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Comparative Study of Various Treatments For Dairy Industry Wastewater

Mrs. Bharati S. Shete, Dr. N. P. Shinkar
1 Dr. Sau. Kamaltai Gawai Institute of Engineering & Technology, Darapur, Amravati, Maharashtra, India
2 Department of Civil Engineering, Government Polytechnic, Amravati, Maharashtra, India

Abstract: - Dairy industries have shown tremendous growth in size and number in most countries of the world. These industries discharge wastewater which is characterized by high chemical oxygen demand, biological oxygen demand, nutrients, and organic and inorganic contents. Such wastewaters, if discharged without proper treatment, severely pollute receiving water bodies. In this article, the various recent advancements in the treatment of dairy wastewater have been discussed and stress is given on the lowest cost of the best possible treatment.

Keywords:- *Aerobic treatment, anaerobic treatment, Anaerobic fixed bed reactor, Dairy industry, Wastewater characteristics*

I. INTRODUCTION

The dairy industry wastewaters are primarily generated from the cleaning and washing operations in the milk processing plants. It is estimated that about 2 % of the total milk processed is wasted into drains. Dairy wastewaters are characterized by high biological-oxygen demand (BOD) and chemical oxygen demand (COD) concentrations, and generally contain fats, nutrients, lactose, as well as detergents and sanitizing agents. Dairy effluents decompose rapidly and deplete the dissolved oxygen level of the receiving streams immediately resulting in anaerobic conditions and release of strong foul odours due to nuisance conditions. The receiving water becomes breeding place for flies and mosquitoes carrying malaria and other dangerous diseases like dengue fever, yellow fever, chicken guniya. It is also reported that higher concentration of dairy wastes are toxic to certain varieties of fish and algae. The casein precipitation from waste which decomposes further into a highly odorous black sludge at certain dilutions the dairy waste is found to be toxic to fish also. Dairy effluent contains soluble organics, suspended, solids, trace organics. They decrease do, promote release of gases, cause taste and odour, impart colour or turbidity, promote eutrophication.

Due to the high pollution load of dairy wastewater, the milk-processing industries discharging untreated/partially treated wastewater cause serious environmental problems. Moreover, the Indian government has imposed very strict rules and regulations for the effluent discharge to protect the environment (Table 1). Thus, appropriate treatment methods are required so as to meet the effluent discharge standards.

Dairy wastewaters are generally treated using biological methods such as activated sludge process, aerated lagoons, trickling filters, sequencing batch reactor (SBR), anaerobic sludge blanket (UASB) reactor, anaerobic filters, etc. Oftentimes the post-treatment of dairy wastewater is also done using the physico-chemical treatment methods consisting of coagulation/flocculation by various inorganic and organic natural coagulants, and membrane processes like nanofiltration (NF) and/or reverse osmosis (RO). Membrane processes produce purified water without milk proteins and lactose and which could be recycled. At the same time the recovered proteins and lactose can be used for non-human consumption[1].

Table 1:- Minimal standards for discharge of effluents from the dairy industry

PARAMETER	MAXIMUM VALUE (mg/l)	
	WORLD BANK REPORT	CPCB, INDIA
pH	6-9	6.5-8.5
BOD_5	50	100 (based on BOD_5)
COD	250	-
Total Suspended Solids	50	150
Oil & Grease	10	10
Total Nitrogen	10	-
Total Phosphoruus	2	-
Temperature Increase	$< = 3^0$ C	-
Coliform Bacteria	400 Most Probable Number / 100 ml	-

II. WASTEWATER GENERATION AND CHARACTERISTICS

Dairy industries are involved in the manufacturing of various types of milk products such as fluid milk, butter, cheese, yogurt, condensed milk, flavored milk, milk powder, ice cream, etc. Typical by-products obtained include buttermilk, whey, and their derivatives. A chain of operations involving receiving and storing of raw materials, processing of raw materials into finished products, packaging and storing of finished products, and a group of other ancillary operations (e.g., heat transfer and cleaning) are examples of some of the great variety of operations performed in the dairy industries. The initial operations such as homogenization, standardization, clarification, separation, and pasteurization are common to most plants and products. Clarification (removal of suspended matter) and separation (removal of cream for milk standardization to desired butterfat content), generally, are accomplished by specially designed large centrifuges. Drying, condensing, etc. are also used in dairy industries for the production of various products. In the dairy industry, some amount of wastewater gets produced during starting, equilibrating, stopping, and rinsing of the processing units (flushing water, first rinse water, etc.). However, a majority of wastewater gets produced during cleaning operations, especially between product changes when different types of products are produced in a specific production unit and clean-up operations (Fig. 1). Figure 1 explains in detail the units involved in milk processing industries and shows the flowchart of Effluent generation from various units

The dairy industry is one of the most polluting of industries, not only in terms of the volume of effluent generated, but also in terms of its characteristics as well. It generates about 0.2–10 liters of effluent per liter of processed milk with an average generation of about 2.5 liters of wastewater per liter of the milk processed. Dairy processing effluents are generated in an intermittent way and the flow rates of these effluents change significantly. Also, the quality and quantity of the product content in the dairy wastewater at a given time changes with the application of another technological cycle in the processing line. Moreover, because the dairy industry produces different products, such as milk, butter, yogurt, ice-cream, and various types of desserts and cheese, the characteristics of these effluents also vary widely both in quantity and quality, depending on the type of system and the methods of operation used.

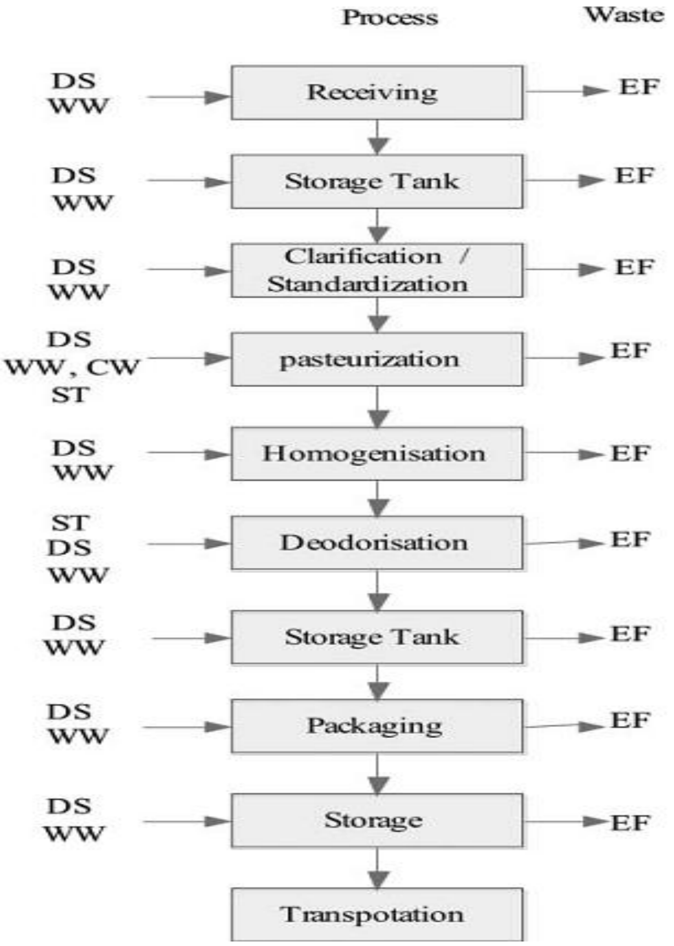

Fig.1: Effluent generation from various units of milk processing. DS-Detergents and Sanitizing Agents, WW-Wash Water, ST-Steam, CW-Cooling Water.

Dairy effluent contains soluble organics, suspended solids, trace organics. All these components contribute largely towards their high biological oxygen demand (BODS) and chemical oxygen demand (COD).The characteristics of a dairy effluent contain Temperature, Color, PH (6.5-8.0), DO, BOD, COD, Dissolved solids suspended solids, chlorides sulphate, oil & grease. The waste water of dairy contains large quantities of milk constituents such as casein, inorganic salts, besides detergents and sanitizers used for washing.[2] It has high sodium content from the use of caustic soda for cleaning. Typical Characteristics of dairy industry wastewaters reported by various authors are given in table 2.

Table 2:-Characteristics of dairy industry wastewaters (composition in mg/l, except pH)

WASTE TYPE	COD	BOD	P^H	TSS	TS	REFERENCES
Milk & Dairy Products factory	10251.2	4840.6	8.34	5802.6		Oneț Cristian,2010 [3]
Dairy effluent	1900-2700	1200-1800	7.2-8.8	500-740	900-1350	U. B. Deshannavar, et al 2012[4]
Arab Dairy Factory	3383 ± 1345	1941± 864	7.9 ± 1.2	831 ± 392		A. Tawfik et. al,2007[5]
Dairy waste water	2,500-3,000	1,300-1,600	7.2-7.5	72,000-80,000	8,000-10,000	Javed Iqbal Qazi et. al, [6]
Dairy effluent (CPCB 1993)	1120-3360	320-1750	5.6-8	28-1900		Kusum Lata, et. al, Biogas forum,1999[7]
Whey	71526	20000	4.1	22050	56782	Deshpande D.P. et. al, 2012[8]
Bhandara Co-operative dairy industry wastewater	1400 to 2500	800 to 1000	7.1-8.2	1045 to 1800	1100 to 1600	Monali Gotmare* et al.,2011[9]
Cheese Whey pressed	80,000-90,000	120,000-135,000	6	8000-11000		Rana Kabbout, et al.,2011[10]
Aavin dairy industry washwater	2500-3300		6.4 - 7.1	630-730	1300-1400	Sathyamoorthy G.L, et al.,2012[11]
Dairy industry wastewater	2100	1040	7-8	1200	2500	A. Arumugam[12]

III. DAIRY WASTEWATER TREATMENT

Common techniques for treating dairy industry wastewaters include grease traps, oil water separators for separation of floatable solids, equalization of flow, and clarifiers to remove SS. Biological treatment consists of the aerobic and anaerobic process. Sometimes anaerobic treatment followed by aerobic treatment is employed for the reduction of soluble organic matter (BOD) and biological nutrient removal (BNR) is employed for the reduction of nitrogen and phosphorus. Aerobic biological treatment involves microbial degradation and oxidation of waste in the presence of oxygen. Conventional treatment of dairy wastewater by aerobic processes includes processes such as activated sludge, trickling filters, aerated lagoons, or a combination of these[1]. But there are more advanced techniques which will be beneficial to us by providing energy generation and Reuse and energy conservation have become the words of the day and anaerobic processes have emerged with a new potential so we study here some of the anaerobic processes studied by different scientists.

Jai prakash kushwaha et. al.[1] [2011] in his paper, "An Overview of Various Technologies for the Treatment of Dairy Wastewaters" have summarized the aerobic treatment of dairy wastewater by various authors. He claimed that among the various aerobic technologies, sequential batch reactor (SBR) seems to be the most promising technology for treatment of dairy wastewater. It is a fill and draw activated sludge system. In this system, wastewater is added to a single batch reactor, treated to remove undesirable components, and then discharged. Equalization, aeration, and clarification can all be achieved using a single-batch reactor.

Table 3:- Comparison of advantages and disadvantages of aerobic and anaerobic treatment of dairy industry wastewaters

FACTORS	AEROBIC PROCESS	ANAEROBIC PROCESS
Reactors	Aerated lagoons, oxidation ditches, Stabilization ponds, Trickling filters and Biological discs	UASB, Anaerobic filter, Upflow packed bed reactor, CSTR, Down flow fixed-film reactor, Buoyant Filter Bioreactor,
Reactor size	Aerated lagoons, oxidation ditches, Stabilization ponds, Trickling filters and Biological discs requires larger land area but SBR needs comparatively lower area.	Smaller reactor size is required.
Effluent Quality	Excellent effluent quality in terms of COD, BOD and nutrient removal is achieved.	Effluent quality in terms of COD is fair but further treatment is required. Nutrient removal is very poor.
Energy	High energy is required.	These processes produce energy in the form of methane.
Biomass yield	In comparison to anaerobic process, 6-8 times greater biomass is produced	Lower biomass is produced.
Loading rate	Maximum 9000 g COD/m^3 d is reported in literature.	Very high Loading rate of 31 kg COD/m^3 d has been reported. This is the reason for smaller reactor volume and lesser area.
Oil and grease removal	These do not cause serious problems in aerobic processes (Komatsu et al., 1991).	Fats in wastewater shows the inhibitory action during anaerobic treatment of dairy wastewaters
Shock loading	Excellent performance in this regard.	Anaerobic processes showed not good responses to this shock loading.
Alkalinity addition	No need.	There is need for alkalinity addition to maintain the pH because pH changes during the digestion of lactose.

Despite various studies and some advantages of the aerobic biological treatment of dairy wastewater (Table.3), there are a number of drawbacks associated with these studies. High energy requirement by aerobic treatment methods is the primary drawback of these processes. Dairy effluents have high COD and organic content and are warm, enabling them to be ideal for anaerobic treatment. Furthermore, no requirement for aeration, low amount of excess sludge production, and low area demand are additional advantages of anaerobic treatment processes in comparison to aerobic processes (Table 3).
Consequently, a number of studies have been reported in open literature for the treatment of dairy wastewater by anaerobic methods.

IV. LITERATURE REVIEW

U. B. Deshannavar et. al.[4] [2012], have studied the upflow anaerobic fixed-bed reactor for digestion of dairy industry effluent using polypropylene pall rings as a packing media and found that average COD removal efficiency of 87% and maximum biogas production of 9.8 l/d was achieved.

T. Ramesh et al [13] [2012]has studied a Fixed Film and Fixed Bed Anaerobic Reactor for treating Dairy Waste Water and found that COD reduction is a maximum of 80.88% for a varying influent COD from 1500 to 4700 mg/lit. for the OLR of 0.004 kg COD/ m^2/day and HLR of 0.003 m^3/m^2.day. The maximum gas conversion ratio is 0.265 m^3 of biogas per kg of COD removed.

Sathyamoorthy G.L et.al[11] [2012] have studied the performance of the anaerobic hybrid reactor (AHR) which is a combination of Upflow anaerobic sludge blanket reactor (UASBR) (suspended biomass) at bottom and Anaerobic Filter Reactor (AFR) (attached biomass) at top to treat dairy wastewater. He used the Bioflow® 30 shape PolyPropylene (PP) inert media as the reactor filter media and revealed that the Anaerobic Hybrid Reactors (AHRs) were effective in the treatment of low-strength dairy wash-water giving 85% COD removal for an OLR of about 4.2 g COD/L.d and HRT of 0.9 d. in BOD , COD and VSS of dairy wastewater in batch and repeated batch cultivation systems. He found that the efficiency of COD removal is associated with the nature and properties of support material. Eventually, the maximum percentage removal of COD, BOD and

VSS turned out to be as 96%, 93% and 90%, respectively, with the application of 21 Kg $COD/m^3/d$ loading in batch reactor filled with gravels.

Deshpande D.P. et. al. [8] [2012], have used the Upflow anaerobic packed bed bioreactor (UAPB) with an internal diameter of 20cm and a height of 45 cm using seashell as a packing material for dairy wastewater treatment. He used the UAPB not only for treatment but he proved that with the help of UAPB dairy industry effluent is very good raw material for production of methane gas, commercially known as BIO-GAS, which can be use as a fuel and can replace the other fuel and COD value also decreases from 71526 mg/lit to 42200mg/lit as the time increases from first day to the 56th day of the experiment.

J. I. Qazi et.al[6] [2011] has studied a number of biofilm support media including foam cubes, bamboo rings, fire bricks, PVC rings and gravels to immobilize biomass for reduction in BOD_5, COD and VSS of dairy wastewater in batch and repeated batch cultivation system in Anaerobic Fixed Film Biotreatment. Eventually, he found that the maximum percentage removal of COD, BOD and VSS turned out to be as 96%, 93% and 90%, respectively, with the application of 21 Kg $COD/m^3/d$ loading in batch reactor filled with gravels.

Monali Gotmare et.al[9] [2011]has studied a UASB reactor treating dairy wastewater. And found that reactor achieved COD, BOD, TSS removal efficiency was observed 87.06%, 94.50%, and 56.54% respectively. The average gas production and methane gas conversion at optimum conditions was observed to be 179.35 m^3/day and 125.55 m^3/day, respectively.

Rana Kabbout et.al[] [2011] has studied the physicochemical treatment of Sweet Whey the major pollutant in Dairy industry by coagulation-flocculation using Aluminum sulphate Al2(SO4)3 as a coagulant because it reduce the hardness and the load of phosphate in the wastewater and found that 33 % of the chemical oxygen demand, 45% of the turbidity, 72 % of suspended matter and 20% of total phosphorus gets reduced.

G. Srinivasan et.al[14] [2009] have carried out experiments on Anaerobic Diphasic Fixed Film Fixed Bed (FFFB) digester in the treatment of a synthetic dairy wastewater in order to reduce the COD of dairy waste water and for the production of biogas. They have reported maximum removal of COD as 70.40 % at a flow rate of 0.006 m^3/day for an overall OLR of 1.265 Kg COD/m^3.day giving a maximum yield of bio-gas at 0.330 m^3 of gas / kg COD removed

G. D. Najafpour, et.al[15] [2009] have used Upflow anaerobic packed bed bioreactor (UAPB) to treat Dairy Wastewater. The Plexiglas reactor column was packed with a seashell, and found that high COD and Lactose removals of 94.5 and 99% at HRT of 16 h having highest yield of methane production and the maximum biogas volumetric production.

G.D. Najafpour, et.al[16] [2008] have used Upflow Anaerobic Sludge-Fixed Film (UASFF) Bioreactor for the Treatment of Dairy Wastewater. UASFF bioreactor was developed with tubular flow behavior in order to shorten the start-up period of UASB reactor at low HRT. In this treatment; the column was randomly packed with seashell and at HRT 48 h and temperature 36°C found that, the COD removal rate and lactose conversion of 97.5 and 98 percent respectively.

A. Arumugam , et.al[6] [2008] have used a three phase fluidized-bed bioreactor (FBBR) for the aerobic treatment of dairy wastewater using culture of living cells immobilized on support particles of ceramic, Teflon, glass supports were studied and found that percentage reduction in COD for ceramic, Teflon and glass particles are 91%, 85% and 78%, respectively.

P. Sankar Ganesh, et.al[17] [2007] have studied the dairy industry wash water treatment by UASB reactor and reveals that about 75-85% of COD was removed from dairy wash waters coming into the UASBs at COD concentrations of 1200-2000 mg/L at 6 h HRT. This means that the wash water exiting from the UASBs have COD in the range 180-500 mg/L. Such dilute effluents can be easily and quickly polished by short duration (1-2 h) aeration.

In this research I would like to use fixed film fixed bed reactor using coir as a support media to treat the dairy industry wastewater which would be at lowest cost and is beneficial to industries. Fixed bed reactors offer the advantage of high-load systems, requiring much less volume and space, and hence less investment as compared to conventional systems. Furthermore, these systems tend to operate more stable under transient conditions, like fluctuations of substrates and pH. Such advantages are of interest to those industries which produce large amounts and/or highly concentrated wastewaters, notably the food, paper and pulp industries.[15]

V. CONCLUSION

Fixed film processes are more superior when compared to suspended processes in several aspects. Small reactor size, simple operation and high reliability make this process a cost-effective system for biological treatment. In fixed-film anaerobic reactors, large amount of biomass remains in the filter to secure solid retention despite a short hydraulic retention times. Biomass accumulation and retention in biomass systems are enhanced by attachment to a fixed medium.

The upflow anaerobic fixed-bed reactors have several advantages over aerobic and conventional anaerobic reactors such as rapid start-up with minimum operational problems; ability to withstand shock loading without significant decrease in digestion efficiency; ability to adapt intermittent feeding and rapidity of restart after lengthy shut down periods; and lower hydraulic retention times.[15] One of the advantages is high biomass per reactor volume which permits higher organic loading rate, short liquid detention times and good performance stability.

Anaerobic fixed bed reactors (AFBRs) has been successfully and widely applied for the treatment of dairy industry wastewater due to its capacity for microorganism retention on the support and, therefore, the hydraulic retention time can be considerably reduced. In addition, AFBRs are easy to acclimatize and can overcome influent variations or shock loads without process failure. Moreover, the construction, operation and maintenance cost of the AFBRs are lower than those required for other high-rate reactors. These characteristics make the AFBR extremely useful for the treatment of high and medium strength wastewaters like dairy industry wastewater.

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