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Utilisation of free floating macrophytes for milk process unit wastewater treatment

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Abstract

With the rapid growth of industrialization, water pollution has increased tremendously. The inadequate wastewater management seriously affects the environment; phytoremediation provides a low cost alternative for the waste management. Most of the waste water discharged into water bodies, disturbs the ecological balance and deteriorates the water quality. Phytoremediation provides the low cost eco-friendly method for the wastewater treatment. These are frequently in use by the large scale organisations for the treatment of the wastewater of choice. These artificial wastewater treatment systems consisting of macrophytes are dependent upon various processes like microbial, biological, physical and chemical process for the treatment of the effluent. For the current study free floating aquatic macrophytes *Lemna sp.* and *Eichornia sp.* were used to treat the effluents from dairy factory, the biological oxygen demand and chemical oxygen demand of dairy effluent were reduced significantly after treatment with phytoremediation experiments.

Keywords: Dairy effluent, Macrophytes, BOD, COD, Lemna, Eichornia

Introduction

Among the industrial processes, the food sector has one of the highest consumptions of water. With respect to the dairy sector, manufacturing of the milk based products produces a huge amount of wastewater that accounts to about 2-3 times of the volume of milk processed (Monroy *et al.,* 1995, Strydom *et al*, 1995). India is one of the largest producers of milk and dairy products in the world with around 150 MT of production. However most of the dairy plants did not have proper wastewater and nutrient removal systems. Due to this the pollution potential is continuously arising, leading to attention in the field of treatment. The situation is particularly hazardous when Dairy wastewater is disposed untreated into the environment or used directly as irrigation water, to overcome this problem an efficient and cost-effective wastewater treatment technology is required. The dairy effluent is usually characterized by low heavy metal content and considerable levels of organic load that poses a great threat to the vicinity of the disposal site. Phytoremediation accounts for the use of plant species to decrease the pollution levels. There is large microbial population in the root area of the plants which plays a significant role in the treatment processes (Omil *et al*, 2007, Belyea *et al*, 1990). The major processes in the dairy processing plants that add up the effluent volume inlcudes washing, rinsing, cleaning the pipelines, utensils like milk cans and bottles, .The waste generated also includes milk solids, portions of spoiled milk and pollutants from other sources like packaging (Dipu et al, 2011, Thopmson & George,1998). Due to high organic load they cannot be disposed without harm since much of oxygen is used up in the water body and increases the Biochemical Oxygen Demand (Britz, 2006). One of the major reasons behind this organic load is the use of nitric acid and phosphoric acid which are used for the cleaning of pipes. So, efficient treatment is required prior to their disposal.

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Material and Methods

Area of Study

The wastewater samples were collected from Gangol Sahkari Dudgh Utpadak Sangh, Partapur, Meerut. It is also known as Parag Dairy and milk processing plant, located at 28°54'55"N and 77°38'49"E. The industries utilize about 4,500 m^3/day of fresh water. The treated and un-treated effluent discharge amounts was 2,350 m3/day i.e., about 52% of the total water used. This has not only created health hazards for local population but also resulted in deterioration of the agricultural yield.

Effluent Sampling and Preservation

Waste water quality was determined by estimating Physico-chemical characteristics of waste water in monthly interval for the period of year 2015-16. Waste water sample was collected by fabricated water sampler of 1L capacity and transported to lab, where analysis was done during the period of 2 days along with that effluent was also collected in 30 litres containers for the reactors. Preservation of waste water sample and methodology of analysis was referred from APHA, 2012. The samples were collected were analyzed for temperature, pH, Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), chlorides, Dissolved Oxygen(DO), Bio-chemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) values, chlorides, alakalinity, total hardness, calcium hardness, free CO_2..

Experiment Setup

Approximately 25 l of raw effluent from dairy plant was brought to the laboratory in plastic containers, and the experiments were set up in glass aquariums of size 25 × 25 × 30 cms. The plants used for the study were collected from local pond included floating wetland macrophytes Lemna and Eichhornia. The plants were placed in the aquariums covering the entire area of the aquarium. The experimental plants were initially subjected to stabilization in aquariums containing pond water for 14 days for acclimatization. Ten litres of the effluent were prepared (one without dilution and the other with 50% dilution) and then transferred to glass aquariums. For each experimental set, a dairy control was maintained with 10 l of raw effluent. Waste water quality was determined by estimating physical, chemical characteristics of effluent in monthly interval for the period of year 2015-2016. For the analysis of Phytoremediation potential of the macrophytes, physico-chemical analysis was done on 7 day, 14 day, and 21 day of treatment.

Results and Discussion

Physico-chemical Characteristics of Waste Water:

Temperature of waste water plays an important role in the life cycle of the organisms; however plants were generally adapted to this waste temperature. For the treatment purposes the maximum temperature that a plant can survive is 38 C. The pH value of waste water varied from 6.58 - 8.1, hydrogen ion concentration represents the alkaline or the acidic character of the wastewater, the effluent was generally alkaline throughout the study period. Phytoremediation generally decreases the turbidity levels that varied form 415 - 625 NTU in waste water. The result was in correlation with other studies done by Gottschall et al, 2007, Vymazal, 2011. Dissolved and suspended matter included Total Suspended Solids which ranged from 4.56 – 9.1mg/L in waste water. On the other hand, total dissolved solid values varied from 845.65 – 1154.56 mg/L in waste water.

Dissolved oxygen determines the oxygen availability to the organisms, lower DO values indicate the pollution levels and severe depletion of the oxygen levels leads to oxygen debt. The DO values ranged from 0.35-1.25 mg/L in waste water Biochemical Oxygen Demand indicates the pollution levels in a water bodies. The values ranged from 1154 g/L to 1397 g/L in the dairy wastewater. Free CO_2 values ranged from 69.12 g/L to 115.45 mg/L in the dairy effluent (Table 2 & 4). Chemical Oxygen Demand (COD) typically shows the organic and inorganic contamination. The COD ranged from 2248 mg/L to 2958 mg/L in the dairy effluent. Alkalinity, Phenolphthalein alkalinity was estimated nil, hence, the value of total alkalinity was similar to the methyl orange alkalinity determined. Total alkalinity values were varying from 195.65 mg/L to 376.98 $CaCO_3$/L. Dairy stream wastewater characterized by Sooknah & Wilkie, 2004 was similar to the trend observed in the study period. Total hardness was found to vary from 168.47mg/L-315.24 mg $CaCO_3$/L for the effluent in the study period. Calcium hardness was ranged from 101.30-198.06 mg $CaCO_3$/L. Sulphate values determined in mg/L ranged from 115.35-198.21 mg/L in the dairy effluent in the study period. Due to the cleaning practices, chloride content increases in the wastewater. Chloride values ranged from 42.51-95.41 mg/L (Table 1 & 3)

Treatment efficiency of the macrophytes:

Experimental studies performed with Eichhornia sp.

When treated with Eichhornia, it was found that the pH decreases from 8.05 to 7.54 in case of undiluted effluent and from 7.89 to 7.71 in diluted effluent. Turbidity was found to decrease in undiluted effluent (69.74%), but after dilution, turbidity also decreased (59.78%).

Table 1: Monthly variation in Physico-chemical parameters during 2015

Parameters Months	Temp. (^{o}C)	pH	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)	DO (mg/L)	BOD_5 (mg/L)	COD (mg/L)	$F.CO_2$ (mg/L)
Jan	26.7	7.85	558	7.24	845.65	1.25	1165	2285	89.45
Feb	28.9	8.05	435	7.59	959.58	0.95	1265	2657	69.78
March	31.4	7.84	525	8.54	956.40	1.05	1205	2354	79.24
Apr	33.9	7.26	585	9.1	1045.40	0.92	1154	2248	85.45
May	35.6	6.74	540	8.65	1009.65	0.73	1258	2415	69.12
Jun	35.9	7.50	469	4.56	1181.32	0.68	1325	2648	73.58
July	34.5	7.91	439	6.85	1085.27	0.53	1250	2958	97.54
Aug	32.1	7.60	510	5.64	1050.92	0.35	1385	2954	115.45
Sep	29.8	6.58	528	5.95	1025.14	0.64	1246	2879	108.25
Oct	27.5	6.91	595	6.58	1015.59	0.49	1397	2957	98.45
Nov	28.4	7.12	625	6.98	898.47	0.57	1284	2847	104.27
Dec	26.4	6.57	547	7.14	992.64	0.61	1258	2795	101.48
Mean	30.93	7.33	529.66	7.07	1068.50	0.73	1266	2666.4	91.01
± SD	3.46	0.54	59.47	1.31	158.60	0.26	75.30	274.41	15.62

Table 2: Monthly variation in Physico-chemical parameters during 2015

Parameters Months	Alkalinity (mg/L)	Total Hardness (mg/L)	Calcium Hardness (mg/L)	Sulphate (mg/L)	Chloride (mg/L)	Nitrogen (NO_3) (mg/L)	Total Phosphate (mg/L)
Jan	205.65	168.47	144.28	121.25	75.64	8.24	23.45
Feb	248.95	195.74	175.54	144.32	42.51	8.15	18.45
March	214.54	225.48	101.25	187.73	95.48	9.49	25.57
Apr	195.65	315.24	198.48	168.25	76.14	12.48	32.56
May	315.84	241.54	149.54	164.22	57.56	12.58	19.57
Jun	365.45	281.24	175.24	145.45	81.24	9.68	25.87
July	376.98	247.67	148.25	158.85	76.51	10.21	27.15
Aug	315.54	201.24	115.24	198.21	95.41	11.28	30.57
Sep	298.4	219.25	125.48	184.25	84.22	12.54	29.47
Oct	289.74	254.24	198.57	171.45	69.24	11.52	28.63
Nov	208.45	211.45	142.27	115.35	84.67	12.56	25.24
Dec	195.84	265.32	184.69	124.48	73.68	13.84	29.84
Mean	269.25	235.57	154.90	156.98	76.03	11.05	26.36
± SD	66.33	40.53	31.90	27.20	14.89	1.87	4.30

Table 3: Physico-chemical parameters of the effluent when treated with *Eichhornia* sp

Parameters analysed	Retention time	Dairy control	Diluted effluent	Undiluted effluent
pH	Initial	7.85	7.43	7.85
	7 days	7.82	7.24	7.68
	14 days	7.71	7.12	7.56
	21 days	7.69	7.10	7.54
TDS (mg/l)	Initial	1,145.65	725.08	1,145.65
	7 days	1,058.58	682.24	1046.54
	14 days	1,021.58	418.89	678.12
	21 days	988.59	326.94	509.46
TSS (mg/l)	Initial	7.24	3.24	7.24
	7 days	7.12	2.43	6.54
	14 days	6.84	2.24	6.21
	21 days	6.54	1.94	5.84
Turbidity (NTU)	Initial	558	412	558
	7 days	534	342	501
	14 days	523	235	346
	21 days	512	195	292
BOD_5 (mg/l)	Initial	1,165	725	1165
	7 days	1,050	405	759
	14 days	1,012	289	507
	21 days	1,003	154	354
COD (mg/l)	Initial	2,285	1,485	2,285
	7 days	2,212	782	1,454
	14 days	2,108	559	924
	21 days	1,854	254	465
Phosphates (mg/l)	Initial	23.45	8.2	23.45
	7 days	18.4	6.6	17.8
	14 days	17.9	5.2	14.3
	21 days	17.5	3.9	10.2
Chlorides (mg/l)	Initial	75.64	62.41	75.64
	7 days	64.12	58.98	65.52
	14 days	52.43	49.54	59.60
	21 days	46.21	29.21	42.21
NNO_3 (mg/l)	Initial	8.24	3.92	8.24
	7 days	8.21	3.75	4.98
	14 days	8.08	3.64	4.62
	21 days	8.04	3.58	4.34

Table 3 Physico-chemical parameters of the effluent when treated with Lemna

Parameters analysed	Retention time	Dairy control	Diluted effluent	Undiluted effluent
pH	Initial	7.85	7.89	8.85
	7 days	7.82	7.71	7.72
	14 days	7.71	7.59	7.61
	21 days	7.67	7.46	7.58
TDS (mg/l)	Initial	1,145.65	725.08	1,145.65
	7 days	1,058.58	672.24	1,021.25
	14 days	1,021.58	541.29	860.21
	21 days	988.59	398.98	529.72
TSS (mg/l)	Initial	7.24	4.45	7.24
	7 days	7.12	3.96	5.98
	14 days	6.84	3.71	4.68
	21 days	6.54	2.58	3.35
Turbidity (NTU)	Initial	558	353	558
	7 days	534	295	495
	14 days	523	225	352
	21 days	512	102	234
BOD_5 (mg/l)	Initial	1,165	795	1,165
	7 days	1,050	484	678
	14 days	1,012	275	560
	21 days	1,003	195	472
COD (mg/l)	Initial	2,285	1,159	2,285
	7 days	2,212	1,014	1,488
	14 days	2,108	716	1,021
	21 days	1,854	429	754
Phosphates (mg/l)	Initial	23.45	7.28	23.45
	7 days	18.4	5.56	13.6
	14 days	17.9	3.57	9.42
	21 days	17.5	1.95	6.95
Chlorides (mg/l)	Initial	75.64	62.41	75.64
	7 days	64.12	58.81	68.15
	14 days	52.43	49.42	62.35
	21 days	46.21	38.46	59.62
NNO_3 (mg/l)	Initial	8.24	3.92	8.24
	7 days	8.21	3.76	4.95
	14 days	8.08	3.58	4.72
	21 days	8.04	3.49	3.98

Total solids showed a pronounced reduction in both diluted and undiluted Effluents. The removal capacity was quiet high for BOD5 (83.08%) and COD (82.53%) in undiluted effluent. In case of diluted effluent, 79.49 and 80.48% reduction was observed with BOD5 and COD, respectively.

Experimental studies performed with Lemna sp.

The pH of the effluent decreased slightly. However for the control, the decrease was 0.49% only. Due to low mass and size the turbidity was not as efficient, in the undiluted effluent it showed the reduction from542–179 NTU (66.97%). TDS of undiluted effluent showed a high level of decrease (59.37%) from the initial. Contrastingly, the well water control value increased from 17.06 to 19.14 mg/l. In undiluted and diluted effluent, BOD_5 reduced by 68.31% and 80% from initial level after 28 days. However, in dairy control, the reduction was only 1.23%. COD in undiluted effluent was reduced by 72.12% from initial level after 15 days.

Table 5: Potential of tested plant species in removing the pollutants after 21 days from undiluted effluent.

Parameters	Dairy effluent	Eichhornia	Lemna
pH	7.85	7.54	7.56
TDS (mg/l)	1,145.65	509.46	559.72
Total suspended solids (mg/l)	7.24	6.54	3.39
Turbidity (NTU)	558	164	194
BOD_5 (mg/l)	1,165	220	472
COD (mg/l)	2,285	510	754
Phosphates ((mg/l)	23.45	11.2	6.95
Chlorides (mg/l)	75.64	52.6	59.62
NNO3 (mg/l)	8.24	3.22	3.98

Conclusion:

The treatment strategy was successful in reducing the organic load of the waste water. After the treatment period of 21 days the macrophytes were removed and analysed for the phytoextraction efficiency. This study resulted in the utilisation of phytoremediation for the treatment of dairy sector pollutants. Eichornia was more efficient in the treatment studies (Table 5). There is need to understand the underlying mechanism of the removal of pollutants, there are certain processes that play a significant role in the removal of COD and BOD, these include root zone area that are associated with the micro-organisms for their degradation and decomposition. The extracted nutrients like phosphates and nitrates typically are important in the growth and development of the plant species but in excess these may potentially harm the plant tissues and along with that it also harms the groundwater near the site of disposal, so dairy effluent must be treated prior to the disposal. In this study Eichornia proved to be excellent source for the treatment purposes for dairy effluent. Extensive root area in this plant helps in the removal of the contaminants leading to the utilisation of macrophytes for such purposes.

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