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AN OVERVIEW ON DAIRY INDUSTRY WASTEWATER AND ITS INDIAN SCENARIO

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Abstract— The dairy industry continues to grow with the growing population. It is considered the most polluting industry in terms of water consumption and wastewater generation. It generates about 6 to 10 litres of organically loaded effluent per litre of milk processed depending upon the products manufactured. Indian Standard (IS) 8682:1977 gives the guidelines for the treatment and disposal of dairy wastewater to protect the environment. The dairy effluent generally has dilutions of milk products generated from washing of floor, storage means such as cans, tanks, milk spillage, liquid effluent of cheese, paneer and yoghurt production called whey. It has high Chemical Oxygen Demand (COD) due to presence of organic contents because of fats, proteins and carbohydrates. To reduce the effect of the dairy wastewater on the environment, it is necessary to adapt some advanced techniques. Generally, all the food industries including the dairy industry look upto the membrane processes to recycle and reuse the wastewater. Membrane filtration is not only used for reclamation and reuse but also for fractionation of whey, recovery from cleaning solutions and various other processes. Thus, this paper is a mini review which gives various details about the dairy industry wastewater.

Keywords— Dairy, milk, recovery, treatment, washing, wastewater

I. INTRODUCTION

The quality of the surface water has deteriorated drastically, states the CPCB report, 2011 (Buabeng-Baidoo et al. 2017). The decrease in the availability of fresh water sources, increase in the cost of procurement of fresh water and generation of huge quantity of effluent has led us to think in the direction of industrial wastewater recycle and reuse (Vourch et al. 2008; Tompe and Wagh 2017). The dairy sector in India is the largest in the world. Milk demand increase with the increase in population (Mulla et.al, 2015). It generates about 6 to 10 litres of effluent per litre of processed milk depending upon the products made in the industry, quantity available and carefulness in usage of water (IS 8682:1977). According to the report published in 2014, dairy consumes about 62 billion m³ of fresh water annually and is expected to

rise to 400 billion m³ by 2025 (Buabeng-Baidoo et al. 2017). Among all the food industries, dairy industry is the most polluting industry in terms of water consumption and wastewater generation (Nagappan, Phinney, and Heldman 2018; Ghatawat et al. 2019). It consumes about 33.96% of water used in all food industries (Nagappan, Phinney, and Heldman 2018). The dairy industry consumes water in Cleaning In Place (CIP) process, in cooling tower operation, as boiler feed and as ingredient in various processes (Nagappan, Phinney, and Heldman 2018; Ezugbe and Rathilal 2020).

II. STANDARD CODE FOR DAIRY WASTEWATER

IS 8682:1977 is the Indian standard code for treatment and disposal of effluents from the dairy and allied industry. This code is a complete compilation of various sources of effluents along with their nature and volume of ill effects with the methods of their prevention, treatment and disposal. The dairies in India mostly make pasteurized and homogenised milk along with ghee from the sour milk (Tompe and Wagh 2017). Some dairies produce ice-cream, cheese, powdered milk, condensed food, baby food, cheese and channa with a few making casein (Shete and Shinkar 2016). India is also experiencing the increase in the production of skimmed milk and toned milk and in the manufacturing of the cheese products in the recent years. (IS 8682:1977).

III. DAIRY WASTEWATER EFFLUENT

According to the wastewater generation standards, allowed wastewater generation in dairy is 3m³/KL of milk processed (EPA rules 1986). Nearly 2% of the milk handled in the dairy goes as a waste (Mehrotra and Trivedi 2018). Wastewater effluent is simple diluted milk and highly biodegradable (Patil, Ahire, and Hussain 2014). The milk has fats, proteins, lactose, minerals and total solids which contributes to the organic content (Ghatawat et al. 2019). The dairy effluent generally has dilutions of milk products from washing of floor, milk spillage, liquid effluent of cheese, paneer, yoghurt production called whey (Vidal et al. 2000; Patil, Ahire, and Hussain 2014). This is always with salts, minerals, detergents, sanitizers, caustic soda, citric acid from



the CIP process, washings from truck, cans, tankers, storage tanks etc (Mehrotra and Trivedi 2018; Mulla Sutar Ranveer 2015). CIP consumes the most water in dairy industry and also contributes maximum to the effluent generated with high pH and salt concentration (Nagappan, Phinney, and Heldman 2018). Table 1 indicates the sources of effluents in dairy industry and its general constituents.

Table-1 Sources and constituents of effluents from dairy industry (IS 8682:1977)

Sr.No.	Sources of effluents in dairy industry	General constituents
1	Effluents from washing cans of milk receiving stations	The wash water consists of milk drippings, rinsing and washing
2	Effluents from pasteurization plant	It contains washing of equipments which contain acid, alkalies, detergents, floor washing, spills and leaks
3	Effluents from manufacture of butter and ghee	Buttermilk, washing of churns and small quantity of butter. Sometimes whole milk, skim milk or cream can also be present.
4	Effluents from manufacture of cheese	Main is discarded whey and washings from vats with that of drains, floor and presser
5	Effluents from casein plant	Whey of milk, mineral acids used for precipitation and washings
6	Effluent from bottle washing plant (bottles and crates)	Alkaline effluent due to use of detergents/ caustic soda
7	Effluent from water softening plant and boiler house	Depending on the use of resins, acidic or highly acidic or saline effluents along with suspended solids
8	Uncontaminated cooling water	Although cooling water can be reused, some cooling water is bled off to prevent built off inorganics and scaling effects
9	Human activities- Toilet, Sanitation	Faecal coliforms, pathogens

IV. OPPORTUNITIES FOR WASTE REDUCTION AND BY-PRODUCT RECOVERY FROM DAIRY EFFLUENT

To make dairy operations more efficient and economical, reduction of wastage and recovery of useful material from waste should be attempted. To achieve this, we need to understand basic operations and adopt some of the methods / procedures listed here:

1. Waste Reduction-This can be achieved by cleaning cans properly with the help of fine spray, preventing overflow, boil over, checking and maintenance of joints to prevent leaks and foaming in pipelines. The reduction in volume of waste by separating clean water from concentrated wastes (Mavrov, Chmiel, and Bélières 2001; IS code 8682:1977 2009).

2. Reclamation of waste products- In abroad, it is used for primary rinsing for feeding animals, for breeding, concentrated and evaporated whey effluent as well yeast on whey as feed for animals (IS code 8682:1977 2009; Azadi, Falahzadeh, and Sadeghi 2015).

3. By Product Recovery- (IS code 8682:1977 2009; Brião et al. 2019; Blandin et al. 2020)

- Butter milk- Recovery of total solids after roller drying and preliminary condensation. The dried powder can be a good source of protein.
- Whey-Pre-condensing in evaporators and spray drying can lead to recovery of whey and used as source of protein in animal feeds.
- Lactose- Whey and milk contains lactose in huge amount. Lactose from whey can be utilized in culturing of yeast which can be used as animal feed.
- Casein-Caseins can be recovered from sour milk by treating with acid and used in the manufacture of resins, plastics, paints and varnishes.
- Butter-Sour or rancid turned butter or cream can be used as raw material in vegetable oil factories.

Dairy wastewater is highly organic in nature. It has high Chemical Oxygen Demand (COD) due to presence of organic contents because of fats, proteins and carbohydrates (Nagappan, Phinney, and Heldman 2018; Wojciech, Beata, and Magdalena 2016). If untreated dairy wastewater is let out in the natural water bodies, it causes eutrophication due to high organic content and excessive nitrogen and phosphorus content (Nagappan, Phinney, and Heldman 2018).

V. POLLUTION CAUSING EFFECTS OF DAIRY WASTEWATER WHEN DISCHARGED IN DIFFERENT SOURCES:

1. Discharge in Inland surface water-

- Depletion of Dissolved Oxygen (DO)- This is the most important problem associated with the dairy industry effluent. When discharged into open nallah or ponds there may be putrefaction due to formation of lactic acid and butyric acid by rapid degradation of lactose, foul odours, breeding of fly, grease floating, growth of aquatic (IS code 8682:1977 2009; Velpula 2017)
- Effect on Fishes- A dilution of 1:15 dairy effluent, excluding whey, has distressing effect on fish. At dilution of 1:35, whey can prove toxic to fishes



within few hours. Soap, lactic acid, butyric acid all are toxic to fishes (IS code 8682:1977 2009; Aydiner et al. 2013).

- Pathogens: Dairy effluent do not contain high number of pathogenic bacteria.
- Radioactivity: Milk as well its effluents can facilitate to concentrate strontium 90 especially on pastures contaminated with radioactive products or fallouts of fission products (IS code 8682:1977 2009; Niamsuwan, Kittisupakorn, and Mujtaba 2011)

2. Discharge on land-

Not all soils are suitable for this purpose. Heavy soils can cause anaerobic conditions to develop with foul odours and ponding, if irrigation system is not designed properly (IS code 8682:1977 2009; Slavov 2017).

3. Discharge into public sewers-

The possibility of sewer water becoming septic in sewer only and more pre-treatment can be required for aeration in sewage treatment plant due to presence of carbohydrates and high temperature of discharge (IS code 8682:1977 2009; Wang et al. 2017).

VI. DAIRY WASTEWATER TREATMENT PLANT

The motive behind designing wastewater treatment systems is to reduce or eliminate contaminants to satisfy discharge regulations. If dairy does not have its own wastewater treatment plant, it sends the effluent to municipal wastewater treatment plant (MWWTP). The MWWTP has set limits for the influent COD, BOD, pH, TDS and if dairy influent exceeds it, they have to pay the penalty. Thus, before discharging the water to waterbodies, treatment is necessary (Nagappan, Phinney, and Heldman 2018). Typical wastewater from all over the world has average COD of about 4000 mg/l, whereas in India it is 500-800 mg/l (Mehrotra and Trivedi 2018). This difference is due to nature of products produced in India and abroad. The dairy industry effluent varies from hour to hour with maximum in afternoon, which is five times of average generally (IS 8682:1977). The pH value, alkalinity, total solids, suspended solids, BOD, COD, oil and grease characteristics of dairy influent and effluent are monitored (Brião et al. 2019). Protein, fat, lactose, total solids, organic solids and BOD of milk and by products are checked (Chandrasekhar 2017).

The five steps in principle for dairy wastewater treatment are 1) Screening, 2) Oil and grease traps, 3) Flow equalization, 4) Activated sludge process, 5) Tertiary treatment along with the reduction of pollution index and reduction in volume and strength of wastewater (Mulla et al., 2015). According to the IS 8682:1977 of dairy treatment, the wastewater plant for dairy should have following units: Screening, Grease traps, Plain sedimentation, Coagulation and flocculation, Equalization and

pre-aeration, Biological treatment which can be done by trickling filter, activated Sludge Process, oxidation ditch, aerobic ponds, anaerobic ponds or stabilization ponds (IS 8682:1977). Focus should not only be on treatment but to reduce cost and efficiency of process and increase profit (Liberman 2018; Aydiner et al. 2014)

The treatment process recommended especially for India by IS 8682:1977 states that dairy treatment plant should have preliminary, primary (with dilution of wastewater) and secondary operations. Secondary operations can be done by oxidation ditch, aerobic lagoons, anaerobic lagoons followed by stabilization ponds. Anaerobic lagoon detention for 10 days would help to reduce BOD by 90% followed by anaerobic lagoon and oxidation pond or dilution to remove residual BOD (IS 8682:1977). Later on, the effluent can be disposed off on agricultural land in irrigation system, drip irrigation, spray irrigation, flood irrigation or furrow if BOD level of effluent is brought below 500 mg/l. The Environment (Protection) Rules, 1986, Schedule VI gives the general standards for discharge of Environmental Pollutants as mentioned in Table 2.

VII. VARIOUS WAYS TO TREAT DAIRY WASTEWATER

To reduce the effect of the dairy wastewater on the environment, it is necessary to adapt some advanced techniques (Mulla et al., 2015). The available treatment methods for dairy wastewater are aerobic, anaerobic, dissolved air flotation (DAF), clarifloculators, advanced oxidation process, activated sludge process, sand bio filters, electrocoagulation, moving bed biofilm reactors, etc. (Nagappan, Phinney, and Heldman 2018). Among the many methods, physio-chemical and biological methods are used mainly to treat the dairy wastewater (Danalewich et al. 1998; Vidal et al. 2000; Al-Shammari et al. 2015). However some studies report the inefficiency of physical process and high cost involved in COD removal through chemical processes (Al-Shammari et al. 2015). The biological process shows good organic removal and better quality effluent (Al-Shammari et al. 2015). The pH of the wastewater generated by some automated cleaning systems varies between 12 to 13. To immobilize biomass for the reduction in COD, BOD₅ and suspended solids of dairy wastewater, biofilm supported media including bricks, foam, gravel was studied and results displayed that the nature and properties of support material. (Qazi et al. 2011).

Table-2 General standards for the discharge of pollutants (EPA rules 1986)



Sr. No.	Parameters	Inland surface water	Public sewer	Land for irrigation	Marine/coastal areas
1.	pH value	5.5-9.0	5.5-9.0	5.5-9.0	5.5-9.0
2.	BOD (5 days, 20°C)	30	350	100	100
3.	COD	250	-	-	250
4.	Suspended solids (mg/l), max	100	600	200	For process wastewater-1000 For cooling water effluent-10% above total suspended matter of effluent cooling water
5.	Inorganic Dissolved solids (mg/l)	2100	2100	2100	-

VIII. MEMBRANE SYSTEM FOR TREATMENT OF DAIRY WASTEWATER

In recent years, shift has been seen towards membrane technologies (Microfiltration, Ultrafiltration, Nanofiltration, Reverse Osmosis) rather than conventional technologies because of their more energy efficiency (Mavrov, Chmiel, and Béliers 2001; Demirel, Yenigun, and Onay 2005; Al-Shammari et al. 2015; Pramanik et al. 2019). Membrane technology works on the principle of selective permeability of components through membrane barrier (Jevons and Awe 2010; Al-Shammari et al. 2015). Generally, all the food industries including the dairy industry look at the membrane processes for water treatment for recycle and reuse (Ezugbe and Rathilal 2020). Microfiltration, nanofiltration, ultrafiltration, low pressure reverse osmosis, two stage nanofiltration, two stage reverse osmosis, integrated membrane process such as nanofiltration and reverse osmosis have been stated to be convenient by several works (Vourch et al. 2008; Kale et al. 2017). Forward osmosis for concentration of waste streams in food and dairy industry has attracted the research interests in recent years due to its low energy consumption and advancement in fabrication of membranes (Wang et al. 2017). Membrane filtration is not only used for reclamation and reuse but also for fractionation of whey, recovery from cleaning solutions and various other processes (Nagappan, Phinney, and Heldman 2018).

IX. CONCLUSION

Dairy industry consumes and generates huge quantity of wastewater which tends to increase with the production of milk for the growing population. The highly organic wastewater needs to be reused and recycled to partly fulfill the huge demand by the dairy industry. The fresh water needs to be recovered in any form from the diluted waste

concentrations to solve the growing water problems of the earth. As compared to many conventional technologies, membrane technologies provide economical and energy efficient solutions for the recovery and reuse of wastewater. Microfiltration, nanofiltration, ultrafiltration, low pressure reverse osmosis, two stage nanofiltration, two stage reverse osmosis, integrated membrane process such as nanofiltration and reverse osmosis have been stated to be convenient. Forward osmosis is the growing technology in the food sector, for the concentration and recovery from the wastewater. As dairy wastewater fluctuates too much in volume and quality, thus heterogeneous wastewater treatment processes are the best options. Final selection of treatment process will depend on volume to be treated, water scarcity, interest of dairy authorities and availability of funds.

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