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Advanced Technologies for Dairy Effluent Treatment

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Abstract

Dairy industry waste water is generally have fats, lactose, whey proteins, nutrients which lead play important role to increase the biological oxygen demand (BOD) of water. With milk components also wastewater contain detergents and sanitizing agents which are result of cleaning process increase the concentration of chemical oxygen demand (COD). There are many ways to reduce the BOD and COD, but biological treatment is the primary mean. Both aerobic and anaerobic technologies have been used, while anaerobic treatment of wastewater has emerged as viable and economical alternative over the conventional aerobic treatment particularly for high BOD. In aerobic technologies number of different treatment methods are there like, activated sludge, sequencing batch reactor, rotating biological contactors trickling filter. In anaerobic treatment methods are up flow sludge blanket (UASB), anaerobic sequencing batch reactors (ASBR), continuous-flow stirred tank reactor, hybrid anaerobic digesters, contact reactor, up flow and down flow anaerobic filter, and two-stage systems that separate the acid-forming and methane forming. There are many cases where aerobic and anaerobic processes are combined in one single treatment system. Membrane technology is alternatives to bio treatment being used for BOD reduction in dairy wastewaters which replaces secondary clarifiers in the waste treatment plants with membranes.

Keywords: Sterilization; Sanitizing agents; Emulsifiers; Coagulants

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Introduction

Dairy industry involves processing of raw milk. The pasteurization, sterilization, separation, filtration and homogenization are several unit operations. In industry the milk processing is done and many products like market milk, condensed milk, milk powder, cream, butter, cheese, curd, yogurt and ice cream and many more products are being made. In preparation of all the products, the by products such as, whey, butter milk, are generated in huge amount [1]. Till now there is no such utilization of these by product, somehow industries have to dispose these by products. Also cleaning water with sanitizing agents which ranges from 1 to 3 L for processing a liter of milk are generated in large quantity of effluent about 2.0-2.5 L of wastewater per liter of milk processed [2]. The by products contain high concentration of organic material such a protein, carbohydrates, fats, grease, minerals having high COD and BOD values. Therefore it needs proper treatment before its discharge from the factory premises [1,3]. The objectives of treating dairy wastes are:

a) Reduce the organic content of the wastewater.

b) Remove or reduce nutrients that could cause pollution of receiving surface waters or groundwater.

c) Remove or inactivate potential pathogenic microorganisms.

d) Dairy effluent requires a specialized treatment to prevent or minimize environmental problems, as it contains high biodegradable organic compounds and this increases the complexity of the treatment process [2].

Dairy Waste Sources

Each unit operation generates dairy waste water like wash water from cleaning of milk cans, process equipment's, tankers, pipelines floors and portions of spilled milk, spoiled milk and milk leakage from milk pumps and pipelines. There are different categories of water such as:

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Cooling water

Cooling water is used in various such as cooling tower, water softener, boiler, back washing of filters and air compressor. Normally cooling water doesn't have any pollutants, so it is discharged as such without any treatment into storm water.

Sanitary waste water

The water which is generated from sanitizing process like cleaning of milk cans, tanks and tankers and floor etc. The high volume sanitary waste water includes lot of organic (milk constituent's viz. proteins, lactose and fat etc.) and inorganic waste (Include phosphates- used as deflocculates and emulsifiers in cleaning compounds), chlorine (used in detergents and sanitizing products) and nitrogen (contained in wetting agents and sanitizers) components so it is directed to the sewage treatment plant with or without first having being mixed with industrial waste water.

Industrial waste water

Water used for cleaning of equipment (CIP) is called as industrial waste water; the amount and concentration of waste water depend on the type of product, capacity and the design of the processing plants. This type of generated effluent is highly unstable in nature and biodegradable [4].

Characteristics of Dairy Waste

The dairy waste is very complex in nature in terms of biodegradability, because it contains easily degradable carbohydrates, mainly lactose and less biodegradable protein and lipids like milk fats [5]. The easily degradable lactose and less degradable fats can be very different in proportion depending on type of operation and product manufactured. Like ghee process is high lipids containing while cheese is protein and carbohydrates [6]. The characteristics of a dairy effluent contain temperature, color, pH (5.5-10.5), BOD (0.35-1.8 kg), COD, dissolved solids, suspended solids, oil and grease. The waste water is normally white in color and usually slightly alkaline in nature and become acidic quite rapidly due to the fermentation of milk sugar to lactic acid [7]. Dairy effluent, in term of BOD varies from 200 to 3500 mg/L [8,9], while COD concentration may be in range of 2 to 2.5 mg/L higher than that of BOD [10,11]. Productions are major sources of BOD in wastewater [2,3]. The biochemical oxygen demand (BOD) in milk and cream is greater than 100,000 mg/L and 400,000 mg/L of BOD, respectively [12]. One gram of milk fat has a BOD of 0.89 g, whereas milk protein, lactose, and lactic acid have BOD values of 1.03, 0.65, and 0.63 g, respectively [13]. Normally milk waste constituents are: 1 kg of milk fat=3 kg COD; 1 kg of lactose=1.13 kg COD; 1 kg protein=1.36 kg COD [1,2]. In respect of pH also the dairy waste streams are very fluctuating and wide variation is there and it's depend on flow rates, production cycle of the different products. Nature of dairy wastewaters in terms of volume and flow rates and also in terms of the pH and suspended solids (SS) content makes it difficult to choose an effective wastewater treatment regime [11].

Dairy Waste Treatment

Two types of treatment methods are normally used in dairy industry i.e., chemical and biological treatment.

Mechanical treatment

This is preliminary stage of dairy waste treatment and in this screens, grit chamber, skimming tank and primary sedimentation tank or clarifier are used. The large material which are floating in nature are removed by removed by screens, otherwise matter may chock the pipes while further effluent processing. Chambers are used to remove the heavier inorganic matter such as sand, grit etc. Skimming tanks are installation purpose is to remove oil, grease, wood pieces, fruit skins; etc. Settling tank or clarifier allows matter at very low velocity or at rest in the sedimentation tank to settles down at the bottom of sedimentation tank. The collected material at the bottom is known as sludge. Sludge and effluent require further additional treatment to make them harmless [14].

Chemical treatment

Chemical treatment is also known as precipitation. The precipitation is done by adding flocculating material called as flocculants to waste water and mixed vigorously by agitators. This process precipitate insoluble phosphate in the form of very fine particles then the particle aggregates into larger flocks. The larger flocks settle down in in the pre-sedimentation basins as primary sludge, where a clear effluent overflows into a basin for biological treatments. Sedimentation basins are equipped with devices that continuously scrape the sediment into a sump and oblique gutters that carry off water from the clarified surface layers [14]

Biological treatment

Dairy effluent contain mostly organic waste therefore, biological degradation is the most promising options for the removal of organic material. However, sludge formed, especially during the aerobic biodegradation processes, can lead to serious and costly disposal problems. This can be aggravated by the ability of sludge to adsorb specific organic compounds and even toxic heavy metals. However, biological treatment has the benefits of microbial transformations of complex organics and possible adsorption of heavy metals by suitable microbes. Biological treatments of waste treatment have great potential for combining various types of biological schemes for selective constituent's removal [15].

Aerobic treatment: In aerobic biological treatment methods the microorganisms grown in an oxygen-rich environment, to degrade the organics to carbon dioxide, water, and cellular material by oxidizing matter. Systems of aerobic treatment can include the conventional activated sludge process, the rotating biological contactors, the conventional trickling filters, etc. [15].

Anaerobic treatment: Anaerobic treatment is basically for treating high strength waste water by biological process. Anaerobic digestion is a process by which microbes are used in the absence of oxygen for the stabilization of organic matters by conversion to biogas (methane and CO_2 biomass and inorganic products. 5% of the organic load in a waste stream can be converted to biogas (methane and carbon dioxide) and the remainder is utilized for cell growth and maintenance. The process reactors are covered to prevent the entrapment of air and the release of odor [15].

Sludge treatment

Each treatment stage generates sludge and that sludge is collected in thickening tanks to which chemical are added to further facilitate the aggregation of solid particles. Sludge is a homogenous, practically odorless, dark-colored Sludge contains high amount of organic material so it has to further break down so that foul-smell reduced down. The eventually pumped into a digester where the organic substances are broken down under anaerobic conditions into methane and carbon dioxide, very small amount of hydrogen gas, ammonia and hydrogen sulfide. Methane and carbon dioxide are main components of digester, which can be utilized as fuel for heating. Sludge has high moisture content of 94-97%. It is therefore dewatered most efficiently in a decanter centrifuge which discharges a solid phase of about 1/8th of the original volume. Dewatered sludge can then be employed as fertilizer or landfill or simply deposited as waste [14].

Advanced Technologies for Dairy Effluent Treatment

The conventional effluent treatment technologies such as aerobic process include activated sludge process (ASP), trickling filter, Rotating biological contactor etc., are commonly adopted in dairy effluent treatment plant which requires more energy for aeration.

Physic-Chemical Process

Electrocoagulation (EC): The electrocoagulation (EC) process can be the alternative process for treating dairy wastewaters. Electrocoagulation is process of electrolysis, which removes dissolved organic waste, turbidity and coloring matter by passing electrical current through the effluent using special electrode. The process helps in significant removal of suspended colloidal particles [11]. Sengil et al. [16] exploited the EC process for treating the dairy waste matter by passing electrical current through the effluent using special electrode. The process helps in significant removal of suspended colloidal particles [11]. Similar kind of study conducted by Sengil et al. [16] on EC process for the treatment of dairy wastewater. During the analysis of waste, they found that efficiencies COD and oil-grease removal was 98 and 99% at electrolysis time of 7 and 1 min, respectively.

Adsorption: Among the various physic-chemical treatment methods, adsorption has been found to be attractive for the removal of organic compounds in wastewaters. For treatment of wastewaters, among other types of adsorbents mostly activated carbon is used. Although some other adsorbents also can be used for treatment of wastewater streams and are also cost effective for e.g., rice husk ash, coal fly ash etc. [17]. Rao et al. [18] used a combination of powdered activated carbon (PAC) along with other low-cost adsorbents for the treatment of wastewater emerging from dairy waste. Compared to other adsorbents including, straw dust, coconut coir, bagasse and fly ash, PAC gives better efficiency in reducing the content of total solids content. Sarkar et al. [19] used chitosan and other inorganic coagulants and thereafter PAC adsorption as pretreatment steps before subjecting the dairy wastewater to membrane separation processes.

Membrane treatment: The common membrane separation processes are microfiltration, Nano filtration, ultrafiltration, reverse osmosis and electro-dialysis. High feasible product recovery is possible with these methods and effluent produced is of high quality able to be directly used [17]. NF membrane treatment is a viable alternative to the conventional treatment by RO because it can operate at lower pressures, lower-energy consumption, and higher permeate recoveries than RO. Frap part et al. [20] reported the recovery of lactose and milk proteins as well as COD and reduction of ionic concentration in dairy process waters (initial COD of 36,000 mg/L) using high shear rate dynamic filtration systems with NF. Vourch et al. [21] recycled the dairy waste using RO treatment until 90-95% water recovery achieved with an average permeate flux around 11 l/h m^2.

Aerobic Process

Sequencing Batch Reactor (SBR): Sequencing batch reactor (SBR) seems to be the most promising technology using which dairy wastewater can be treated consists of a set of tanks that operate on basis of a fill-and draw activated sludge for removing undesirable components. The tanks may be an earthen or oxidation ditch, a rectangular basin, or any other concrete/ metal type structure. Each tank in the SBR system is filled during a discrete period of time and then operated as a batch reactor. After desired treatment, the mixed liquor is allowed to settle and the clarified supernatant is drawn from the tank. The essential difference between the SBR and the conventional continuous flow activated sludge system is that SBR carries out functions such as equalization, aeration and sedimentation in a time rather in a space sequence [22,23]. A single-batch reactor can be used for equalization, aeration, and clarification. Therefore elimination of clarifiers and other equipment can be used to save the total cost [24]. Investment cost of SBR treatment is low because it is often operated with higher TS [25]. The operating parameters such as hydraulic retention time (HRT), organic loading, pH, dissolved-oxygen concentration, temperature, mixed liquor-suspended solid (MLSS), and the strength of the wastewater affect the operation treatment efficiency of SBR [17]. Bandpi et al. [23] study a bench scale aerobic SBR to treatment of industrial milk factory wastewater. During the study they found that more than 90% COD removal efficiency by varying the COD concentration from 400 to 2500 mg/L. Neczaj et al. [26] studied the effect of operating parameter on treatment efficiency using two SBR for the treatment of dairy wastewaters (initial COD concentration 400-7500 mg/L). For removal of 98.6% COD and 80.1% TKN, the required aeration time of 19 h and an anoxic phase of 2 h was required. Removal efficiencies reduced with increasing organic loading or decreasing HRT.

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Anaerobic Process

Anaerobic process is a biological process performed by active microorganisms in the absence of exogenous electron acceptors. It was reported that up to 95% of the organic load in waste water stream can be converted to biogas (methane and carbon dioxide). Anaerobic process of dairy waste also yields methane, which can be employed as a heat or power source. Another, advantages associated with this process are less sludge is generated, thereby reducing problems associated with sludge disposal, low area demand, no energy requirement and absent bad odors. Anaerobic systems are generally seen as more economical for the biological stabilization of dairy wastes, as they do not have the high-energy requirements associated with aeration in aerobic systems. [17]

Up Flow Anaerobic Sludge Blanket (USAB): UASB reactors have been most widely used for the treatment of dairy and food wastewater [27]. The basic components of a typical UASB reactor are a sludge blanket, gas-solid separator, influent-distribution system and the effluent-withdrawal system. In the UASB reactor, the influent is distributed at the bottom and travels in up-flow mode [28]. Gavala et al. [27] found that, COD reduction of 90% at organic loading rate of 0.031 kg COD/ m^3d was achieved operating in steady-state conditions using a wastewater with a COD influent of 2050 mg/L. Dairy wastewater contains fats and the inhibitory action of the fat to the anaerobic treatment does not allow fast and increased removal efficiency [29]. Various authors reported that the enzymatic hydrolysis of fats as pretreatment may remove this problem. Cammarota et al., [30] found that treatment of dairy wastewaters in a UASB reactor containing elevated fat levels (868 mg/L), results in removal more than 50% COD and volatile suspended solids (VSS) up to 944 mg/L. However, the same dairy wastewater pre-treated with Penicillium restrictum lipases showed higher COD removal efficiency of 90% when treated in the same UASB reactor. Many authors have reported reduced efficiency of continuous UASB reactors due to the buildup of organic matter in the reactor. Monali et al., [31] studied performance evaluation of up flow anaerobic sludge blanket (UASB) reactor for treating dairy effluent and estimate the biogas generation efficiency. They observed removal efficiency of COD, BOD, and TSS was 87.06%, 94.50%, and 56.54%, respectively and the VFA/Alkalinity ratio varies from 0.28 to 0.43. The pH of reactor was found to be 6.9-7.1. The average biogas production was 179.35 m^3/day, out of which methane constitute 75% of the biogas.

Hybrid anaerobic digesters: A lab scale on mesophilic hybrid anaerobic digester, consist of combination an UASB and an anaerobic filter design, was used for dairy effluent treatment. The anaerobic digester provided a methane yield of 0.354 m^3 CH4/kg COD removed at an HRT of 1.7 days [32]. The treatment of acidic cheese whey by a lab scale up flow hybrid reactor resulted in removal efficiencies of more than 95 percent, at 2 days of HRT and up to an OLR of about 11 kg COD/(m^3day) [33]. Koshta [34] evaluated the performance of the anaerobic fixed film reactor for the dairy effluent with two reactors (A and B). Optimal COD removal efficiency of 87.69 and 89.42 were achieved in reactor A at 3 days HRT and reactor B at 2 days HRT, respectively. Biogas production achieved at HRT of 5, 3, 2 days were 20.46, 28.63 and 28.75 l/day for reactor A and 20.00, 28.83 and 30.83 l/day for reactor B. Optimum biogas yield and methane yield achieved at HRT of 3 days were 0.73 and 0.43 l/g COD removal for reactor A and 0.80 and 0.52 l/g COD removal for reactor B. Simultaneously, TDS removal was 58.56 and 60.09 percent in reactor A and reactor B, respectively.

Anaerobic Sequencing Batch Reactors (ASBR): ASBRs also used for obtaining high quality of dairy effluents. The lab scale study on ASBR system was carried out to provide removal of COD and BOD_5 rates of 62 and 75 percent respectively, at a hydraulic retention time (HRT) of 6 h, at 58 C, for a substrate containing non-fat dry milk. While in temperature range between 5 and 20°C, and at an HRT range between 24 and 6 h, soluble organic removal rates ranged between 75 and 90% for BOD_5, and 62 and 90 percent for COD [35]. In another lab scale study, thermophilic ASBR and mesophilic ASBR systems provided volatile organic solids removal between 26-44 percent, and 26-50 percent for dairy wastewater respectively [36].

Conclusion

Anaerobic treatment is most widely used for treating dairy wastewaters, predominantly UASB and hybrid anaerobic digester. The up flow anaerobic slug blanket reactors are most widely used and appropriate for treating dairy industry wastewaters, since they can be treat large volumes of influents in a relatively short period of time. But, these processes partly degrade wastewater containing fats and nutrients as dairy wastewater. So, further treatment is essential for anaerobically-treated dairy wastewater. In aerobic process, the fats and nutrients could easily be removed but high energy requirement is primary drawback due to the supply of aeration. In order to reduce energy consumption in aerobic of treatment, physic-chemical treatment processes is used as the primary purification before aerobic treatment of dairy wastewater. Now a day's membrane treatment methods gain importance for producing high quality effluent suitable for direct reuse. Different combinations of RO, NF, and UF with each other and/or with biological and/or chemical methods are likely to become new era of future research.

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