DEVELOPMENT OF A SUSTAINABLE LOW COST ECO FRIENDLY REED BED SYSTEM FOR TREATING DAIRY EFFLUENT

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Abstract: Dairy is an industry where milk is processed and various milk products are manufactured. Dairy, in which the cleaning silos, tanks, heat exchangers, homogenizers, pipes and other equipment, engenders a large amount of effluent with a high organic load. The effluents are organic compounds that pollute the environment and are hazardous to the living beings. The BOD and COD of effluent water were found higher than the acceptable limits. So, as a result, the ill effects of these effluents have caused severe damage to the environment. The damage is increasing further due to a rapid increase in industrialisation. To resolve this issue, an attempt was made to treat the effluent coming out of the dairy industry by reed bed wastewater treatment technique. Random samples were collected and their physico-chemicals characteristics examined to access the extent of pollution in the wastewater. The BOD and COD of treated wastewater were found to have decreased significantly. The wastewater obtained after the treatment was found to be suitable for irrigation purpose. The BOD and COD removal efficiency was observed as 72.91 and 62.15 percent respectively.

Keywords: Reed Bed, Dairy, Industry, COD, BOD, Wastewater.

1. Introduction: Dairy industry is one of the major food industries in India, and India ranks first among the maximum milk producing nation [6].The dairy industry is a major source of milk products processing waste water [2]. The milk industry generates wastewater in the range of 3.739 to 11.217 Million m^3 annually; this is 1 to 3 times the volume of milk processed [4]. Waste water generated in milk processing unit are mostly during pasteurization, homogenization of fluid milk and the production of products such as butter, cheese, milk powder etc. Most of the milk processing unit use Clean in Place (CIP) system which pumps cleaning solutions through all equipment in the following order as caustic solution (sodium hydroxide) wash, water rinse, acid solution (phosphoric or Nitric acid) wash, water rinse, and sodium hypo-chlorite disinfectant. These chemicals eventually become a part of waste water [5]. Large amount of water is used to clean the processing plants and the resulting waste water may contain detergent, sanitizers, base, salts and organic matter, depending upon source [1].

Waste water volume and strength fluctuate widely every day due to differences in production. The data of effluent or waste water volume per unit of product processed (liters of waste water/kg product) and waste water concentration (mg L^{-1}) and weight of waste generated per unit of product processed (g of waste/kg of product) keeps changing [3].

Climate of the area and production of the dairy plant are two major causes for changing waste water character. This variation is not only from one industry to another dairy industry but also from season to season and even hour to hour. The land receiving the waste water is affected and the soil quality and soil structure and part of waste water can also leach is to underlying groundwater and affect its quality. The problem is more serious, when it concerns waste water discharge before treatment from dairy or milk processing industry. It is one of the largest sources of industrial effluents in many countries like Europe and India. A typical European dairy factory generates approximately 50 m^3 waste water daily with considerable concentration of organic matter (fat, protein and carbohydrates) and nutrients mainly (Nitrogen and Phosphorous) originating from the milk and the milk products [7] .

The annual cost of treatment and disposal for the typical plant appears to be in the order of a million dollars. Disposal of untreated water is rapidly becoming a major economic and societal problem for the dairy processing industry [1]. Almost all the dairy factories are facing the problem of wastewater disposal and utilization of the waste water. Disposal of waste water into rivers, land, fields and other aquatic bodies, without or with partial treatment, in crude tanks, will result in serious problems to health and hygiene.

The above facts have caused engineers to search for a cost effective, de-centralized and environmentally safe way to control the pollution of fresh water bodies. Alternate systems designed to mimic nature *viz.,* constructed wetlands (Reed Beds) are operating around the world very effectively. Wide range of wastewater has been treated in these eco-friendly systems and reused successfully for irrigation as well as safe disposal to the fresh water bodies.

2. Materials and Methods:

2.1 Construction of reed bed: The reed bed system was constructed as per the design dimensions in the following order.

i) Site preparation: The site was prepared such as by cleaning vegetation, cleaning the site, rough grading and berm construction was carried to give initial shape to site.

ii) Basin excavation: The required dimension 12 m length, 3m breadth, 0.80 depth was marked and excavated.

iii) Basin shaping and lining: Basin shaping was carried out in order to stabilize the side slopes of the basin. The side shaping carried out by keeping the side slope as 1:1. The mixture of lime and fine sand in water was used as a low cost lining material (1:5). This was applied on the side slopes of the basin to arrest side seepage. The thickness of lining was kept as 5 cm.

iv) Influent conveyance channel: This is a channel which conveys dairy wastewater to the inlet zone of the reed bed. In present study a diversion channel was constructed for diverting the waste water from the main dairy wastewater drain. The channel capacity was kept such that it should carry the proposed peak discharge (2 m^3/d). 4 m long semi-circular, earthen channel was excavated to suit the site requirement. Uniform gradient was provided while laying the channel to use gravitational force for the wastewater flow.

v) Inlet zone: Inlet zone length was kept as 1 m. The width was same (3 m) as the basin. This was separated from filter zone with the help of brick wall and also the brick wall helps in initial settling of impurities. An influent pipe (PVC) of 7.5 cm diameter was fitted at the entrance of inlet zone so that it releases influent from conveyance channel to inlet zone. Four orifice openings were kept in the wall along its length at height of 0.6 m from bottom to divert the wastewater from inlet zone to the filter zone.

vi) Filter zone: The length of the planted filter zone was kept as 12 m of the width as 3 m as per the design calculations. The depth of basin was 0.80 m. The selected filter material i.e., pebbles, gravel and fine sand were spread uniformly over the bed in the layers of 0.22 m, 0.22 m and 0.1 m, respectively so as to get total filter bed thickness of 0.54 m. The quantities of pebbles, gravel and soil required for filter bed were 6.49 m^3, 6.49 m^3 and 2.95 m^3 respectively. The free board of 0.28 m was kept to account the sediment deposition as time passes. At the inlet zone side, filter was supported by brick wall and on opposite side, it was supported by a solid Galvanised Iron mesh. While filling the filter materials, vertical pipes of 90 mm diameter and 0.45 m length were inserted in the bed at 5 m interval. These pipes serves dual functions of oxygen diffusion to the filter-media and as a sampling stations.

vii) Outlet zone: The main purpose of this zone is to achieve proper drainage of treated water to the effluent reservoir. The length of this zone was kept as 1 m to accommodate the drainage system. The width was kept as 3 m. At the bottom of this zone, a perforated pipe of length 2 m and diameter 7.5 cm was installed. This pipe was connected to the effluent reservoir by the same diameter blind pipe with the help of *'Tee joint'*. The drainage pipe was firmly supported with the help of cement blocks. This tank was filled with broken bricks up to a depth of 0.15 m. Thus for outlet zone the quantity of broken bricks required was 0.45 m^3.

viii) Effluent reservoir: A concrete Tank was constructed as an effluent reservoir. Though the reed bed system was designed to handle the worst quality of wastewater (i.e. of higher BOD_5) it could also handle higher quantity of relatively the better quality of wastewater (i.e. low BOD_5). Also for easy effluent handling flexibility by giving some extra allowance, the effluent reservoir of 15 m^3 size was constructed.

The effluent pipe from the outlet zone bottom was entering the tank at a height of 0.6 m from top of the tank. A pipe was connected to this outlet pipe end with the help of *Tee joint*. This is necessary to maintain the recommended constant water level in the filter zone as well as to achieve required hydraulic gradient for gravity flow of wastewater. On the third end of *Tee*, one pipe piece with end cap was fixed. This was provided to drain out the filter completely after each 4 to 5 months to clean the filter.

ix) Identification of wetland vegetations: Macrophyte is one of the major parts of reed bed system which affect the treatment efficiency. For this study Cattail (*Typha angustifolia*) was chosen according to literature recommendations and local availability. These plants were identified in the water stream running near the lake of Perur, about 2 km from the project site.

x) Transplanting the vegetation on the filter bed: The selected rhizomes of Cattail (*Typha angustifolia*) were planted in the native soil layer on the filter bed in a depth of 10 cm and spacing of 0.5 m x 0.5 m in staggered manner. A buffer of 2 m from inlet zone was kept for proper maintenance and to prevent initial clogging.

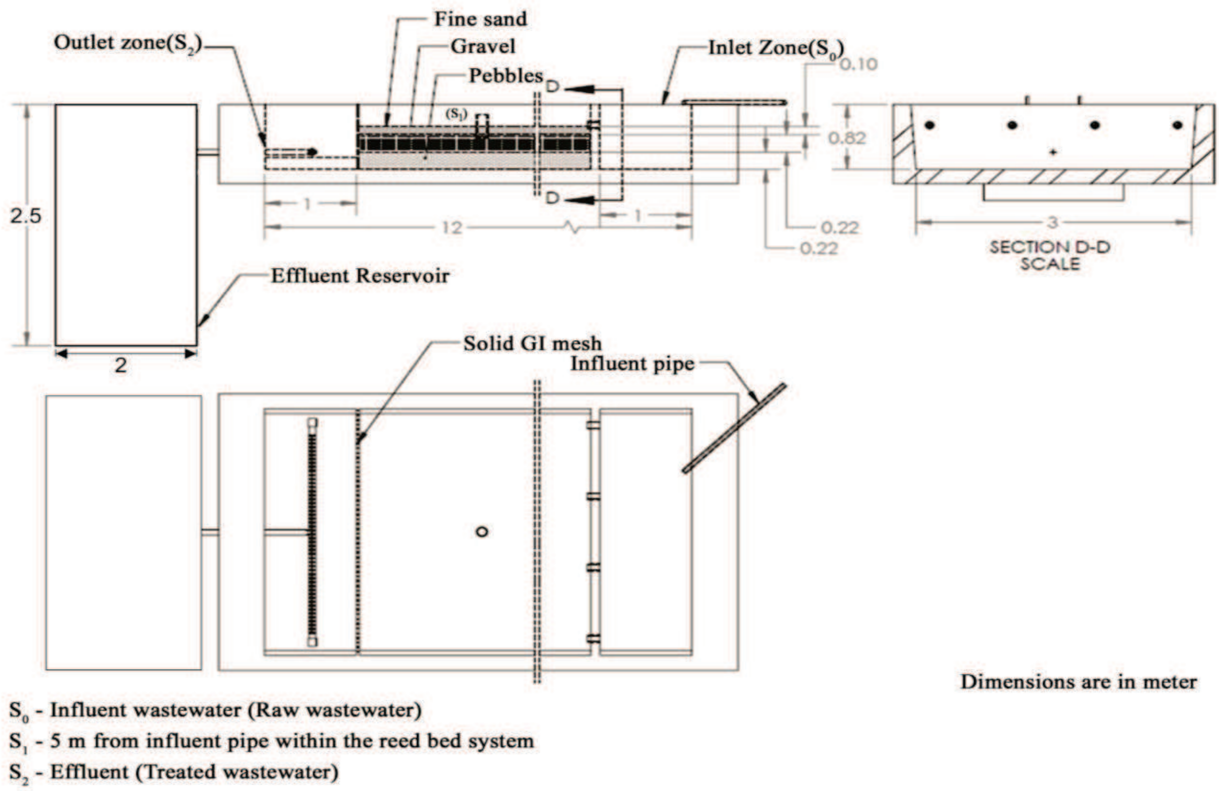

Figure 1 Reed bed System

xi) Water quality monitoring in the reed bed: To evaluate the performance of reed bed system, the water samples were collected from one fixed sampling points in influent tank as well as effluent tank and centre of the reed bed at weekly interval (S_o, S_1 and S_2 sampling points shown in Fig 1).The water samples were collected on fortnight basis and analysed for various quality parameters like pH, EC, TDS, Turbidity, DO, BOD, COD, cations and anions.

4. Results and Discussion: 4.1 Water quality variation along the reed bed length: Samples were analyzed for water quality parameters like pH, EC, and TDS, BOD, COD, Carbonate, Bicarbonate, Calcium, Magnesium, SAR, Chloride and Heavy metals.

4.1.1 pH : It was found that there was a notable reduction in pH was noticed after the every fortnight from influent to effluent. This trend showed that pH value decreased gradually. The range of pH from inlet to outlet was 7.76 to 7.47.

4.1.2 Electrical Conductivity (EC) : It was noticed that EC values decreased as wastewater passed through the reed bed along its length. There was a reduction of EC from 2.32 dSm^{-1} in the inlet to 2.00 dSm^{-1} in the outlet. This might be due to settling, entrapment and adsorption of some dissolved substances due to chemical processes in the media, precipitation of some salts along with uptake of a few heavy metals by the plant (*Typha angustifolia*).

4. 1.3 Total dissolved solids (TDS) : It was found that there is declining trend from influent to effluent, but this reduction is small. There was a reduction of TDS from 2362.36 mg L^{-1} at inlet to 1900 mg L^{-1} at the outlet. This might be due to the transformation of salts from one form to other, but a little reduction in the overall TDS concentration.

4.1.4 Biochemical oxygen demand (BOD): The average BOD values for wastewater flowing through the bed during the study period are ranging from 1400 mg L^{-1} at inlet to 490.15 mg L^{-1} at the outlet. It was found that a gradual declining trend lead to the reduction of BOD from influent to effluent. This might be due to the root penetration of macrophytes (*Typha angustifolia*) to its maximum root depth in the reed bed and absorption wastewater passing through the reed bed along with macrophytes.

4.1.5 Chemical Oxygen Demand (COD): The COD values along the bed were 1841.71 mg L^{-1} at influent (S_o) and 900.01 mg L^{-1} at the effluent tank (S_2). The higher values of COD as compared to BOD might be attributed to relatively higher concentration of non-biodegradable pollutants in the wastewater. It was found that mean COD value was reducing along the bed length from influent to effluent tank.

4.1.6 Carbonate and Bicarbonate: It was found that the value declined from 43.38 mg L^{-1} to 29.47 mg L^{-1}. This variation showed steady reduction in carbonate values up to the effluent. Bi-carbonate value was found to decline from 247.62 mg L^{-1} to 182.67 mg L^{-1}.

4.1.7 Calcium and Magnesium: A steady decline from, 119.88 mg L^{-1} to 102.63 mg L^{-1} was noticed. This variation showed steady reduction in calcium value in the final effluent collection. Magnesium value also showed a declining trend of 30 mg L^{-1} to 26.26 mg L^{-1}.

4.1.8 Sodium Adsorption Ratio (SAR): SAR value was found in the range of 12.95 to 8.08. This variation showed steady reduction in SAR value in the effluent. The results indicate that it could be used for irrigation purpose, as the SAR values are within the accepted level.

4.1.9 Chlorides: Chloride values ranged from 718.63 mg L^{-1} to 635.69 mg L^{-1} from influent to effluent. There was a fluctuating trend in the removal of chlorides along the bed length. But there was a mild reduction in chlorides in effluent than the influent.

Table 4.1 Pollutant removal performance of the designed reed bed

S. No	Parameter	Influent (mean)	Effluent (mean)	Average Removal η (%)	Maximum Removal η (for entire collection) (%)
1	**EC (dS/m)**	2.32	2.00	13.85	25.42
2	**TDS (mg L^{-1})**	2362.36	1900.00	19.56	29.23
4	**BOD5 (mg L^{-1})**	1400	490.15	64.97	72.91
5	**COD (mg L^{-1})**	1841.71	900.01	51.16	62.15
6	**Cadmium (mg L^{-1})**	0.031	0.015	49.23	55.00
7	**Nickel (mg L^{-1})**	0.023	0.014	39.84	45.98
8	**Lead (mg L^{-1})**	0.054	0.021	54.25	72.62
9	**Chromium (mg L^{-1})**	0.04	0.033	16.23	19.57
10	**Carbonate (mg L^{-1})**	43.38	29.47	33.19	57.14
11	**Bi-Carbonate (mg L^{-1})**	247.62	182.67	26.22	51.22
12	**Calcium (mg L^{-1})**	119.88	102.63	13.38	28.85
13	**Magnesium (mg L^{-1})**	30.00	26.26	12.56	29.82
14	**Chlorides (mg L^{-1})**	718.63	635.69	11.71	25.63
15	**SAR**	12.95	8.08	37.35	43.47

4.1.10 Heavy metals: Heavy metals like Pb, Cd, Ni and Cr were detected in low concentration in both untreated and treated effluent.

4.2 Purification efficiency (η) of reed bed system: Since the water samples were collected on fortnightly basis for duration of study period the purification efficiency of the system for the total period was combined and presented in Table 4.1. From the table, it was found that there was a significant reduction in all the water quality parameters, indicating that the reed bed treated wastewater could effectively be used for irrigation.

Conclusion: The reed bed system was found highly efficient in reducing the pH, EC, TDS, BOD, COD, cadmium, nickel, lead, chromium, carbonate, bicarbonate, calcium, magnesium, chloride and SAR respectively. The removal efficiency and maximum removal efficiency was found showing a positive trend. The results indicate that the reed bed system has effectively controlled eutrophication in water bodies. The reed bed system offered an economically viable solution of disposing wastewater into the water bodies and reuse for irrigation.

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