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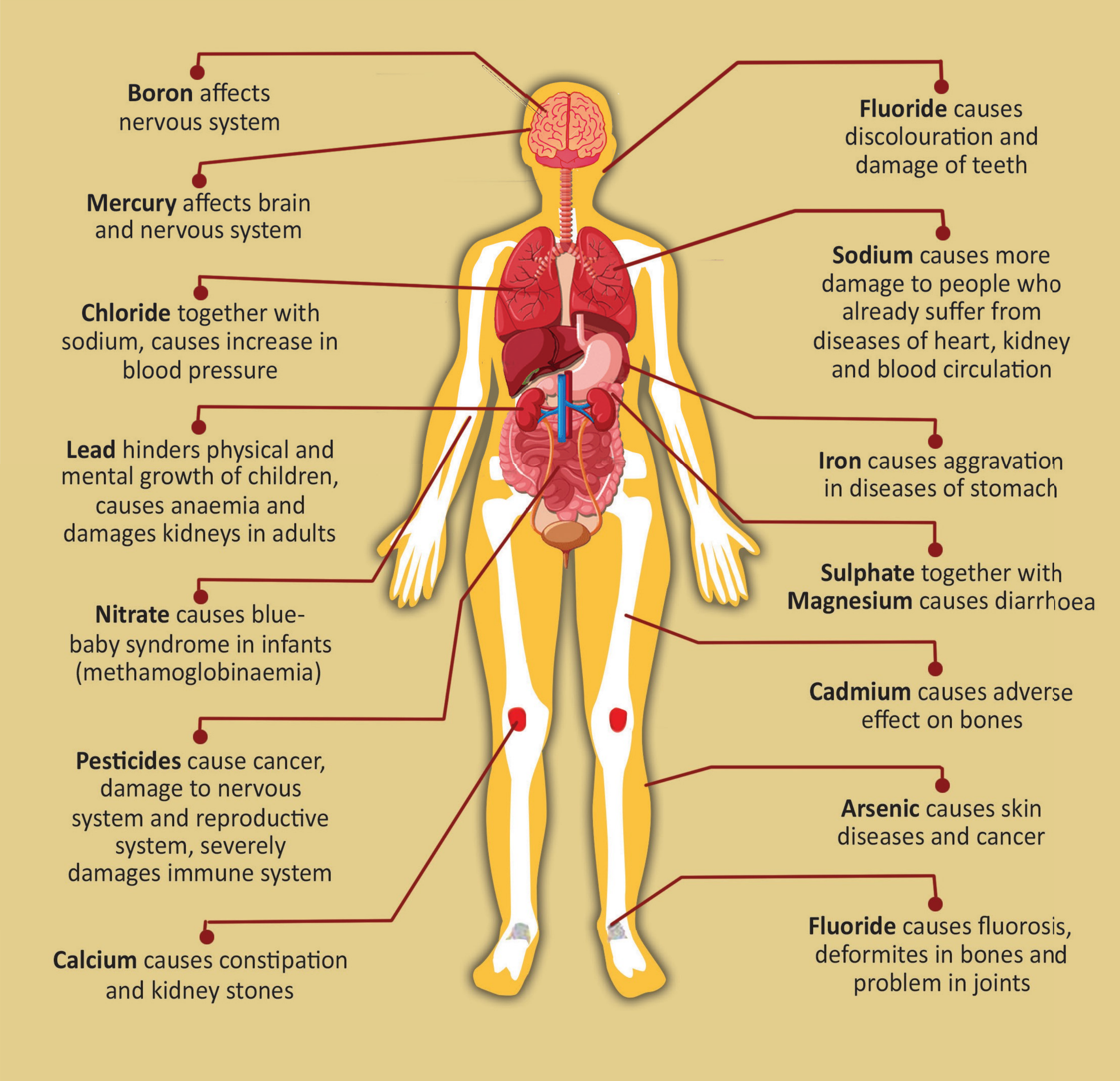

Adverse Effects of Drinking Water with Chemical Contamination
(To Know if water is potable or not, Get it tested in laboratory)

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INDEX

Efficiency of Aquatic Macrophytes for Treatment of Milk Processing Unit Effluent – A Case Study

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Abstract: *India is the world leader in milk production and contributes to about 22 percent of the world's production. Dairy industries generate a huge amount of wastewater during processing of milk. The effluent is characterized by high values of TDS, BOD and COD. In the present study an attempt was made to observe the efficiency of Eichhornia crassipes (*Mart.*)* Solms *and Lemna minor in individual and in combination for the treatment of milk processing unit effluent under laboratory conditions. Maximum removal efficiency was observed as 74.38 % of Chemical Oxygen Demand (mg/L), 73.94 % as of Biological Oxygen Demand (mg/L), 58.69 % as of Total Dissolved Solids (mg/L), 43.77 % of Total Kjeldahl Nitrogen (mg/L) was obtained with Eichhornia sp. and Lemna sp. combination, whereas among the monoculture macrophytes, Eichhornia sp. performed better than Lemna sp.. Thus a combination of Eichhornia sp. and Lemna sp. proved to be low cost sustainable method to treat dairy industry effluent.*

Key Words: *Dairy effluent, Eichhornia, Lemna, COD, BOD.*

1. INTRODUCTION

India continued to be first in the world in milk production with an estimated production of 187.7 million tonnes in 20118-19 and a share of about 22 percent in world production. There was an increase of around 6.5 percent against 176.3 million tonnes production in 2017-18 (NDDB Annual report, 2019). One of the main reasons behind this significant growth includes Operation flood launched in 1970s and later named as White revolution. Due to increase in population, this demand for milk is continuously increasing. Dairy industry also generates huge amount of effluent during processing of milk as water plays key role in the processing of milk and is also used in cleaning, washing, disinfection.

During processing it is converted into various products such as ghee, cream, butter, etc. and generates about 0.2 to 05 liters of effluent per litre of processed milk (Karadag *et al.*, 2015, Vourch *et al.*, 2008). Most of the times this effluent is disposed of into waterbodies or nearby surface without or little treatment which deteriorates the water quality and aquatic life of the receiving water bodies (Najafpour et al., 2008). Dairy wastewater contains high values of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), Total Suspended Solids (TSS) and other organic contents such as phosphates, nitrates, chlorides, sulphate with unpleasant odour and white colour (Cristian, 2010). These physico-chemical parameters are highly variable in dairy wastewater depending upon the quality of milk received.

High BOD and COD content in dairy effluent is due to the presence of organic content, carbohydrates, proteins and lipids (Demirel *et al*., 2005). Conventional wastewater treatment techniques requires large amount of capital for development of infrastructure and are also inefficient in treatment of such effluent due to high organic content. Natural systems using plants and microbes are gaining acceptance in recent years for treatment of industrial wastewaters. Phytoremediation serves to be an effective and cost efficient approach for treatment of dairy effluent and has been used extensively in recent years (Dipu *et al*., 2011, Tripathi *et al.*, 2004).

Characterization of phytoremediation wetlands is done on the basis of type of water-flow and differentiated into two types: Free surface water and subsurface water. Free surface water type treatment have advantages over the other, as it does not require supporting material like soil etc. and has greater efficiency due to their floating nature as it helps in increasing the surface area. Free floating macrophytes have been used for treatment of various industrial effluents like textile, pharmaceutical, municipal wastewater (Ajayi & Ogunbayio, 2012, Kumari & Tripathi, 2014). Therefore in the current study aquatic macrophytes, *Eichornia* and *Lemna* were selected to reduce the organic load of dairy effluent. Selected plants were abundantly available near the study site. The macrophytes were planted in monoculture (individual) and in combination to utilize the most of nutrients in the effluent.

Obejctive of the current study: 1) Characterisation of Milk processing unit effluent. 2) Comparison of efficiency of macrophytes planted in monoculture and mixed culture.

2. MATERIALS AND METHOD

2.1 Experimental Bio-Filtration Units

The study was performed in four experimental systems (Fig 2.1) of same dimensions 12 inches X 12 inches X 15 inches and were maintained in the open area of Ecological Modelling Lab, Department of Zoology and Env. Sciences, GKV, Haridwar. Each experimental unit has surface area of 0.0929 m^2, with a control maintained with only effluent without macrophyte and 2 units having individual plants (*Eichhornia sp. & Lemna sp.*) and 1 unit with combination of both the plants. Operational conditions of the experiment was maintained throughout the study period under the natural day-light regime.

2.2 Experimental Plants

Eichhornia crassipes (Mart.) Solms: Free floating macrophyte, around 40-50 cm in height, stem is short and long roots which are fibrous in nature, petiole is spongy.

Lemna sp.: simple free floating plant which grows mainly by vegetative reproduction, has pale green fronds.

The experimental macrophytes were collected from local pond in the nearby area of G.K.V. and were subjected to acclimatization in stock tanks containing bore-well water for 1 month. Number of plant and wet weight of each plant varied due to its shoot and root ratios and morphological characters. For the treatment study, almost entire surface area of the experimental setup was utilised. The experiment were performed in outdoor area of the department under the natural day light regime.

2.3 Sample Collection and Analysis

Sample was collected from ETP inlet of Parag Milk Processing Unit (PMPU) located in Meerut. Sampling was done monthly for a period of February 2015 to July 2015 in BOD bottles and 35L Jerry Cans. Approximately 15 L of effluent was utilized in each experiment. Sample was collected from the respective treatment sets after an interval of 07 days, 14 days, 21 days and 28 days of hydraulic retention time. Samples were analysed for Temperature, pH, Total Dissolved Solids (TDS mg/L), Total Suspended Solids (TSS mg/L), Biological Oxygen Demand (BOD mg/L, 3 days at 27^{o}C), Chemical Oxygen Demand (COD mg/L), Total Kjeldahl Nitrogen (TKN mg/L), as per the standard methods (APHA, 2013). To reduce the experimental error, treatment was repeated quarterly in April & July and was maintained in triplicate. Reduction in the values of physico-chemical parameters were used to calculate the efficiency of plants.

$$\textit{Removal efficiency (\%)} = \left(\frac{Ci - Cf}{Ci} \right) X\ 100$$

Where,
Ci = initial concentration of parameter
Cf = final concentration of parameter (after 28 days)

Statistical analysis: Kruskal-Wallis one way- ANOVA was used to find significant difference among the means, which was further tested with Dunn's multiple comparison test to assess the difference between treatment groups.

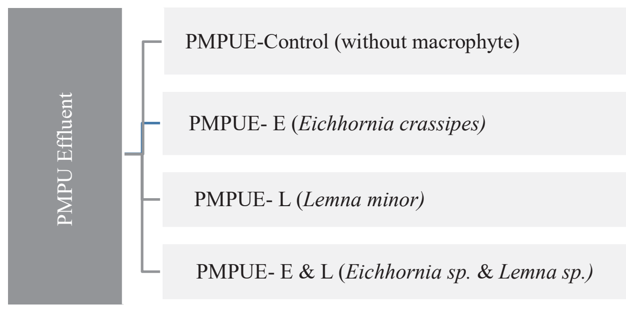

Fig 2.1 *Experimental workflow and bio-filtration units.*

3. RESULTS AND DISCUSSION

3.1 Characterisation of Effluent

Physico-chemical parameters of Milk Processing Unit effluent (Table 3.1) showed variations that may arise due to variation in the quality of milk received for processing. TDS, COD, BOD values of the effluent for disposal to surface water and inland sewers are given in Table 3.1. Physico-chemical parameters of milk processing unit effluent were reported by (Raghunath et al., 2016, Shete & Shinkar, (2013), Kotteswari et al., 2012). pH of effluent was near to neutral during the sampling period and in range of standards for wastewaters. pH values are primarily due to release of organic acids by microbes. TDS values in the effluent were above 500 mg/L and are composed of inorganic compounds including carbonates, bicarbonates, chloride etc. Variations in the TDS values may be attributed to the large volumes of biodegradable organic matter in the effluent. TSS values were above 150 mg/L and may be attributed to discharge of in-house cleaning activities. Variation in the TSS values leads to instability in the biodegradation of effluent (Slavov, 2017). BOD values during the sampling ranged more than 150 mg/L. Fats, lactose, milk proteins and also the by-products released after processing of milk add up to BOD requirements. High BOD values in dairy industry effluent was reported by various researchers (Karadeg et al., 2015, Bharati and Shinkar, 2013, Demirel et al., 2004).

Table 3.1 Physico-chemical characteristics of Milk Processing Unit Effluent

Parameter	Values (mean±sd, n =3)	CPCB Limits
Temp (°C)	28.86±1.55	*
pH	7.06±0.15	5.5- 9
TDS (mg/L)	580.32±3.38	---
TSS (mg/L)	183.72±2.53	100[a], 200[b], 600[c]
BOD (mg/L)	162.35±1.96	30[a], 350[b], 100[c]
COD (mg/L)	654.05±3.51	250
TKN(mg/L)	43.78±2.18	100

** shall not exceed 5°C above the receiving waters*
[a]:Inland surface water, [b]:Public sewers, [c]:Land for irrigation

3.2 Removal Efficiency of Macrophytes

Combination of macrophytes (*Eichhornia sp*. & *Lemna sp*.) removed maximum amount of all the studied pollutants (Table 3.2). For COD, removal efficiency ($p < .05$) of74.38 % was observed the combination plants, while *Eichhornia sp*. alone reduced 65.74 % of COD and *Lemna sp.* removed 52.83 % of COD from the dairy wastewater. Reduction in COD values of industrial effluent by using *Eichhornia sp.* was observed in various studies (Karadag et al., 2015, Nadais et al., 2010). In the control setup, COD was removed upto 15 %. Significant removal by combination experimental setup may be attributed to the rhizosphere degradation supported by extensive root system of *Eichhornia sp*. and maximum utilization of niche area by the short leaved plant, *Lemna sp*. Variation of removal efficiency in different treatment groups was also observed as a function of hydraulic retention time (Fig. 3.1).

Reduction in BOD values ($p < .05$) was observed as a maximum of 73.94 % by combination experimental plants, while *Eichhornia sp*. removed 67.68 % BOD & *Lemna sp*. removed 53.91 % of BOD from the wastewater. High rates of BOD reduction in municipal wastewater using combination of *Eichhornia sp.* and *Salvenia sp.* was reported by Kumari & Tripathi (2014).

TDS and TSS values were reduced 58.69 % and 54.92 % by *Eichhornia sp*. & *Lemna sp*. combination, while removal efficiency of individual plants was 51.20% & 37.35 % for TDS, 47.28 % & 29.69 % for TSS. Similar reduction rate

Table 3.2 Removal Efficiency of Different treatment group

PMPU	pH	Control-PMPU	PMPU -E	PMPU -L	PMPU -E&L	TDS (mg/l)	Control-PMPU	PMPU -E	PMPU -L	PMPU -E&L
-E		7.06±0.15	7.06±0.15	7.06±0.15	7.06±0.15		580.32±3.38	580.32±3.38	580.32±3.38	580.32±3.38
7 days		7.05±0.12	6.99±0.09	7.03±0.04	6.87±0.10		567.24±0.87	495.08±1.51	506.65±1.21	471.05±1.95
14 days		7.03±0.05	6.85±0.11	6.92±0.02	6.75±0.09		548.85±1.21	434.15±1.85	447.78±0.95	415.35±2.15
21 days		7.01±0.09	6.81±0.09	6.84±0.10	6.72±0.04		534.25±1.14	325.64±2.13	368.84±1.12	302.21±1.49
28 days		6.98±0.11	6.78±0.14	6.87±0.04	6.65±0.10		523.52±2.15	283.05±0.81	363.35±1.95	239.56±2.01
RE (%)		1.13±0.10	3.96±0.19	2.69±0.11	5.80±0.12		9.73±2.31	51.20±1.95	37.35±1.64	58.69±1.25
PMPU	TSS (mg/l)	Control-PMPU	PMPU -E	PMPU -L	PMPU -E&L	BOD (mg/l)	Control-PMPU	PMPU -E	PMPU -L	PMPU -E&L
-E		183.72±2.53	183.72±2.53	183.72±2.53	183.72±2.53		162.35±1.96	162.35±1.96	162.35±1.96	162.35±1.96
7 days		179.86±0.76	166.57±0.35	170.08±1.25	156.35±1.02		159.58±0.59	119.38±0.45	131.64±1.02	105.65±0.58
14 days		175.54±0.59	142.02±0.71	154.62±0.46	134.02±1.27		152.25±0.91	98.65±0.28	113.15±0.88	87.54±0.95
21 days		172.24±1.04	124.11±0.49	140.38±0.79	119.08±0.98		147.58±1.15	75.18±0.71	98.47±1.08	69.17±0.78
28 days		169.58±1.31	96.47±1.07	128.65±1.45	82.48±0.79		142.31±0.85	52.35±1.42	74.65±0.87	42.21±1.25
RE (%)		7.33±1.05	47.28±0.87	29.69±1.02	54.92±1.41		12.15±0.69	67.68±1.05	53.91±0.91	73.94±1.05
HRT	COD (mg/l)	Control-PMPU	PMPU -E	PMPU -L	PMPU -E&L	TKN (mg/l)	Control-PMPU	PMPU -E	PMPU -L	PMPU -E&L
Initial		654.05±3.51	654.05±3.51	654.05±3.51	654.05±3.51		43.78±2.18	43.78±2.18	43.78±2.18	43.78±2.18
7 days		621.41±1.89	520.12±1.25	585.65±0.95	498.51±0.18		42.15±0.87	39.54±1.02	41.25±1.21	37.58±1.38
14 days		589.32±1.09	434.05±0.89	475.21±0.81	398.74±0.93		40.28±0.82	34.01±0.52	36.57±0.49	32.14±1.02
21 days		567.84±1.21	341.05±0.95	381.01±0.97	274.51±0.38		39.17±0.49	29.25±0.15	32.14±0.34	27.08±0.48
28 days		545.21±1.26	224.05±0.85	308.47±0.71	167.54±1.08		38.59±0.76	27.85±0.43	30.23±1.21	24.74±1.30
RE (%)		16.63±0.91	65.74±1.18	52.83±0.94	74.38±0.28		12.29±0.92	36.70±1.20	31.29±0.76	43.77±0.72

HRT: Hydraulic Retention Time, RE (%): Removal Efficiency, Values are represented as mean±sd *(n=3)*

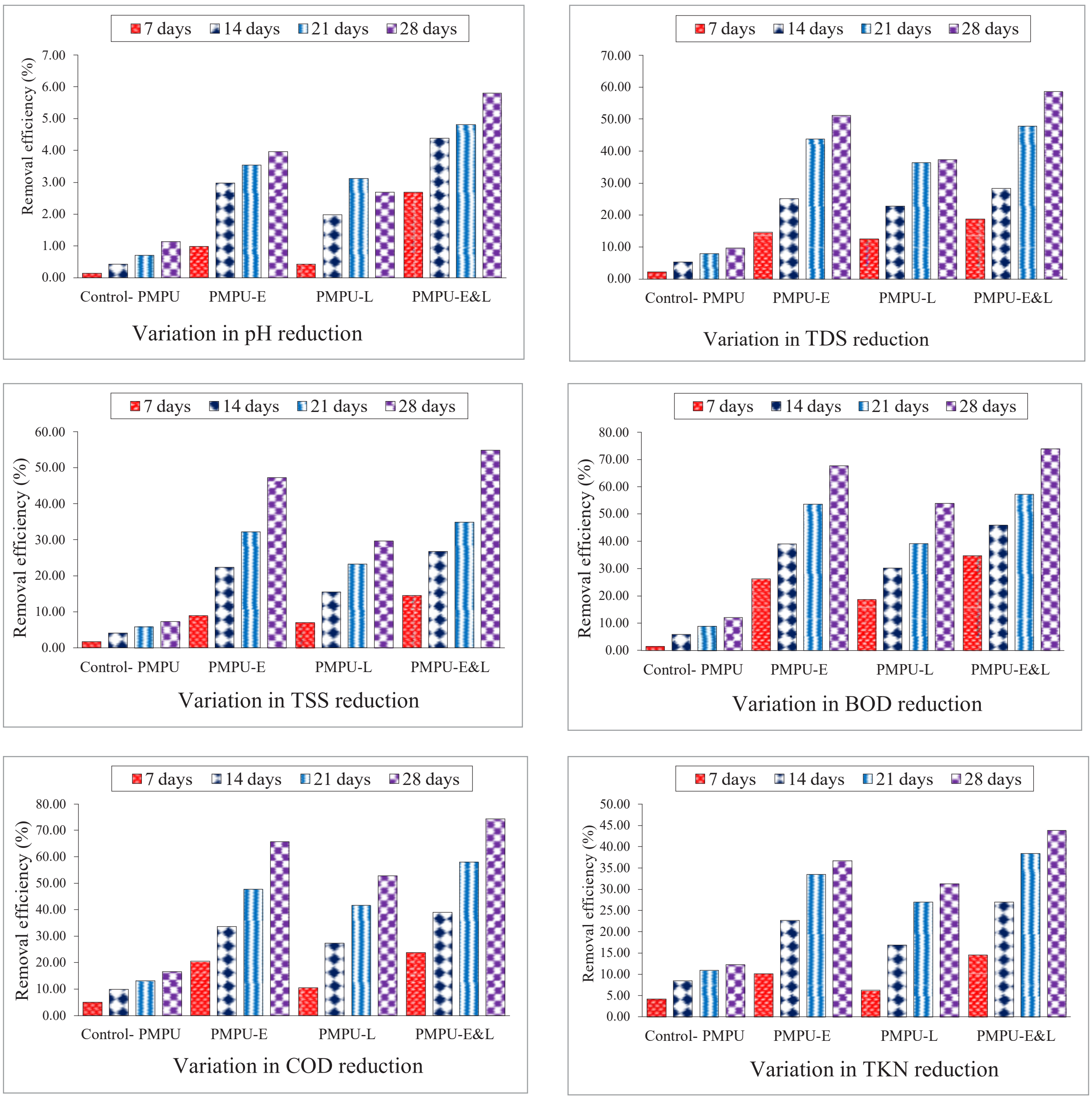

Fig. 3.1 Variations in Removal Efficiency among different treatment groups and as a function of HRT

(>50%) using *Eichhornia sp.* was reported for treatment of domestic sewage, effluent of petrochemical industries (Valipour et al., 2010, Ugya and Imam, 2015). Use of *Eichhornia sp.* is also reported (Ajayi & Ogunbayo, 2012) for TSS reduction in petrochemical effluent.

TKN content in the effluent was significantly removed ($p < .05$) by combination plants as well as the individual plants. Removal efficiency of 43.77 %, 36.70 %, 31.29 % was observed by *Eichhornia sp.* & *Lemna sp.* combination, *Eichhornia sp.*, *Lemna sp.* respectively.

Excellent removal capacity of combination treatment group (*Eichhornia sp.* & *Lemna sp.*) may be attributed to the increased surface area for removal of pollutants and also the synergistic association between the broad leaf (*Eichhornia sp.*) and the short leaf *Lemna sp.*). This association also augmented the increase in oxygen content which was due to extensive root system and played a significant role in removal of COD and BOD.

4. CONCLUSION

The present study resulted in successful application of aquatic macrophytes viz. *Eichhornia sp*. & *Lemna sp*. for the treatment of milk processing unit effluent over a retention period of 28 days. Among the different bio-filtration units combination of *Eichhornia sp*. & *Lemna sp*. proved to be the best in removal of pollutants and hence can be suggested for dairy wastewater treatment.

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