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Treatment of industrial waste water using Water hyacinth (*Eichornia crassipus*) and Duckweed (*Lemna minor*): A Comparative study

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Abstract

As we all know that water is essential to all forms of life and makes up about 70% of the human body weight. Due to the direct link of water quality with human welfare, the quality of water is of vital concern. Industrialization plays major role in the development of a country's economy. However, these plants and industries generate hazardous by-products and discharge them directly or partially treated into the environment which contaminates the surface water, ground water and soil causing a great threat to the life of human beings, animal and plants. In the present investigation an attempt has been made to identify the potential of water hyacinth (*Eichornia crassipus*) and Duckweed (*Lemna minor*) for the treatment of industrial waste water generated from Dehradun industrial area using phytoremediation technology on the basis of different physicochemical parameters such as pH, EC, DO, ORP, Salinity, TDS, BOD, COD, Hardness and Temperature. *Eichornia crassipus* shows maximum decrease in pH, TDS and COD and *Lemna minor* shows maximum decrease in EC, ORP, Salinity, BOD and TH. In case of DO maximum decrease was observed in control experiment. During the assessment period *Lemna minor* was found highly efficient in comparison to *Eichornia crassipus.* Both water hyacinth (*Eichornia crassipus*) and Duckweed (*Lemna minor*) shows maximum removal between 1st to 5th day of treatment but the removal goes down as the experiment proceeds towards the end as the retarded growth of plants was observed due to toxicity of accumulated pollutants inside the palnts.

Key words: ***Eichornia crassipus, Lemna minor, enormous investments, xenobiotics, engineering based remediation.***

Introduction

Water is essential natural element for all kinds of life present on the earth. Due to the direct link of water quality with human welfare, the quality of water is of vital concern. It is unique liquid, without which life is impossible (Bhutiani *et al.*, 2016). Industrialization due to release of untreated and partially treated effluent has become a great threat to the environment. There are a number of reasons the effluents are not treated properly by the industries. Among all one reasons is due to the lack of highly efficient and economic treatment technologies. Due to the rapid urbanization and industrialisation, wastewater has been continuously released in excess amount into the environment, causing significant impacts on human and wild life (Borkar *et al.*, 2013). Both industrial and household wastewater contains a large quantity of chemicals and biological matter that impose a great demand on the oxygen present in water and industrial effluents also contain that are directly harmful to human health and the ecosystem. In recent years due to the urbanization and industrialization, the rate of discharge of pollutant into the environment have been on the increase . During the last fifty years, in India the number of small and large scale industries has grown rapidly. Both in small as well as small scale industries do not have adequate effluent treatment facilities. Most of these defaulting industries are sugar mills, distilleries, pulp and paper mill and leather-processing industries. Small-scale industries, which cannot afford enormous investments in pollution control equipment due to their profit margins, are major producers of contaminated effluent (www.tappi.org/paperu/grow_up/great Career.htm. 2003). The use of phytoremediation technology for the treatment of industrial effluent has become

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popular due to its simplicity and low energy energy requirement in comparison to more sophisticated technology (Sooknah and Wilkie, 2004; Padmapriya and Murugesan, 2012; Kumar and Chopra, 2016, Kumar *et al.*, 2016). The term is a combination of two words, phyto (from Greek) which means plant and Latin word remediation which means to remove, which refers the use of plants based technologies to clean the contaminants (Cunningham *et al.*, 1997; Flatman and Lanza, 1998). Phytoremediation is an alternative or complimentary technology that can be used in place of and some timers in combination with mechanical conventional clean-up technologies that often require high capital inputs and labour and energy intensive. Phytoremediation is an emerging, clean, efficient, inexpensive ecological and environment friendly and solar-energy driven clean-up technology, based on the concept of using nature to cleanse nature (UNEP, Undated). Higher plants due to ability for the degradation and metabolism of many recalcitrant xenobiotics, can be considered as "green livers", which acts as an important sink for environment damaging chemicals (Schwitzguebel, 2000). It is a non-invasive alternative technology for engineering based remediation methods (Weis and Weis, 2004). The primary objective for the development of phytoremediation technologies is use the potential of macrophytes for low-cost remediation (Weis and Weis, 2004; Ensely, 2000). The present study has been taken to explore the phytoremediation potential of *Eichhornia crassipes* (*E. crassipes*) and *Lemna minor* (*L. minor*) in treatment of industrial waste water.

This followed the underlying objectives:-

1. To assess phytoremediation potential of *E.crassipes* and *L. minor* in treatment of industrial waste water.
2. To investigate effect of phytoremediation on physico-chemical characteristics of industrial waste water.

Materials and Methods

Collection of Industrial wastewater: Industrial wastewater was collected from industrial area located at Dehradun. Sampling was carried out in plastic container which was rinsed properly before collecting waste water. pH, EC, Salinity, ORP, DO, TDS and temperature was measured using Multipara meter system of model No. SensION+ MM 150 (Hach). Each time before taking the reading, calibration of the instrument was done. The measurements were taken at regular intervals of 3 days. Then the sample was carried to the laboratory and stored at 4^0C for further analysis. The various physico-chemical parameters including Hardness, BOD, and COD of the wastewater samples were analyzed using standard methods described by APHA, 2012; Trivedy and Goel, 1986; Khanna and Bhutiani, 2008.

Collection of Macrophytes: *E. crassipes* and *L. minor* was collected from a pond located near Ramnagar, Roorkee. Both the macrophytes were collected on the same day and brought to laboratory for experimental setup and plants was thoroughly washed with tap water followed by distill water and finally roots were rinsed with acetone to avoid any contamination.

Experimental Setup: Plastic tubs of round shape of 5litre capacity were selected for starting the experiment. Tubs were properly washed and dried with tissue. All the tubs were filled with the waste water. Container 1 was fixed as a control and it was without any plant. *E. crassipes* was grown in container 2, and *L. minor* was put in container 3. Samples were taken after every 5 days separately from all three tubs and were analyzed for pH, EC, DO, ORP, salinity, TDS, BOD, COD, Hardness and temperature. This assessment was carried out for 30 days at a regular interval of 5 days.

***Eichhornia crassipes* (Water hyacinth):** *E. crassipes* which belongs to family Pontederiaceae is one of the world's most prevalent invasive aquatic plants. Between water hyacinth and water-hyacinth. "Waterhyacinth" is the most standard spelling approved by the Weed Science Society of America. Approximately 10 to 100% of existing seeds was observed to germinate within a period of six months, with dry conditions promoting germination (Ueki and Oki, 1979). Nutrients and temperature are the strongest determinants for water hyacinth growth and reproduction (Wilson *et al.*, 2007). Salinity constraints generally limit water hyacinth establishment in coastal areas and within estuaries (Mangas-Ramirez and Elias-Gutierrez, 2004). Low temperatures and winter ice cover currently limit water hyacinth from spreading into cooler latitudes (Rodríguez-Gallego *et al.*, 2004). However, recent climate change models suggest that the distribution of aquatic invasive species is likely to expand in temperate regions (Hellmann *et al.*, 2008; Rahel and Olden, 2008). The distribution of water hyacinth is prevalent in tropical and subtropical water bodies because of high nutrient level due to agricultural runoff, deforestation, and insufficient wastewater treatment (Bartodziej and Weymouth, 1995; Brendonck *et al.*, 2003; Lu *et al.*, 2007; Martinez Jimenez & Gomez Balandra, 2007; Gibbons *et al.*, 1994). Prior research on water hyacinth's effects on water quality was performed by (Rommens *et al.*, 2003; Mangas-Ramirez and Elias-Gutierrez, 2004; Perna and Burrows, 2005; Giraldo and Garzon, 2002; Meerhoff *et al.*, 2003; Troutman *et al.*, 2007; Greenfield *et al.*, 2007). Water hyacinth also absorbs heavy metals (Tiwari *et al.*, 2007), organic contaminants (Zimmels *et al.*, 2007), and nutrients from the water column (Aoi and Hayashi, 1996). The capacity of hyacinth to absorb nutrients makes it a potential biological alternative to secondary and tertiary treatment for wastewater (Cossu *et al.*, 2001; Kumar *et al.*, 2017a, b).

***Lemna minor* (Duckweed):** *Lemna* belongs to family Lemnaceae is commonly known as duckweed. They commonly grow in stagnant or slow-flowing, nutrient-enriched waters throughout tropical and temperate zones. (Mkandawire and Dudel 2005a, 2005b; Les *et al.*, 2002). Anatomically, they are a diffuse unit known as a frond which is composed of leaflets and a root-like structure. They are also considered as model plant representative of higher plants for a large number of chemical and biogeochemical studies involving regulation of element assimilation in higher plants. Apart from phytoremediation studies *Lemna* spp. are among the most standardized test organisms in aquatic ecotoxicology (EPA 1996; DIN 2000; Eberius 2001; ISO 2001; OECD 2002).

Results and Discussion

Physico-chemical characteristics of waste water

Before starting the experiments, physico-chemical analysis of waste water was carried out in the laboratory. Waste water was analyzed for pH, temperature, electrical conductivity (EC), oxidation-redox potential (ORP), dissolved oxygen (DO), biochemical oxidation demand (BOD_5), chemical oxidation demand (COD), salinity, total dissolve solids (TDS), hardness (as $CaCO_3$) (Table 1).

Table 1. Physico-chemical characteristics of industrial waste water

S.No	Parameter	Unit	Value
1.	pH	-	9.6
2.	Electrical Conductivity (EC)	Micro S/cm	4009.0
3.	Oxidation-Redox potential (ORP)	mV	-151.9
4.	Total dissolved solids (TDS)	mg/L	2650.0
5.	Salinity	mg/L	2650.0
6.	Biochemical oxygen demand (BOD_5)	mg/L	356.26
7.	Chemical oxygen demand (COD)	mg/L	519.0
8.	Dissolved oxygen (DO)	mg/L	2.53
9.	Hardness (as $CaCo_3$)	mg/L	1.84
10.	Temperature	^0C	24.5

Effects of Macrophyte treatment on wastewater quality: Industrial waste water was treated with *E. crassipes*, and *L.minor* during the experimental period. Sample was filled in plastic containers (capacity -5.0 litres). Assessment of phytoremediation efficiencies of *E. crassipes, and L.minor* was carried out in 5 assessments periods (Table 2).

Effects of *E. crassipes* and *L. minor* treatments on industrial waste water quality: *E. crassipes, and L.minor* were grown separately in industrial waste water to assess the phytoremediation efficiency of selected plants in terms of changes in waste water parameters such as pH,

Table 2. Details of Assessment number and period for experimental period

S.No.	Assessment number	Assessment period
1.	First	01/05/15 to 05/05/15
2.	Second	05/05/15 to 09/05/15
3.	Third	09/05/15 to 13/05/15
4.	Fourth	13/05/15 to 17/05/15
5.	Fifth	17/05/15 to 21/05/15
6.	Sixth	21/05/15 to 25/05/15
7.	Seventh	25/05/15 to 29/05/15

temperature, electrical conductivity (EC), oxidation-redox potential (ORP), dissolved oxygen (DO), biochemical oxidation demand (BOD_5), chemical oxidation demand (COD), salinity, total dissolve solids (TDS) and hardness. Wastewater was analyzed at an interval of 5 days for 30 days and compared with control to assess the treatment potential of *E. crassipes, and L. minor*.

pH: During the study period when the effluent was treated with *Eichhornia* and *Lemna a* decrease in pH was observed. In control experiment a decrease in pH was observed from 9.60±0.03 to 8.2±0.01 from initial to final day of treatment. Maximum decrease of 0.31unit was observed between 1st to 3rd day of treatment whereas minimum decrease of 0.01unit was found between 13th to 17th day. During 30 days of treatment total 1.4 unit pH decrease was observed in control treatment (Fig 1 and Table 3). *Eichhornia* treatment resulted into change in pH from 9.6±0.04 to 7.6±0.03 throughout treatment days. Maximum decrease of 0.86unit was recorded between 1st to 5th day of treatment and minimum decrease of 0.01unit was recorded between 9th to 13th day of treatment. *Eichhornia* treatment leads to a total drop of 0.20unit in pH of wastewater. *Lemna* treatment showed a decrease in pH from 9.5±0.02 to 7.3±0.01. pH decrease was more or less similar during all 6 assessment periods during treatment days. pH decrease in this treatment ranged between 0.2 to 0.4 unit between successive assessment periods. *Eichhornia* treatment showed more pH decrease compared to *Lemna* treatment during treatment days. Similar findings were observed by Mahmood *et al.,* 2005 and Dipu *et al.,* 2011.

Electrical Conductivity (EC): During assessment period, EC varied from 4009.0±9.0 to 3998.0±5.0 µS/cm in control; 4007.0±4.0 to 2715.0±3.0 µS/cm in *Eichhornia*; and 4000.0±5.0 to 1965.0±5.3 µS/cm in *Lemna* treatment (Fig 2 and Table 3). Maximum decrease was recorded in *Lemna* treatment followed by *Eichhornia* and control. In control, EC showed a maximum decrease of 45.0 µS/cm during third assessment period, whereas minimum decrease of 17.0 µS/cm was found during 5th assessment period treatment. In *Eichhornia* treatment decrease in EC was fluctuated between 94.0 to 258.0 µS/cm among all assessment periods. Maximum decrease of 258.0 µS/cm was observed in third assessment period whereas minimum decrease of 94.0 µS/cm was recorded during last assessment period of the treatment. *Lemna* treatment provided better results in terms of EC decrease during entire treatment period. Maximum decrease of 368.0 µS/cm was observed during sixth assessment period. Similarly, Minimum EC reduction of 220.0 0 µS/cm was recorded in second assessment period (5th to 9th May, 2015). Average EC decrease of 6.8, 43.1 and 67.8, µS/cm/ day was observed in Control, *Eichhornia* and *Lemna* treatment.

Among all three treatments *Lemna* showed maximum reduction in EC followed by *Eichhornia* and Control. EC reduction occurs as result of nutrient uptake of macrophytes and it suggests that *Lemna* has a better nutrient uptake potential compared to *Eichhornia*. Electrical Conductivity reflects the amount of ions in waste water as in the phytoremediation ions are absorbed by plants growing in waste water, therefore a decrease in EC was observed during study period. The drastic decrease in electrical conductivity values by growing L. minor in paper mill effluent might be due to absorption of pollutants by plants. Similar kinds of reports were also obtained by Mahmood *et al.*, 2005; Selvarathi and Ramasubramanian 2010 on working with Eichhornia species. These authors reported 55.71%reduction of conductivity after 12 days of treatment period.

Oxidation-Redox potential (ORP): ORP increased from -151.9±-6.3 to -113.9±-4.4 mV in control, -151.9±-6.2 to -80.5±-2.3mV in *Eichhornia*, and -148.4±5.5 to -37.6±-1.5 mV in *Lemna* treatment during treatment days (Fig 3 and Table 3). ORP reduction rate was observed as 25.0, 47.0 and 74.7mV in control, *Eichhornia* and *Lemna* treatment respectively thorough the treatment days. Average ORP change of -1.3, -2.4 and -3.7 mV/day was observed in control, *Eichhornia* and *Lemna* treatment during treatment days. In control treatment, maximum ORP increase of -8.0 mV was observed in first, second and third assessment treatment each, while minimum increase of -3.0 mV was recorded on 6thassessment period. In *Eichhornia* treatment, maximum increase of -19.5 mV was recorded in first assessment period whereas minimum ORP increase -3.1 mV was observed in 6th assessment period. Increase in ORP value with time reflects the oxidation of organic matter present in waste water due to microbial and macrophytes.

Total dissolved solids (TDS): TDS concentration dropped from 2650.0±8.0 to 2252.0±7.0 mg/L in control, 2650.0±10 to 1192.0±8.0 mg/L in *Eichhornia* and 2678.0±5.0 to 1205.0±8.0 mg/L in *Lemna* treatment during treatment period. TDS removal of 15.0% was achieved by control treatment whereas 55.0% removal was observed in both *Eichhornia* and *Lemna* treatments during assessment period (Fig 4 and Table 3). Control treatment showed 37.0 to 87.0 mg/L of TDS removal between two consecutive assessment periods. Highest TDS removal was observed between 2nd and 3rd assessment period. *Eichhornia* treatment, showed high fluctuations in TDS removal between two consecutive treatment periods compared to control treatment. Maximum TDS removal of 469.0 mg/L was recorded in second assessment period whereas minimum removal of 1.0 mg/L was recorded in 7th assessment period. After 17th day of treatment TDS removal rate dropped down significantly because *Eichhornia* plant could not survive afterwards. *Lemna* treatment showed consistent results in terms of TDS removal between two consecutive assessment periods. TDS removal fluctuated between 191.0 to 227.0 mg/L between two consecutive assessment periods. TDS reflects the Total Dissolved Solids in the waste water which are up taken by plants and used for their own growth (Greongerg *et al.*, 1995), therefore we have observed a decrease in TDS with time during study period. A more or less similar trend was observed by Mishra *et al.*, 2013.

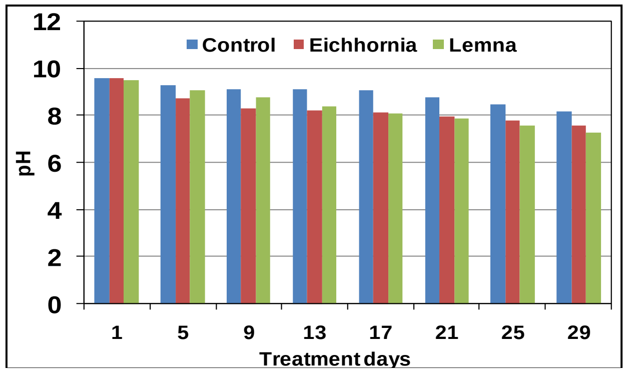

Fig 1. Changes in pH level in control, Eichhornia and Lemna treatment during study period.

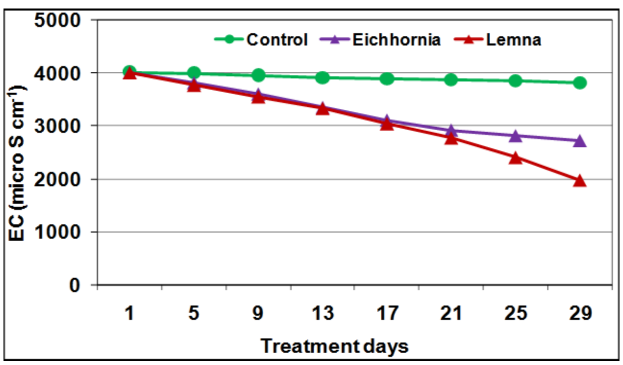

Fig 2. Changes in EC level in control, Eichhornia and Lemna treatment during study period.

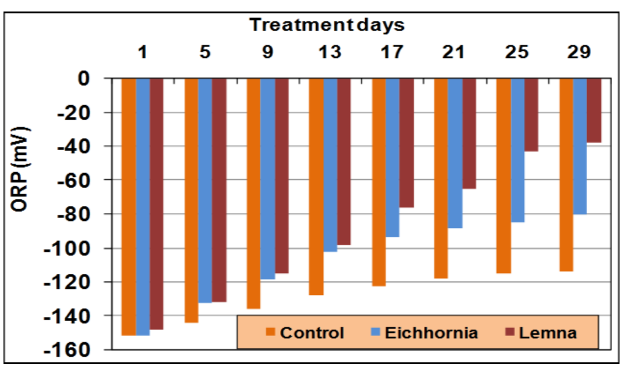

Fig 3. Changes in ORP level in control, *Eichhornia* and *Lemna* treatment during study period.

Salinity: Salinity represents all dissolved salts in the wastewater. Salinity showed a drop from 2650.0±7.0 mg/L to 2384.0±6.0 mg/L in control, 2450.0±9.0 mg/L to 1029.0±5.0 mg/L in *Eichhornia* and 2453.0±6.0 mg/L to 600.0±5.0 mg/L in *Lemna* treatment (Fig 5 and Table 3). In control treatment, highest salinity removal of 50.0 mg/L was achieved during first assessment period whereas lowest salinity removal was recorded during 7th assessment period. *Eichhornia* treatment showed large fluctuations in salinity removals during assessment periods (27.0-474.0 mg/L). Lemna treatment also provided better removals for salinity compared to Eichhornia treatment Removal efficiency fluctuated between 11-20% in assessment periods. Highest removal was achieved during 6th assessment period. Macrophytes have a tendency to absorb dissolved salts present in waste water through their roots, therefore there is a decrease in salinity during study period which reflects that macrophytes absorbed the dissolved salts efficiently from the waste water.

Biochemical Oxygen Demand (BOD_5): In control, *Eichhornia* and *Lemna* treatments BOD value showed a drop from 356.0±3.4 to 293.0±4.0, 356.0.0±5.3 to 231.0±4.2 and 361.0±3.7 to 174.0±4.5 mg/L respectively (Fig 6 and Table 3). Total BOD removal during treatment period was recorded as; 17.8% for control, 35.0% for *Eichhornia* and 51.8% for Lemna. In addition, Average BOD removal per day during assessment period was found as 2.1, 4.2 and 6.2 mg/L in control, *Eichhornia* and *Lemna* respectively. Highest BOD removal was achieved by *Lemna* followed by *Eichhornia* and control. Control treatment was resulted in maximum BOD removal of 15.0 mg/L during 7th assessment period and a minimum removal of 1.0 mg/L during 5th assessment period. *Eichhornia* treatment showed fluctuated BOD removal among different assessment periods; maximum of 33.3 mg/L between 1st to 5th day of treatment and minimum of 4.0 mg/L between 21st to 25th day of treatment. *Lemna* treatment also showed higher BOD removal during treatment period. BOD removal rate fluctuated between 17.0 to 46.0 mg/L between consecutive assessment periods. Higher removal rate (46%) was observed in 26th to 30th day of treatment. The duckweed contribution for the removal of organic material is due to their ability to direct use of simple organic compounds. BOD is the amount of oxygen required by microorganisms for degradation of organic matter present in waste water. The microbes convert organic matter into simpler nutrients which are further absorbed by macrophytes. A decrease in BOD was observed during study period which shows that microorganisms effectively degraded the organic matter present in waste water (Bhutianin et al., 2016).

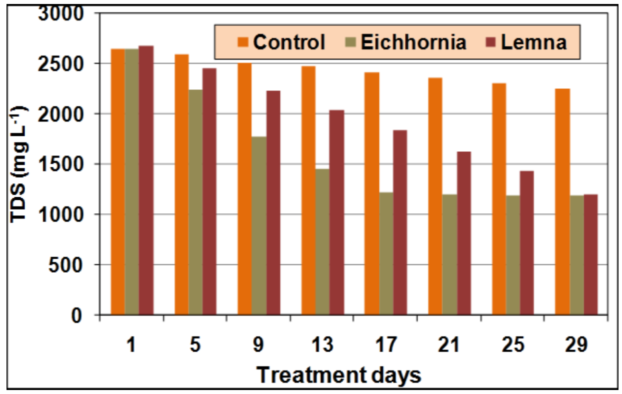

Fig 4. Changes in TDS level in control, *Eichhornia* and *Lemna* treatment during study period.

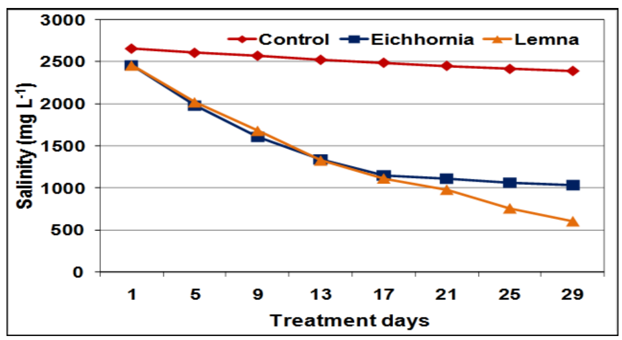

Fig 5. Changes in Salinity level in control, *Eichhornia* and *Lemna* treatment during study period.

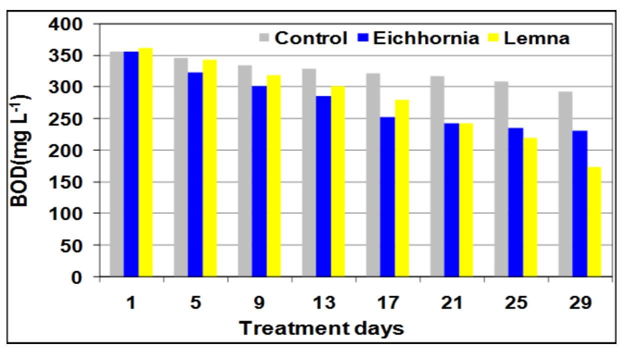

Fig 6. Changes in BOD level in control, *Eichhornia* and *Lemna* treatment during study period.

Chemical Oxygen Demand (COD): Chemical oxygen demand is amount of oxygen required to oxidize the organic and inorganic pollution present in waste water. Control treatment showed a decrease in COD value from 519.0±7.0 to 436.0±4.0 mg/L throughout the assessment period (Fig 7 and Table 3). COD removal rate in control treatment was recorded as 16.0%. Average COD removal was recorded as 2.8 mg/L/day. COD removal fluctuated between 7.0 to 25.0 mg/L within assessment periods. Maximum removal was recorded in 5th assessment period while minimum removal was observed in 7th assessment period. *Eichhornia* treatment provided a decrease in COD from 519.0±4.9 to 321.0±6.5 mg/L during treatment. Total COD removal in this treatment was observed as 38.2% and average COD removal was recorded as 6.6 mg/L/day during assessment period. Maximum COD removal of 49.0 mg/L was observed between 4th assessment periods. In *Lemna* treatment, COD value decreased from 516±7.0 to361±4.0 mg/L. A more or less similar trend in COD reduction was observed by Deshmukh *et al.*, 2013. Presence of plants in wastewater can deplete dissolved CO_2 during the period of high photosynthetic activity. This photo-synthetic activity increases the dissolved oxygen of water, thus creating aerobic conditions in wastewater which favour the aerobic bacterial activity to reduce the BOD and COD (Reddy, 1983).

Dissolved Oxygen (DO): In control, *Eichhornia* and *Lemna* treatment, dissolved oxygen concentration dropped from 1.84±0.02 to 1.24±0.01 mg/L, 1.82±0.11 to 1.32±0.03 mg/L and 1.83±0.04 to 1.43±0.06 mg/L respectively (Fig 8 and Table 3). Total DO decrease was assessed as 32.6, 27.5 and 20.6% in control, *Eichhornia* and *Lemna* treatment respectively during treatment period. Maximum DO drop was observed in control followed by *Eichhornia* and *Lemna*. Average daily decrease in DO was observed as 0.1, 0.04 and 0.02 mg/L /day control, *Lemna* and *Eichhornia* respectively. Microorganisms consume DO during degradation of organic matter in waste water, we have observed a decrease in DO level in all treatments, and however this decrease was less in the treatment of *Eichhornia* and *Lemna*. This suggests that during phytoremediation aquatic plants help in enriching the waste water with oxygen by photosynthesis process. The results favours the findings of Mangas-Ramirez and Elias-Gutierrez, 2004 and Perna and Burrows, 2005 but are opposites to Darr *et al.*, 2011 and Shah *et al.*, 2010.

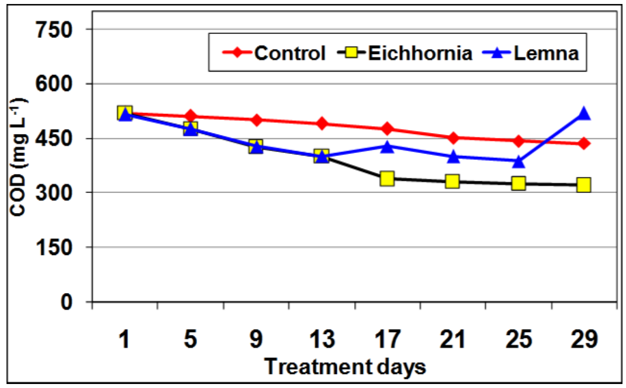

Fig 7. Changes in COD level in control, *Eichhornia* and *Lemna* treatment during study period.

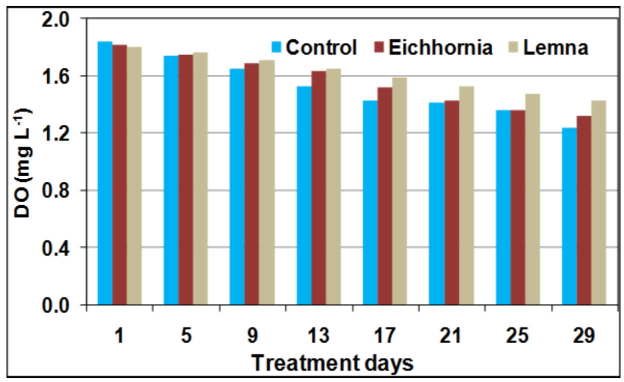

Fig 8. Changes in DO level in control, *Eichhornia* and *Lemna* treatment during study period.

Hardness (as $CaCO_3$): Hardness was decreased in all treatments during treatment period i.e. 150.0±4.5 to 111.0±4.2 mg/L in control; 152.0±3.6 to 106.0±4.6 mg/L in *Eichhornia* and 147.0±4.1 to 89.6.0±4.2 mg/L in *Lemna* treatment (Fig 10 and Table 3). Total Hardness removal was found highest (39.0%) in *Lemna* treatment followed by 30.3% in *Eichhornia* and 26.0% in control. Average hardness removal was observed as; 1.3 mg/L /day in control, 1.5 mg/L in *Eichhornia*, and 1.9 mg/L in *Lemna* treatment. Removal range between successive assessment periods varied from 3.0 to 8.0 mg L^{-1} in control, 3.0 to 9.0 mg/L in *Eichhornia*, and 3.4 to 11.0 mg/L in *Lemna* treatment. Similar trend of hardness removal was also observed by Fonseka and Amarasinghe, 2016 and Shah *et al.*, 2010.

Table 3. Showing the changes in physico-chemical properties of industrial effluent control treatment and after the treatment with *Eichhornia and Lemna.*

		pH	EC (μ s cm^{-1})	ORP (mV)	DO (mg L^{-1})	temp. (^{0}C)	TDS (mg L-1)	BOD (mg L-1)	COD (mg L-1)	Hardness (mg L-1)	Salinity (mg L-1)
1/5/2015	Control	9.6	4009	-151.9	1.84	25.3	2650	356	519	150	2650
	Eichhornia	9.6	4007	-151.9	1.82	25.3	2650	356	519	152	2450
	Lemna	9.5	4000	-148.4	1.8	25.3	2678	361	516	147	2453
5/5/2015	Control	9.29	3988	-144.0	1.74	25.9	2600	345	510	143	2600
	Eichhornia	8.74	3818	-132.4	1.75	26.3	2245	323	476	143	1976
	Lemna	9.1	3765	-132.3	1.76	26.2	2456	342	476	136	2015
9/5/2015	Control	9.13	3945	-136.0	1.65	28.4	2513	334	501	135	2565
	Eichhornia	8.3	3603	-118.9	1.69	28.3	1776	301	427	136	1603
	Lemna	8.8	3545	-115.2	1.71	27.7	2234	318	428	126	1675
13/5/2015	Control	9.11	3900	-128.0	1.53	25.3	2476	329	490	127	2517
	Eichhornia	8.23	3345	-102.2	1.63	24.4	1454	285	400	128	1335
	Lemna	8.4	3323	-98.4	1.65	24.4	2043	301	401	118	1323
17/5/2015	Control	9.1	3882	-123.0	1.43	25.6	2416	321	476	122	2482
	Eichhornia	8.14	3105	-93.6	1.52	25.7	1225	252.4	338	119	1145
	Lemna	8.1	3035	-76.4	1.59	25.9	1845	280	428	109	1109
21/5/2015	Control	8.8	3865	-118.0	1.41	24.4	2365	317	451	117	2445
	Eichhornia	7.96	2916	-88.3	1.43	23	1201	243	331	116	1103
	Lemna	7.9	2765	-65.4	1.53	23.7	1632	242	400	99	976
25/5/2015	Control	8.5	3845	-115.0	1.36	27.5	2312	308	443	114	2408
	Eichhornia	7.82	2809	-85.2	1.36	27.3	1193	235	325	111	1056
	Lemna	7.6	2397	-43.3	1.47	27.8	1432	220	388	93	754
29/5/2015	Control	8.2	3806	-113.9	1.24	28.3	2252	293	436	111	2384
	Eichhornia	7.6	2715	-80.5	1.32	27.5	1192	231.5	321	106	1029
	Lemna	7.3	1965	-37.6	1.43	27.1	1205	174	361	89.6	600

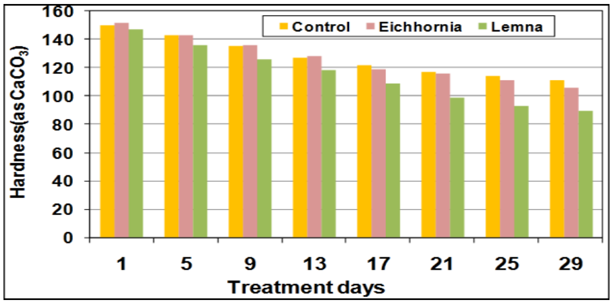

Fig 9. Changes in Hardness level in control, *Eichhornia* and *Lemna* treatment during study period.

Conclusion

Phytoremediation, an eco-friendly concept, involves the use of plants to clean-up the contaminated environments. Beside all the technologies present today's the use of foliage plants and trees may be the best means of improving the water quality. An interdisciplinary technological approach that used aquatic plants are appropriate for the treatment of wastewater due to their tremendous capacity of absorbing nutrients and heavy metals from wastewater to bring down the pollution load. Due to rapid growth on wide range of pH and tolerance to cold climate grow throughout the year but aquatic plants, such as water hyacinth, can only grow in summer, Duckweed appear to be better alternative for wastewater treatment .This study revealed that the duckweed (*L.minor*) showed a better lead removal than others from polluted water and may be helpful in research studies and phytoremedial approaches. Present study shows that phytoremediation is promising technology for treatment of low BOD industrial waste water. In *Eichhornia* treatment, maximum ORP drop of -19.5 mV was recorded in first assessment period. *Eichhornia* treatment showed large fluctuations in salinity removals during assessment periods (27.0-474.0 mg/L). Average BOD removal per day during assessment period was found as 2.1, 4.2 and 6.2 mg/L in control, *Eichhornia* and *Lemna* respectively. Highest BOD removal was achieved by *Lemna* followed by *Eichhornia* and control.

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