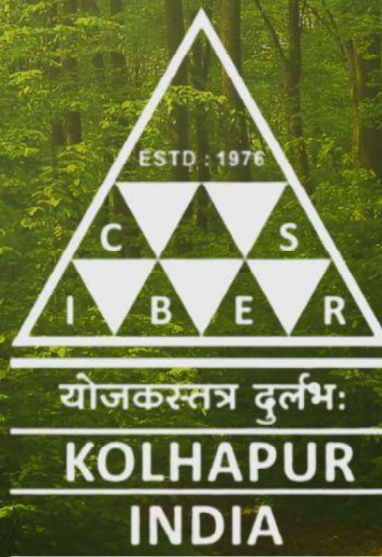




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Treatment and Management of Dairy Wastewater Reference is Gokul Dairy, Kolhapur

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Mr. Piyush Sunil Sharbidre

Abstract

Dairy industries generate large volumes of wastewater that contain high levels of organic matter, nutrients, suspended solids, and fats. Untreated discharge can cause severe environmental problems, including water pollution and ecosystem damage. This study explores various treatment methods for dairy wastewater, evaluates their effectiveness, and provides suggestions for efficient and sustainable wastewater management. Both conventional and advanced treatment methods are discussed, with a focus on biological, physicochemical, and hybrid techniques. Key findings highlight the need for cost-effective, energy-efficient, and eco-friendly solutions for small- and medium-scale dairy farms.

Like all wastes produced by a production plant, dairy wastewater needs to be treated before it is discharged into water bodies. Owing to their composition and organic matter content, biological treatments are emphasised and, currently, activated sludge is one of the most used processes. This treatment, completed by other unitary operations, achieves the quality levels required for the discharge. However, dairy wastewater has interesting potentialities. Its unique composition can support energy production and its treatment, under some conditions, can allow the recovery of water for its reuse. Different technologies are currently available to accomplish these objectives: anaerobic reactor to treat carbon pollution and producing biogas, membrane bioreactor and membrane filtration for treating and producing water for reuse. Some dairy plants already use these technologies and their feedbacks are positives.

Keywords: wastewater treatment, dairy industry, anaerobic reactor, membrane bioreactor, membrane filtration, water reuse, biogas production.

Introduction

The dairy industry is a significant part of the global food sector, contributing substantially to economic development and food security. However, it also poses environmental challenges due to the high volume and pollutant load of its wastewater. Dairy wastewater is primarily composed of milk residues, detergents, sanitizers, and other processing chemicals. If not treated properly, it can contaminate water bodies, harm aquatic life, and affect public health. This paper aims to provide an in-depth review of current treatment technologies, identify gaps, and suggest feasible solutions for sustainable dairy wastewater management.

The demand for milk and dairy products has increased significantly worldwide, leading to a rise in the number of dairy industries. Dairy waste management is crucial to minimize environmental harm by handling and disposing of byproducts effectively. Dairy wastewater, a byproduct from milk processing, contains high organic content such as lactose, proteins, whey, and salts. If discharged untreated, these can cause severe environmental damage.

In India, the dairy sector has grown rapidly and has become one of the largest milk producers globally. However, the dairy industry also contributes heavily to pollution due to the high organic load in wastewater, which necessitates advanced treatment methods. The goal of dairy waste management is to separate valuable components like lactose and protein from wastewater using technologies like ultrafiltration.

Milk and Milk Products have to be considered to be an important nutritional food because they are good sources of proteins, vitamins and calcium. The dairy sector in India has shown remarkable development in past decade and India has now become one of the largest producers of milk and value added milk products in the world. The dairy sector has developed through co-operatives in many parts of the State. During 1997-1998, the state had 60 milk processing plants with an aggregate processing capacity of 5.8 millions liters per day. In addition to this processing plants, 123 government and 33 co-operatives milk chilling centers operate in the state.

Dairy is considered to be one of the most important agriculture based industry in Indian scenario but despite of this fact dairy industry is also one of the most polluting industries in terms of the organic content in dairy effluent. This effluent contains a high concentration of organic matter mainly lactose, protein, whey, and mineral salts. They can be harmful to the environment, if discharged directly with the other liquid effluents from the dairy industry. It requires multistage processing before its discharge. Additionally, the milk components present in the effluent possess large applications in food, chemical and drug industry. In this study, separation and recovery of components from dairy effluent was investigated. The Polysulfone (PSF) membrane based ultrafiltration process was adopted to separate lactose and protein with high yield and purity. The quantitative analysis were done for the recovery of the milk components from the effluent and it was observed that upto 90% of the lactose recovery could be achieved using the advanced separation technology.

A large amount of effluent is generated during the processing of milk in dairy. This Effluent is characterized by their relatively increased temperature, high organic content and wide pH range, which requires special

purification in order to eliminate or reduce environmental damage. Conventionally it is done by the destructive methods like aerobic or anaerobic digestion. This leads to loss of nutritional components like proteins and lactose from the effluent. The effluent is characterized by high biological oxygen demand and chemical oxygen demand concentrations. It decomposed rapidly and depletes the dissolved oxygen level of the receiving streams immediately resulting in release of strong foul odour due to nuisance condition. Thus it is highly necessary to treat the effluent before its discharge. On the other hands the components from this effluent possess very high nutritional, food and drug value. Hence their recovery is highly advisable.

Dairy wastewater is a byproduct generated during the processing of milk and other dairy products. When milk is transformed into cheese, yogurt, or butter, water is used in various stages—cleaning, cooling, and even direct incorporation into the products. However, this water doesn't exit the process as it entered; it becomes dairy wastewater. Laden with organic materials, chemicals, and residues. Therefore, it isn't something you can simply pour back into nature without consequences to aquatic life and even human health.

Literature Review

Moodley et al. (2024) – Enzyme-based Anaerobic Digestion

Used enzyme-producing microbes to pre-treat dairy wastewater, improving biogas yield and organic removal. Found effective but cost-intensive.

Gavlak et al. (2024) – Mobile Bed Membrane Bioreactors

Improved traditional MBRs by adding mobile beds. Achieved >98% COD removal and better membrane performance. Reduced cleaning needs.

Shapiro Ellis et al. (2025) – Nutrient Recovery with Biochar

Tested biochar to recover nitrogen and phosphorus from dairy wastewater. Showed effective nutrient adsorption and potential for reuse.

Kanagam & Rajasekaran (2023) – Algal (Phycoremediation) Treatment

Applied microalgae to treat dairy effluents. Achieved good nutrient and BOD/COD removal. Also generated usable algal biomass.

EAOPs Review (2024) – Electrochemical Oxidation Methods

Reviewed electro-Fenton, photo-electro-Fenton, etc. Effective in removing tough pollutants. High energy and chemical costs limit scale-up.

Rajeshwari et al. (2000) – Anaerobic Treatment Systems

Investigated anaerobic digestion (especially UASB reactors) for high-strength industrial wastewater including dairy effluents. Reported over 80% BOD and COD removal with biogas recovery. Recommended anaerobic pre-treatment followed by polishing steps for best results.

Kushwaha, Srivastava & Mall (2011) – Integrated Treatment Approaches

Reviewed biological and physico-chemical treatment methods. Highlighted the effectiveness of combined treatments (e.g., coagulation followed by aerobic biological treatment). Identified limitations of conventional treatments in removing color, odor, and nutrients.

Cosenza et al. (2013) – Membrane Bioreactors (MBRs)

MBRs demonstrated superior pollutant removal and space efficiency. Issues like membrane fouling and operational cost remain challenges. Suitable for medium-to-large dairy plants with high wastewater volumes.

Prajapati et al. (2014) – Algal and Biological Treatment

Studied the use of microalgae for nutrient removal and biomass generation. Emphasized the dual benefit: wastewater treatment and resource recovery (biofuel, fertilizer).

Simate et al. (2011) – Advanced Oxidation and Electrochemical Techniques

Reviewed ozone, Fenton, UV, and electrocoagulation methods. Effective in removing refractory pollutants and disinfecting effluents. High energy and chemical costs limit large-scale use.

Objectives

The main objectives of this study on dairy waste management are:

1. To explore the concept of wastewater management in the dairy industry.
2. To analyze the role of Effluent Treatment Plants (ETP) in dairy waste management.
3. To understand the significance of dairy waste management in environmental protection.
4. To promote water reuse and recycling in dairy industries.

Research Methodology

The study is based on:

Exploratory Study: Investigating the current practices and challenges in dairy waste management.

Survey Research: Gathering data through surveys of dairy effluent treatment plant workers and industry experts.

Data collection methods include:

Primary Data: Direct observations and surveys in the dairy industry.

Secondary Data: Secondary data refers to information collected by someone else, often for different purposes, but is available for use. Existing literature, reports, and databases on dairy waste management.

Scope of Dairy Wastewater Management:

1. **Pollution Control:**
Treating dairy wastewater helps prevent environmental pollution, especially of water bodies.
 2. **Water Reuse:**
Treated water can be reused for cleaning, gardening, or cooling systems, reducing freshwater demand.
 3. **Resource Recovery:**
Nutrients (like nitrogen and phosphorus) and by-products (like biogas from anaerobic digestion) can be recovered.
 4. **Regulatory Compliance:**
Proper wastewater management helps dairy industries comply with environmental laws and avoid penalties.
 5. **Public Health Protection:**
Prevents contamination of drinking water sources and reduces risk of waterborne diseases.
 6. **Sustainable Operations:**
Supports eco-friendly practices and improves the sustainability of dairy industries.
 7. **Cost Savings:**
Long-term savings through water recycling, energy recovery, and reduced waste disposal fees.
 8. **Corporate Social Responsibility (CSR):**
Enhances the company's image by showing commitment to environmental protection.
- Effective dairy waste management is crucial due to the following reasons:

Environmental Protection: Improper waste disposal can lead to water pollution, soil contamination, and air pollution, harming ecosystems and public health.

Resource Recovery: Dairy waste contains valuable components such as organic matter, which can be used for biogas production and as fertilizers.

Economic Benefits: Efficient waste management reduces disposal costs and increases dairy operation profitability.

Pollution Control: Dairy wastewater is rich in nutrients, and untreated discharge can cause eutrophication in water bodies, depleting oxygen levels and affecting aquatic life.

Soil Protection: Wastewater high in BOD and COD can degrade soil fertility if used untreated for irrigation.

Odor and Aesthetic Issues: Untreated waste can cause foul smells and unsightly conditions, especially near dairy plants.

Technical Process

The technical process involves several stages:

Milk Reception: Chilling and testing for quality.

Pasteurization: Heating milk to 72°C for 15 seconds to kill harmful bacteria. **Homogenization:** Ensures uniform fat distribution.

Separation and Standardization: Separation of cream and adjustment of fat content. **Product Manufacturing:** Milk is converted into products like ghee, curd, and paneer. **Packaging:** Hygienic and tamper-proof packaging.

Effluent Treatment Plant

Effluent Treatment Plants (ETPs) play a crucial role in maintaining environmental compliance and sustainability at Gokul Dairy. The plant is designed to treat and safely discharge wastewater generated during the production of milk and other dairy products.

Nature and Characteristics of Dairy Effluent

High BOD: 1000–3000 mg/L High COD: 2000–5000 mg/L High TSS: 500–2000 mg/L Presence of fats, oils, and greases Wide pH range (4.5 to 9.0)

High levels of nitrogen, phosphates, and pathogens



Fig No.1 Sewage treatment plant

Stages of Effluent Treatment

A. Preliminary Treatment Screening: Removes large solids.

Slag Removal Tank: Filters heavy solids.

Fat Removal Tank: Uses bacteria for aerobic degradation.

B. Equalization Tank

Buffers pH and flow rate to prevent shock loading.

C. Anaerobic Treatment (UASB) Reduces BOD/COD by 80–90% Produces biogas for energy use

D. Aerobic Treatment Retention Time: 18–20 hrs DO: 1–2 mg/L

Uses stirrers, nutrients (urea, DAP)

E. Clarifier Removes sludge

Recycles or dries sludge

F. Tertiary Treatment

Final filtration, pH correction

Treated water reused for irrigation/gardening

Chemical Dosing and Monitoring

Chemicals: HCl/NaOH (pH), Alum/PAC (coagulants), Urea/DAP (microbial support) Monitoring: pH, BOD, COD, DO, TSS

Performance Metrics

Parameter	Raw Effluent	Treated	MPCB Norms
pH	5.0–7.5	6.5–7.8	5.5–9.0
BOD	2500 mg/L	20–30	≤30
COD	4500 mg/L	200–250	≤250
Oil & Grease	80–100 mg/L	5–10	≤10
TSS	1200 mg/L	50–100	≤100
TDS	2500–3500 mg/L	1800–2000	≤2100

Environmental & Economic Benefits

Biogas recovery helps in cutting energy costs by utilizing waste for energy generation. Water reuse is implemented for non-potable purposes, conserving freshwater resources. Treated sludge is used as fertilizer, thereby serving as manure and reducing waste.

The system ensures regulatory compliance by meeting MPCB norms.

Challenges and Recommendations

It is important to improve sludge management to enhance efficiency and reduce environmental impact.

Expanding membrane filtration can improve water quality and system performance.

There is a need to integrate automation and sensors for better monitoring and control of processes.

Regular training for ETP staff is recommended to ensure proper operation and maintenance.



Fig no. 2 Effluent treatment plant

Findings

- The Biochemical Oxygen Demand (BOD) was reduced from an average of ~2500 mg/L in raw effluent to ~25 mg/L in treated effluent, achieving a ~99% reduction, which is well within the MPCB limit of 30 mg/L.
- The Chemical Oxygen Demand (COD) showed a similar reduction from ~4500 mg/L to ~225 mg/L, again meeting the MPCB standard of 250 mg/L.
- Total Suspended Solids (TSS) dropped from ~1200 mg/L to ~75 mg/L, complying with the limit of 100 mg/L.
- pH levels were adjusted from an acidic range (5.0–7.5) to a neutral and acceptable range (6.5– 7.8), staying comfortably within the MPCB-prescribed range (5.5–9.0).
- All treated effluent parameters consistently complied with MPCB discharge standards on a daily basis, showing stable and efficient performance of the treatment plant.
- Daily monitoring data shows minimal fluctuation in performance, suggesting well-maintained operations, timely interventions, and effective treatment process management.
- The treatment process ensures that no untreated or non-compliant wastewater is released into the environment, supporting the dairy's commitment to sustainability and pollution control.

Suggestions / Recommendations

Automate Monitoring and Data Logging

Implement digital sensors and SCADA systems for real-time monitoring of key parameters like pH, BOD, COD, and flow rate to improve accuracy and reduce manual errors.

Conduct Periodic Efficiency Audits

Perform monthly or quarterly efficiency audits of the ETP to identify operational bottlenecks and ensure consistent compliance with MPCB norms.

Install Flow Equalization Tank (if not present)

A flow equalization tank can help manage fluctuations in wastewater volume, improving the consistency and effectiveness of treatment.

Regular Maintenance and Sludge Management

Schedule preventive maintenance of pumps, aerators, and filters.

Ensure proper sludge disposal or reuse, as sludge buildup can affect treatment efficiency and lead to odor issues.

Introduce Waste Minimization at Source

Encourage water-saving measures in dairy processes to reduce the load on the ETP. Segregate high-load wastewater (e.g., from cleaning processes) to allow targeted treatment.

Conclusion

Effective dairy waste management is essential for environmental protection, resource recovery, and cost savings in dairy industries. With growing milk production, the need for proper effluent treatment systems. Dairy wastewater poses a significant environmental challenge, especially in regions with intensive dairy farming. While several treatment technologies exist, their feasibility depends on scale, cost, and local conditions. An integrated and context-specific approach is essential for effective treatment. Investment in sustainable technologies, combined with regulatory support and education, can mitigate the environmental impact of dairy wastewater and promote a circular economy within the dairy sector.

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