salinity 2.5 ppt, removal of calcium was 47.7%. Lu et al. (2011) recorded reduction in Ca^{2+} content by using *Pistia stratiotes*. Calcium is highly essential and plays a major role in plant metabolism, structural material of cell wall and signalling (Patel & Kanung 2010). But with increasing salinity of 5 and 7.5 ppt, calcium removal capacity was slightly decreased and it was 36.04 and 23.13% respectively. With an increase in salinity, there was increased concentration of calcium level, which caused lower uptake of calcium. High concentration of calcium is phytotoxic, therefore its appropriate concentration is needed for proper growth and physiological functions of plants (Azarpira et al. 2014). In plants treated with Zn, the relative growth was increased in 5 and 10 mg.L^{-1} treatments but decreased in 20 and 40 mg.L^{-1} treatments (Xiaomeilu et al. 2004). Delgado et al. (1993) found that in long term experiment (24 days), water hyacinth exposed to 9 mg.L^{-1}, of Zn resulted in 30% reduction in weight. According to Akinbile et al. (2014), macrophytic root system provided extensive surface area to promote physical, chemical and microbial processes for absorption of nutrients and nitrification processes and also claimed that *E. crassipes* and *Pistia stratiotes* were effective in nutrient uptake.

A significant improvement was noted in water quality parameters. In first cycle at 2.5 ppt salinity the initial concentration of TH, TA, K and CO_2 was 833.33, 166.66, 2.7

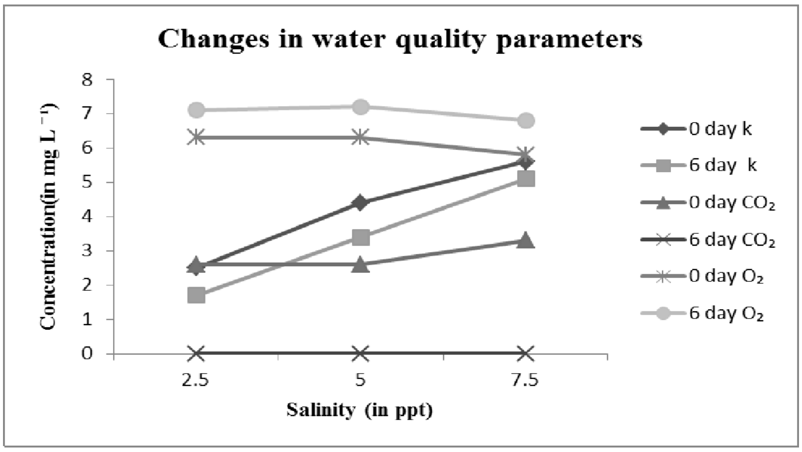

Fig. 3a: Changes in salinity on 4th and 6th day of experiment.

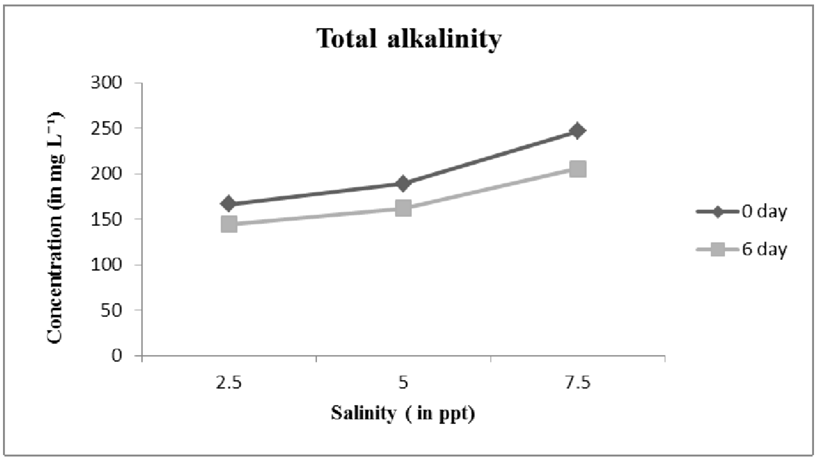

Fig. 3b: Changes in total alkalinity on 4th and 6th day of experiment.

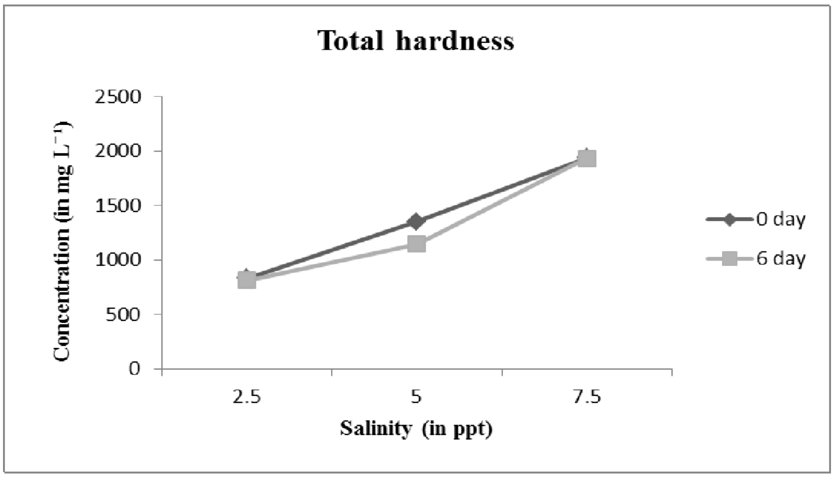

Fig. 3c: Changes in total hardness at 4th and 6th day of experiment.

Table 4: Changes in water quality parameters of the integrated system incorporating *E. crassipes.*

Parameters (in mg.L^{-1})	1st cycle		2nd cycle		3rd cycle	
	0th day	6th day	0th day	6th day	0th day	6th day
			2.5 ppt			
TH	833.33	813.33	730	723.33	826.66	753.33
TA	166.66	144.66	156	148	158	139.33
K	2.7	1.7	2.6	1.5	3.2	2.5
CO_2	2.6	0	2	0	2.6	0
DO	6.3	7.1	6.3	7.3	6.2	7.3
pH	8.5	8.2	8	8.4	8	8.2
			5 ppt			
TH	1353.33	1146.66	1476.66	1410	1230	1133.33
TA	189.33	162	187.33	166	173.33	144.66
K	4.4	3.4	3.5	2.9	4.5	3.1
CO_2	2.6	0	3.3	0	2	0
DO	6.3	7.2	6.3	7.2	6.1	7.4
pH	8.3	8.7	8.5	8.4	8.3	8.1
			7.5 ppt			
TH	1936.66	1933.33	1846.66	1803.33	1836.66	1726.66
TA	246.66	205.33	270.66	243.33	286	260.66
K	5.6	5.1	5.8	5.33	6.3	5.3
CO_2	3.3	0	2.6	0	2.6	0
DO	5.8	6.8	6.6	7.4	6.2	7.4
pH	8.3	8.6	8.5	8.5	8	8.2

TH- Total hardness, TA- Total alkalinity, K- Potassium, CO_2- Free carbon dioxide and DO- Dissolved oxygen, pH- unit less

and 2.6mg L^{-1} which got decreased to 813.33, 144.66, 1.7 and 0 mg.L^{-1} respectively at the end of the experiment. Similarly there was decrease in concentration of pH from 8.5 to 8.2 at the end of experiment. Similar type of result was obtained for the other cycles. There was significant decrease in concentration of TA (from 833.33 to 813.33mg L^{-1}) and TH (from 166.66 to 144.66mg L^{-1}) in the experiment. This reduction was due to utilization of calcium and partial utilization of bicarbonate ions by the plants for their body formation and development. There was significant decline in CO_2 concentration which was due to higher rate of carbon dioxide consumption in photosynthesis. Decreased concentration of K indicates that it is essential in nearly all the processes needed to sustain plant growth and reproduction. It plays a vital role in photosynthesis, translocation of photosynthates, protein synthesis, activation of plant enzymes, control of ionic balance and regulation of plant stomata. Dipu et al. (2010) recorded significant decrease in potassium in dairy effluent using *Typha* and other aquatic macrophytes. Similarly Lu et al. (2011) reported reduction in potassium by using *Pistia*. There was a little decrease observed in concentration of pH from 8.5 to 8.2. The optimal water pH for growth of *E. crassipes* is neutral but it can tolerate pH values from 4 to 10 (Center et al. 2002). There was an increase noted in concentration of DO i.e., 6.3 to 7.1 mg.L^{-1}. Moorhead & Reddy (1988) reported that an increase in oxygen level after the culture of aquatic plants in domestic wastewater was due to exchange of oxygen from aerial tissue into root zone. The reason for the increase in DO level during the experimental period was growth of plants and higher production of oxygen through photosynthesis (Patel & Kanungo 2010).

CONCLUSION

The integrated system demonstrated (SF+CF+CBF with *E. crassipes*) that it was efficient for calcium removal. At lower salinity (2.5 ppt), efficient calcium removal can be obtained on 4th day 47.76 ± 0.83 mg.L^{-1} (mean ± SE) while for higher salinities (5 and 7.5 ppt) it required longer time period. By using this integrated system, significant calcium uptake was noted at 5 and 7.5 ppt on 6th day, which was 33.36 ± 1.41 mg.L^{-1} (mean± SE) and 23.13 0.68 mg.L^{-1} respectively. This system was also helpful in improvement of water quality characteristics. In first cycle at 2.5 ppt salinity, the initial concentration of TH, TA, K, CO_2 and pH was 833.33, 166.66, 2.7, 2.6 and 8.5 mg.L^{-1} which got decreased to 813.33, 144.66, 1.7, 0 and 8.2 mg.L^{-1} respectively at the end of the experiment. But an increase was noted in concentration of DO i.e., 6.3 to 7.1 mg.L^{-1}. Similar type of result obtained for other cycles.

The findings of this study will serve as a baseline for treatment of inland saline water to make it useful for various agricultural and aquaculture applications.

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REFERENCES

Akinbile, C.O. and Yusoff Mohd., S. 2014. Assessing water hyacinth (*Eichhornia crassipes*) and lettuce (*Pistia stratiotes*) effectiveness in aquaculture wastewater treatment. Int. J. Phytoremediation, 14: 201-211.

Azarpira, H., Behdarvand, P., Dhumal, K. and Pondhe, P. 2014. Wastewater remediation by using *Azolla* and *Lemna* for selective removal of mineral nutrients. Int. J. Bio. Sci., 4: 66-73.

Bennett, L.E., Burkhead, J.L., Hale, K.L., Terry, N., Pilon, M. and Pilon-smits, E.A.H. 2003. Analysis of transgenic Indian mustard plants for phytoremediation of metals-contaminated mine tailings. J. Environ. Qual., 32: 432-440.

CSSRI 2011. Central Soil Salinity Research Institute, Annual Report 2010-2011. CSSRI, Karnal, pp. 21-22.

Delgado, M., Bigeriego, M. and Guardiola, E. 1993. Uptake of zinc, chromium and cadmium by water hyacinth. Water Res., 27: 269-272.

Dipu, S., Anju, A., Kumar, V. and Thanga, S.G. 2010. Phytoremediation of dairy effluent by constructed wetland technology using wetland macrophytes. Global Journal of Environmental Research, 4(2): 90-100.

Ebbs, S.D., Kochian, L.V. 1998. Phytoextraction of zinc by oat (*Avina sativa*), barley (*Hordeum vulgare*), and Indian mustard (*Brassica juncea*). Environ. Sci. Technol., 32: 802-806.

FAO 2008. Land and plant nutrition management service. htpp://www.fao.org/ag/agl/agll/spush.

Foster, S.S.D. 1995. Groundwater for development - an overview of quality constraints. In: H. Nash and G.J.H. McCall (Eds.), Groundwater Quality. 17th Special Report, pp. 1-3, Chapman and Hall, London.

Gardea-Torresdey, J.L. 2003. Phytoremediation: Where does it stand and where will it go? Environ. Progress., 22(1): A2-A3.

Jana, S.N., Garg, S.K and Patra, B.C. 2004. Effect of periphyton on growth performance of grey mullet, *Mugil cephalus* (Linn.), in inland saline groundwater ponds. J. Appl. Ichthyol., 20: 110-117.

Khaiwal, R. and Vinod, K.G. 2007. Hydro-chemical survey of groundwater of Hisar city and assessment of defluoridation methods used in India. Environ. Monit. Assess., 132: 33-43.

Khan, F.I., Hussain, T. and Hejazi, R. 2004. An overview and analysis of site remediation technologies. J. Environ. Manage., 71: 95-122.

Klassen, S.P., Mc Lean, J.E., Grossel, P.R. and Sims, R.C. 2000. Fate and behavior of lead in soils planted with metal-resistant species (River birch and Smallwing sedge). J. Environ. Qual., 29: 1826-1834.

Lu, Q., He, Z.L., Graetz, D.A., Stofella, P.J. and Yang, X. 2011. Uptake and distribution of metals by water lettuce (*Pistia stratiotes* L.). J. Environ. Sci. Pollut. Res., 18: 978-986.

Meagher, R.B. 2000. Phytoremediation of toxic elemental and organic pollutants. Curr. Opin. Plant Biol., 3: 153-162.

Moorhead, K.K. and Reddy, K.R., 1988. Oxygen transport through selected aquatic macrophytes. Journal of Environmental quality, 17(1): 138-142.

Mor, S., Ravindra, K., Dahiya, R.P. and Chandra, A. 2006. Leachate characterization and assessment of groundwater pollution near municipal solid waste landfill site. Environ. Monit. Assess., 118: 435-456.

Mukul, Bishnoi and Shalu, A. 2007. Potable groundwater quality in some villages of Haryana, India: focus on fluoride. J. Environ. Bio., 28(2): 291-294.

Pathak, M.S., Appidi, K.R., Harikrishna, V., Suresh, D.D. and Komalsing, K.S. 2013. Inland saline aquaculture in India: status and prospectus. Int. J. Pharm. Chem. Bio. Sci., 3: 993-1000.

Patel, D.K. and Kanungo, V.K. 2010. Ecological efficiency of *Ceratophyllumdemersuml* in phytoremediation of nutrients from domestic wastewater. Int. Quart. J. Environ. Sci., 4: 257-262.

Prem Singh, Saharan, J.P., Kavita, S. and Sunita, S. 2012. Physio-chemical & EDXRF analysis of groundwater of Ambala, Haryana, India. J. Water Resour. Protect., 2(1): 68-75.

Reed, S.C., Crites, R.W. and Middlebrooks, E.J. 1995. Natural Systems for Waste Management and Treatment. 2nd ed. New York: McGraw-Hill.

United Nations Environment Program (UNEP) 1999. Global Environment Outlook 2000. UK: Earthscan.

Xiaomei, Lu, Maleeya, K., Prayad, P. and Kunaporn, H. 2004. Removal of cadmium and zinc by water hyacinth, *Eichhornia-crassipes*. Sci. Asia, 30: 93-103.