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Biological Unit operation for waste water treatment: Aerobic Process

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ABSTRACT

Dairy is one of the major industries causing water pollution. Considering the increased milk demand, the dairy industry in India is expected to grow rapidly and have the waste generation and related environmental problems are also assumed increased importance. Poorly treated wastewater with high level of pollutants caused by poor design, operation or treatment systems creates major environmental problems when discharged to the surface land or water. Aerobic biological treatment methods depend on microorganisms grown in an oxygenrich environment to oxidize organics to carbon dioxide, water, and cellular material. activated sludge is used to indicate the sludge which is obtained by settling sewage in presence of abundant oxygen. The activated sludge is biologically active and it contains a great number of aerobic bacteria and other microorganisms which have a got an unusual property to oxidize the organic matter. The activated sludge process has been employed extensively throughout the world in its conventional form and modified forms Various unit operations like physical, chemical and biological can play vital role in reduction of the waste water. Aerobic treatment of biological waste water like activated sludge, trickling filter, RBC, aerated lagoon with advance aerobic treatment unit SBR and summery of aerobic treatment unit with advantages and disadvantages are to be discussed in article.

Keywords: *Biological Treatment; Activated Sludge; Trickling Filter; Sequencing Batch Reactor; Lagoons; Waste Water.*

1.0 Introduction

Biological treatment processes are those that use microorganisms to coagulate and remove the non settle able colloidal solids to stabilize the organic matter. Biological waste water treatments are primarily used to remove dissolved and colloidal organic matter in a waste.

The effluent from the primary sedimentation tank contains about 60-80% of the unstable organic matter originally present in sewage.

This colloidal organic matter, which passes the primary clarifiers, without settling there, has to be removed by further treatment. This further treatment of sewage is called secondary treatment in which biological and chemical processes are used to remove most of the organic matter.

The secondary treatment is directed principally towards the removal of biodegradable organics and suspended solids. It comprises of 99.9% water and 0.1% solids (Shete et al., 2013)

2.0 Sources of Dairy Waste

Dairy waste water includes wash water from milk cans, tankers, process equipments, pipelines and floors, portions of spilled milk, spoiled milk and milk leakage from milk pumps, overflow and spillage. These can be further divided into three categories: a) Cooling water- water is used in various utilities such as cooling tower, boiler, water softener, back washing and air compressor. As cooling water is normally free from pollutants, it is discharged into the storm water piping system without any treatment. b) Sanitary Waste water- includes water used for cleaning of milk cans, tanks and tankers, dairy floor etc. The sanitary waste water is normally piped direct to the sewage treatment plant with or without first having being mixed with industrial waste water. The effluent generated is high in volume and contains

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higher organic load. c)Industrial waste water- arise from acidic, curdled milk, discharge of sour whey, spillage of milk and products thereof and from cleaning of equipment (CIP) that has been in contact with milk products. The concentration and composition of the waste depends on the production programme, operating methods and the design of the processing plants. The effluent generated is highly unstable in nature and biodegradable (Sharma, 2008 and Boghara et al., 2003).

3.0 Wastewater Generation and Characteristics

The dairy industry generates about 0.2–2.5 liters of effluent per liter of processed milk (Vourch et al., 2008) with an average generation of about 2.5 liters of wastewater per liter of the milk processed. It is estimated that about 110 million tonnes of the milk and about 275 million tonnes of wastewater will be generated annually from the Indian dairy industries by the year 2010. Dairy wastes are white in colour and usually slightly alkaline in nature and become acidic quite rapidly due to the fermentation of milk sugar to lactic acid (Kolhe et al., 2009).Dairy effluents contain dissolved sugars, proteins and fats and possibly residues of additives. Strength of dairy effluent, in term of BOD varies from 200-3500 mg /l (Lal and Verma, 1989) while COD concentration may be in range of 2 to 2.5 times higher than that of BOD (Boghra et al., 2003), total suspended solids, at 100–1,000 milligrams per liter (mg/l); total dissolved solids: phosphorus (10–100 mg/l), and nitrogen (about 6% of the BOD level) depending upon the type and qualities product processed.

3.1 Food to microorganism ratio (F/M)

This ratio represents the mass of bio-available organic compounds (substrate) loaded into the aeration chamber each day in relation to the mass of microorganisms contained within the aeration chamber. Typically this ratio is expressed in terms of mass of BOD per day per mass of microbes in the treatment unit. The microbial population is dynamic and responds to changes in life-sustaining parameters. In aerobic processes, waste is stabilized by aerobic and facultative microorganisms; in anaerobic processes, anaerobic and facultative microorganisms are present.

4.0 Dairy Waste or Waste Water Treatment

The common methods of treatment of waste water in dairy industry are: mechanical, chemical and biological treatment.

4.1 Mechanical treatment

The preliminary stage of waste treatment comprises screens, grit chamber, skimming tank and primary sedimentation tank. The screens are provided to remove floating matter of large size which may choke up the small pipes or affect the working of sewage pumps. Grit chambers are provided to remove the heavier inorganic matter such as grit, sand etc. Skimming tanks are installed to remove such floating matter such as grease, oil, soap, wood pieces, fruit skins; etc. Sedimentation is also known as settling tank or clarifier. Influent is either rest or moving with a very low velocity in the sedimentation tank so that inorganic matter settles down at the bottom. Material collected at the bottom of sedimentation tanks is known as 'sludge' and partially treated waste water is known as 'effluent'. Sludge and effluent both require further additional treatment to make them harmless (Parekh and Devsani, 2003).

4.2 Chemical treatment

Chemical treatment is also known as precipitation. The precipitation stage starts with flocculation tanks where the flocculants are added and vigorously mixed into the water by agitators. This results in precipitation of insoluble phosphates, initially in the form of very fine particles which, however gradually aggregates into larger flocs. The flocs settle out in pre-sedimentation basins from which a clear effluents overflows in to a basin for biological treatments. Pre-sedimentation is the final step in combined mechanical and chemical treatment. The water is allowed to flow slowly through one or more basins where the finer particles gradually settle to the bottom as primary sludge (Parekh and Devsani, 2003).

4.3 Biological treatment

Biological degradation is one of the most promising options for the removal of organic material from dairy wastewaters. However, sludge formed, especially during the aerobic biodegradation processes, may 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 systems have the advantage of microbial transformations of complex organics and possible adsorption of heavy metals by suitable microbes. Biological processes are still fairly unsophisticated and have great potential for combining various types of biological schemes for selective component removal.

The biological treatment processes have been further divided into the following two categories:

- Suspended growth processes.
- Fixed growth processes.

(1) Suspended growth processes refer to treatment systems where microorganisms and wastewaters are contained in a reactor. Oxygen is introduced to the reactor allowing the biological activity to take place. Examples of suspended growth processes include ponds, lagoons and activated sludge systems.

(2) Fixed growth processes refer to systems where a biological mass is allowed to grow on a medium. Wastewater is sprayed on the medium or put into contact in other manners. The biological mass stabilizes the wastewater as it passes over it. Examples of fixed growth processes include trickling filters and rotating biological contractors.

4.3.1 Aerobic treatment:

Aerobic biological treatment methods depend on microorganisms grown in an oxygen-rich environment to oxidize organics to carbon dioxide, water, and cellular material. Systems of aerobic treatment can include the conventional activated sludge process, the rotating biological contactors, the conventional trickling filters, etc (Carta-Escobar et al.,2004) All compounds of dairy wastewater are biodegradable except protein and fats which are not easily degraded. Owing to the presence of high organic matter, dairy wastewaters are well suited for biological treatment, especially anaerobic treatment (Rico Gutierrez et al.,, 1991). However, the presence of fats shows the inhibitory action during anaerobic treatment of dairy wastewaters (Vidal et al., 2000). This inhibition is due to the presence of long-chain fatty acids formed during the hydrolysis of lipids, which causes retardation in methane production. Long-chain fatty acids were reported to be inhibitory to methanogenic bacteria (Koster, 1997) but lipids do not cause serious problems in aerobic processes (Lareo, 2007)

5.0 Biological Aerobic Unit Operation For Waste Water Treatment:

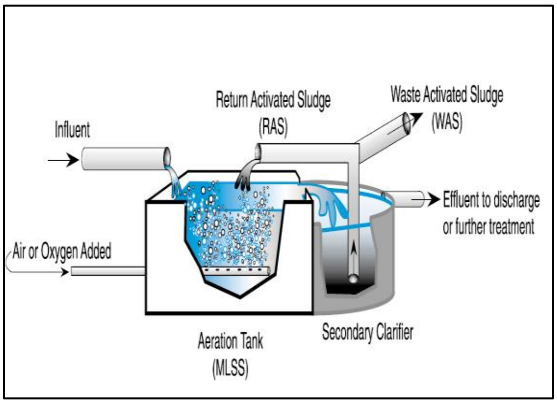
Biological treatment processes are those that use microorganisms to coagulate and remove the non settleable colloidal solids to stabilize the organic matter. Different aerobic biological treatments are as follows:

1. Activated Sludge Process
   - Tapered aeration
   - Extended aeration
   - Contact stabilization
   - Oxidation ditch
2. Trickling filter
   - Standard rate trickling filters
   - High-rate trickling filters.
   - Accelo-filter system
   - Biofiltration
   - Aero-filter system
   - Enclosed filtration.
   - Alternating double filtration
3. Rotating biological contactors
4. Aerated lagoons
5. SBR (Sequencing Batch Reactor)

(Rangwala, 2011; Lateef et al., 2013)

5.1 Activated sludge process:

This Process was developed in England in 1914 by Ardern and Lockett and it was so named as it involved the production of an activated mass of microorganisms capable of aerobically stabilizing a waste. The various modifications of the original process have been made. But in principle, they are fundamentally the same. The term activated sludge is used to indicate the sludge which is obtained by settling sewage in presence of abundant oxygen. The activated sludge is biologically active and it contains a great number of aerobic bacteria and other microorganisms which have a got an unusual property to oxidize the organic matter. The activated sludge process has been employed extensively throughout the world in its conventional form and modified forms, all of which are capable of meeting secondary treatment effluent limits. It includes preliminary treatment consisting of bar screen as a minimum and, as needed, comminutor, grit chamber, and oil and grease removal units (Rangwala, 2011). (http://www.d.umn.edu/~rdavis/courses/che4601/articles/Ac tivated%20Sludge.pdf



In activated sludge process wastewater containing organic matter is aerated in an aeration basin in which micro-organisms metabolize the suspended and soluble organic matter.

Part of organic matter is synthesized into new cells and part is oxidized to CO2 and water to derive energy. In activated sludge systems the new cells formed in the reaction are removed from the liquid stream in the form of a flocculent sludge in settling tanks.

A part of this settled biomass, described as activated sludge is returned to the aeration tank and the remaining forms waste or excess sludge.

5.1.1 Activated Sludge Process Variables

The main variables of activated sludge process are the mixing regime, loading rate, and the flow scheme.

Mixing regime

Generally two types of mixing regimes are of major interest in activated sludge process: plug flow and complete mixing.

Loading rate

A loading parameter that has been developed over the years is the hydraulic retention time (HRT), q, d

q = V/Q Where, V= volume of aeration tank, m3, and Q= sewage inflow, m3/d

5.1.2 Modification in activated sludge process

1. Tapered aeration
2. Extended aeration
3. Contact stabilization
4. Oxidation ditch

5.1.3 Advantages and disadvantages of activated sludge process advantages

- The cost of installation is low.
- The effluent of good quality is obtained.
- The process requires small area of the land and hence, the design may be made compact.
- There is comparatively very small loss of head through the treatment plant.
- There is freedom from fly and odor nuisance due to high degree of treatment given to the sew age in this process.
- Allows good nitrification since COD is uniformly low
- Able to handle peak loads and dilute toxic substances
- Used in smaller systems, like package plants

Disadvantages

- If there is sudden increase in the volume of sewage or if there is sudden change in the character of sewage, there are adverse effects on the working of the process and consequently the effluent of bad quality is obtained.
- The cost of operating the process is relatively high.
- The increased quantity of wet sludge obtained at the end
- and of process requires suitable method for its disposal.
- The process is sensitive to certain types of industrial wastes.
- The process requires skilled supervision for its efficient working. It becomes necessary to ascertain that the sludge actually remains active during the process.

5.2 Trickling filters

These are also known as the percolating filters or sprinkling filters. The concept of a trickling filter was made mainly to design a device which would overcome the limitations of a contact bed and the first trickling filter was put into operation in 1893 in England. The first municipal installation of trickling filter in the States took place in 1908 and since then they have been used to provide the biological sewage treatment. The sewage is allowed to sprinkle or to trickle over a bed of coarse, rough, hard material and it is then collected through the underdrainage system. The oxidation of the organic matter is carried out under aerobic conditions. A bacterial film known as a bio-film is formed around the particles of filtering media and for the existence of this film, the oxygen is supplied by the intermittent working of the filter and by the provision of suitable ventilation facilities in the body of the filter. The colour of this film is blackish, greenish and yellowish. It consists of bacteria, fungi, algae, lichens, protozoa, etc.

5.2.1 Types of trickling filters

The trickling filters are broadly divided in to two categories:

(1) Standard rate trickling filters

(2) High-rate or high capacity trickling filters

5.2.2 Types of high rate trickling filters

- Accelo-filter system
- Biofiltration
- Aero-filter system
- Enclosed filtration.
- Alternating double filtration

5.3 Rotating biological contactors

Rotating Biological Contactors are used to treat in a cost effective manner from 5,000 gallons to millions of gallons per day of domestic and industrial wastewaters. The RBC process provides an extremely high degree of treatment providing effluent qualities as low as 5 mg/l of soluble Biochemical Oxygen Demand (BOD) and 1 mg/lit ammonia nitrogen. They are also used for significantly lowering the levels of soluble organics and Chemical Oxygen Demand (COD) (Kadu et al., 2013)

5.3.1 Advantages

- Low power requirements
- Low construction and installation costs
- Easily installed under any hydraulic gradient,
- Minimum Headloss
- Capability to treat high temperature waste – up to 90OF with standard media material
- Eliminates the need for operator control of oxygen and solids return
- Reduced chemical and electrical needs minimize operation costs
- Flexible design allows for units to be shipped fully assembled or knocked down for assembly in existing buildings
- Treatment flexibility with wastewater flow path variation.

5.4 Aerated lagoon

Aerated lagoon technology, especially that of highperformance systems. This misunderstanding is largely the result of its evolution from the technology of facultative lagoons, in which algae play a vital role and hydraulic retention times are long. In fact, the technology of highperformance aerated lagoons has much in common with that of activated sludge. With proper design and operation, aerated lagoons can deliver effluents that meet limits of 30 mg/L. Furthermore, with modification or with the addition of low-tech process units, they can be designed to nitrify. The major advantages of aerated lagoon systems are their low cost and their minimal need for operator attention. The performance of aerated lagoon systems, as well as the diagnosis and remedies of their operational problems

6.0 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. Advance technology can need to minimize energy consumption like SBR.

6.1 Sequencing batch reactor (SBR)

Amongst the various aerobic technologies, sequential batch reactor (SBR) seems to be the most promising technology for treatment of cheese whey. 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. Hence, savings on the total cost are obtained by elimination of clarifiers and other equipment In recent trends, aerobic granular activated sludge SBR (GAS-SBR) have been reported to give a very high-rate of aerobic treatment and better settling (Wichern et al., 2008). Schwarzenbeck et al., (2005) reported removal efficiencies of 90% COD, 80% TN, and 67% total phosphorus in a GAS-SBR. Loperena et al., (2007) reported that although the commercial and mixed activated-sludge inocula gave similar COD removal in batch experiments for the treatment of a dairy industrial effluent; however, the COD degradation rate was greater for the commercial inoculum.

The treatment efficiency of SBR depends on the operating parameters such as

- Phase duration,
- Hydraulic retention time (HRT) and
- Organic loading,
- Temperature,
- Mixed liquor-suspended solid (MLSS),
- pH,
- Dissolved-oxygen concentration, and
- The strength of the wastewater

Sequencing Batch Reactor has five basic operating: Fill, React, Settle, Draw and Idle (Franta et al., 1997; Bandpi and Bazari, 2004). Amongst 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. Hence, savings on the total cost are obtained by elimination of clarifiers and other equipment (Mahvi, 2008). SBR is often operated with higher TS, thus decreasing investment costs for the treatment plant. The treatment efficiency of SBR depends on the operating parameters such as phase duration, hydraulic retention time (HRT), organic loading, temperature, mixed liquor-suspended solid (MLSS), pH, dissolved-oxygen concentration, and the strength of the wastewater (Kushwaha et al., 2011). Bandpi and Bazari (2004) used a bench scale aerobic SBR to treat the industrial milk factory wastewater. More than 90% COD removal efficiency was achieved when COD concentration was varied from 400 to 2500 mg/l. The optimum dissolved oxygen in the reactor was 2 to 3mg/l and the mixed-liquor volatile-suspended solids (MLVSS) were around 3000 mg/l (Franta et al., 2013)

Neczaj et al., (2008) studied the dependency of the removal efficiency on the operating parameters using two SBR for the treatment of dairy wastewaters having initial COD concentration in the range of 400-7500 mg/l. The aeration time of 19 h and an anoxic phase of 2 h gave 98.6% COD and 80.1% TKN (Total kjeldahl Nitrogen) removal. The removal efficiencies of the SBRs decreased with increasing organic loading or decreasing HRT. The best effluent quality was observed under organic loading of 0.8 kg BOD5/m3 d and HRT of 10 day. Amongst 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. Hence, savings on the total cost are obtained by elimination of clarifiers and other equipment (U.S. Environmental Protection Agency, 1999). The treatment efficiency of SBR depends on the operating parameters such as phase duration, hydraulic retention time (HRT) and organic loading, temperature, mixed liquor-suspended solid (MLSS), pH, dissolvedoxygen concentration, and the strength of the wastewater. Mohseni-Bandpi and Bazari (2004) used a bench scale aerobic SBR to treat the industrial milk factory wastewater. More than 90% COD removal efficiency was achieved when COD concentration was varied from 400 to 2500 mg/l (Wichern et al., 2008)

7.0 Conclusion

In order to reduce energy consumption in aerobic treatment, physico-chemical treatment processes may be combined with aerobic treatment as the primary purification of dairy wastewater. Membrane methods are promising for producing high quality effluent suitable for direct reuse. Combinations of RO, NF, and UF with each other and/or with biological and/or chemical methods are likely to become areas of future research.

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