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Treatment of Dairy Industry Effluent using Membrane Bioreactor

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ABSTRACT

The raw milk is processed into various milk products in the dairy industry like consumer milk, butter, cheese, ghee and other bi-products handled each day. The increased production of milk based food products by these industries leads to generation of large quantity of wastewater consisting of high levels of organic contaminants, which leads great damage to aquatic ecosystem. There are many methods available for treatment of dairy effluents generated from different dairy industries but among those, the application of membrane technologies has become an emerging arena. These applications are more energy efficient as compared to conventional methods. In the present study treatment of dairy industry effluent was performed using membrane bioreactor technology (MBR). Several physico-chemical parameters like pH, temperature, conductivity, turbidity, total dissolved solids (TDS) and chemical oxygen demand (COD) were assessed. Mixed microbial culture were used in side stream MBR (HF-UF) incorporated with UF10KDa MWCO membrane and found effective in reducing TDS from 4220 to 1590 ppm, turbidity from 32 to 3 FAU, conductivity from 11 to 2.7 S/m and COD from 6000 to 280 mg/L. Further analysis was studied by integrating MBR with RO membrane (graphical sketch). The RO treated water revealed a TDS of 415 ppm, turbidity 1 FAU, conductivity 2.6 S/m and COD 150 mg/L. Only MBR treated effluent showed 95.33% COD, 62.3% TDS and 90.6% Turbidity, whereas MBR integrated with RO exhibited 97.5% COD, 90.2% TDS and 97% Turbidity reductions respectively. MBR integrated with RO treated water can be recycled for industrial purpose in cooling systems, groundwater recharge, recreational lakes, washing plant floor's, aquaculture, cattle/poultry industry, green irrigation purposes and other indirect human uses etc.

Key words: *Dairy Effluent, Membrane Bioreactor, COD rejection, Flux, Water recovery.*

INTRODUCTION

Water is one of the precious natural sources for human survival and industrial development and it is essential for the existence, survival and metabolic process of all living organisms[1]. The quality of water resources usually depends on its physical, chemical and biological characteristics.

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The need of water source has increased due to rapid growth in population, industrialization and improved living standards[2]. Major water sources on the earth surface are saline water (seawater) i.e. of 99% and remaining 1% water sources on earth and ground includes fresh water bodies. Ground water is an important source for agriculture, domestic and industrial purposes. Now a day, the quality of ground water level is getting decline due to the population explosion, urbanization and industrialization in major cities and urban circle[3]. Among the major industries in India, food industry is one of the highest consumption of water and one of the biggest producers of effluents per unit of production. The dairy industry is one of the sector produces large quantity of waste such as solids and liquids, in addition they generate a large volume of sludge during biological treatment[4,5].

Milk plays an important in human life. Dairy industry includes processing of raw milk into products like consumer milk, butter, cheese, ghee and other bi-products etc. The quantity of water required in a milk processing plant depends upon the size of the plant and the processes involved[6]. The wastewater generated from milk processing through milk spillage, drippings, washing of cans, tankers, bottles, equipments and floors etc. Generally this wastewater contains large quantities of fat, casein, lactose, and inorganic salts, besides detergents, sanitizers etc used for washing[7]. Dairy industry is a multi product based factory, where milk is processed and various milk products are manufactured. Large amount of liquid waste generated from dairy industry contains high organic loads, odorous with high levels of chemical oxygen demand (COD), biological oxygen demand (BOD), oils and grease, nitrogen and phosphorus. Loss of valuable biomass and nutrients are much higher than permissible limits in effluent water. If the milk processing industries discharges untreated/partially treated wastewater into environment that causes major ecological challenges and serious affect on environmental problems normal operations of ecosystems, flora and fauna[8,9,10]. To reduce the high load content of pollutants in wastewater generated from food industries like dairy industry several methods are available but shows very poor performance with high production of sludge, when compared to conventional treatment processes. Among various available methods, membrane filtration technology is considered as one of the promising process for treatment of wastewater for reuse1[1,12,13].

ROLE OF MEMBRANE TECHNOLOGY

Membrane filtration technology is a pressure driven process in which membrane acts as a selective barrier for passage of clear water through it and it restrict the passage of organic and inorganic pollutants, suspended solids, dissolved solids, nutrients, turbidity, microorganisms etc. The membrane filtration process is classified into four classes based on pore size, such as microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO). Several studies reported that ultrafiltration and reverse osmosis process was used for treatment of different wastewaters for the production of reusable water can use for various applications[14]. Past few years membrane bioreactor (MBR) technology is practically proven and one of the most effective and economically feasible for treatment of different types of effluents with high strength, toxicants with high level of organic loads etc can be removed. Present study reveals that ultrafiltration membrane which is made up of ployethersulfone with molecular weight cut-off 10 KDa is used for treatment of dairy wastewater with combination of mixed microbial culture for biological treatment. Permeate which is obtained from this process is passed through RO membrane to get high quality water for reuse and other parameters was studies and analyzed[15].

The main aim of this study is to evaluate the applicability for treatment of dairy industry wastewater by using biological and physico-chemical methods with hydrophilized ultrafiltration membrane for membrane bioreactor (MBR) through aerobic process followed by reverse osmosis (RO) for reuse water in various applications. Initially study was evaluated for removal efficiency of organic matter, suspended solids, dissolved solids and color intensity with MBR process and combined with RO system to get high quality water for reuse. The treated effluent/water is used for various purposes after characteristics analysis with the standards of APHA. It is very important to use reverse osmosis as next step to get high quality of product for further reuse of treated water in cooling towers, gardening, toilet flushing and other purposes. This work is carried out to minimize dairy wastes which are directly discharged into environment that causes harm to aquatic and other problems by using UF membrane process[16,17].

COLLECTION AND PRESERVATION OF DAIRY INDUSTRIAL EFFLUENT

The effluent was collected from a dairy industry which has capacity of 50000 Litres/day. The sample was collected in a clean sterile plastic container of 30 litres and analysis was carried out according to the standard methods of American Public Health Association (APHA)[18,19].

CHARACTERZATION OF DAIRY EFFLUENT

Dairy effluent was collected in sterile plastic containers and brought to the laboratory. Physio-chemical characteristics of the sample like pH, total dissolved solids (TDS), total suspended solids (TSS), Turbidity, Conductivity, COD and BOD etc values were analysed and mentioned in below Table 1.The techniques and methods for collection, preservation and analysis of effluent are followed by standard procedures[20,21,22,23,24].

Table: 1. Characteristics of dairy wastewater

S. No	Quality parameter	Units	Feed value
1	pH	-	8.66
2	TDS	ppm	4220
3	TSS	mg/L	2875
4	Turbidity	FAU	32
5	COD	mg/L	6000
6	Conductivity	mS/cm	11

ISOLATION OF MIXED MICROBIAL CULTURE

The mixed microbial culture was isolated form dairy effluent which was collected. Isolation of mixed microbial culture from sample was serially diluted in sterile distilled water and plated on nutrient agar plates. Agar plates were incubated at 30±2°C over night incubation and morphological colonies were observed. Isolated colonies were in pure form and maintained on slopes of respective agar slants for further experimental purpose.

PREPRATION OF INOCULUMS

In order to prepare inoculums, a loop full of freshly grown colonies on agar plates/slants was transferred into a 1000 ml of conical flask containing 500 ml of nutrient broth media incubated at 30°C for overnight in an incubator. For preparation of 1 liter nutrient broth 1000 ml of distilled water was taken and kept in an autoclave at 121°C for 15 minutes and 15 lbs pressure[25].

a. TREATMENT OF DAIRY INDUSTRIAL EFFLUENT

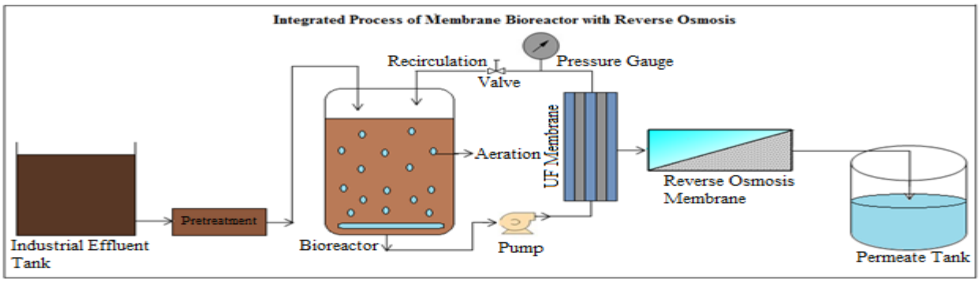

Fig. 1: Schematic diagram of aerobic integrated SSMBR+RO

b. DESCRIPTION OF SIDE STREAM/EXTERNAL MBR (SSMBR)

Fig. 2: Experimental Setup of Side Stream Membrane Bioreactor (SSMBR)

Description of side stream/external MBR (SSMBR) aerobic integrated with RO was explained in Fig 1. The experimental model of SSMBR with 30L feed capacity is described in Fig 2. The reactor was side stream/external with Hydrophilized Ultrafiltration (HF-UF) membrane module of 10 KDa molecular weight cut off (MWCO) and the flow line was connected to a booster pump to membrane for drawing the permeate as final treated effluent. The industrial wastewater was taken into reactor to which 8% of mixed microbial culture was added and oxygen was supplied for aerobic digestion by the aerator. The filtration unit was operated in batch mode at normal room temperature. The wastewater level in the bioreactor was maintained constant in order to keep the hydraulic retention time (HRT) at a value of 25 days was 23 L/h. Continuous coarse bubble aeration by air diffuser was applied to promote local cross flow velocity along the membrane surface and simultaneously produce enhanced dissolved oxygen (DO).

ANALYTICAL MEHTODS

The performance of the MBR system was assessed by monitoring both water quantity and quality under various operating conditions. The rate and extent of the membrane fouling were quantified by determining permeate flux at constant suction pressure. The water quality parameters were measured for the permeate water produced by MBR system. Permeate and reject samples were analysed at regular intervals for TDS, TSS, COD according to APHA methods. Turbidity was evaluated by using a HACH make DR/890-Calorimeter. The conductivity was determined using DCM-900 model digital conductivity meter, Global Electronics, Hyderabad, India) and pH was determined using model DPH-504 pH meter, Global Electronics, Hyderabad, India). COD was determined by closed reflux titrimetric method and modified Winkler's method. The total suspended solids concentration was assessed by weighing a sample after filtering with whatmann filter and drying for an hour at 105ºC [26,27].

MEMBRANE FOULING AND ITS PREVENTION

In general, fouling of membrane is caused by suspended solids, inorganic salts, microbes and organic compounds present in the feed water that accumulate either on the membrane surface or within the pores. The membrane modules were removed out from the reactor and cleaned at regular intervals, of 1hour each by chemical cleaning followed by backwashing with water at 0.2 bar pressure. Chemical cleaning was performed by treating with 2-3 % citric acid, washed for 20 min followed by water wash for 10 min. The membrane was further washed with 0.5% mixture of NaOH and EDTA for 20 min followed by water wash for 10 min. Further the membrane was washed with 1% of SLS followed by water wash for 10 min. Following the above washes the scales formed were completely removed. In case the colour persists in the recirculation tank was subject to the membrane for an additional wash[28,29]. For further use of membrane for experimental purpose, membrane can be stored in sodium metabisulphite (SMBS).

RESULTS AND DISCUSSION

Water quality from milk processing unit was assessed by analysing physico-chemical characteristics of wastewater.

Table 2: Characteristics of industrial wastewater before and after MBR process

S. No	Parameters	Units	Feed	MBR Permeate
1	Total Dissolved Solids (TDS)	ppm	4220	1590
2	Turbidity	FAU	32	3
3	Conductivity	mS/cm	11	2.7
4	Chemical Oxygen Demand (COD)	mg/L	6000	280
5	pH	-	8.66	8.19

Table 3: Characteristics of industrial wastewater by integrating with MBR+RO

S. No	Parameters	Units	MBR Permeate	RO Permeate
1	Total Dissolved Solids (TDS)	ppm	1590	415
2	Turbidity	FAU	3	1
3	Conductivity	mS/cm	2.7	1.6
4	Chemical Oxygen Demand (COD)	mg/L	280	150
5	pH	-	8.19	6.93

pH

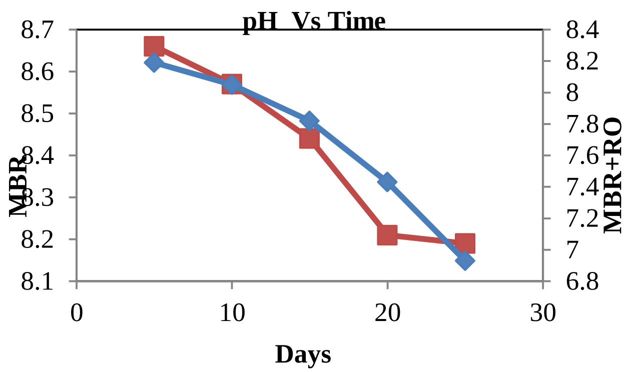

Fig. 3: Decrease in maximum range of pH

pH is one the important parameter of wastewater which shows acidic and alkaline based on its intensity. In this experiment initial pH of the industrial wastewater (feed) is 8.66. After that it was observed that the gradual decrease in pH from 8.66 to 8.19 over a period of 25 days of experimental performance in which permeate comes to base which is non hazardous to the environment in Fig 3. The extreme pH i.e., very high acidic or low basic ranges of pH causes problems to aquatic life survival in the wastewater. The water with high or low pH is not suitable for agriculture and irrigation purposes. After collection of MBR permeate was passed through RO membrane, pH value was decreased from 8.19 to 6.93, pH was reached to neutral.

Total Dissolved Solids (TDS)

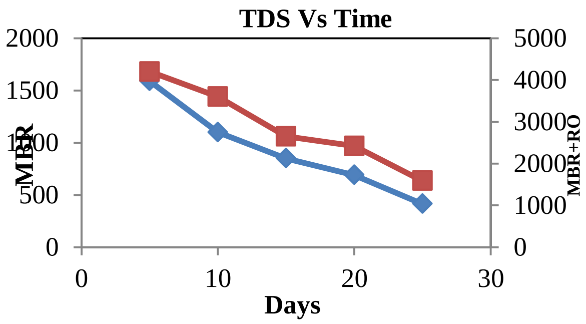

Fig4: Reduction of TDS from high to low level

Total dissolved solids was measured based on organic and inorganic contents present in the solution/liquid which have taken for experiment. The effluent samples which are released from various industries show higher TDS when compared to permissible limit of WHO and Indian standards. In the present study the inlet feed sample TDS is 4200 ppm. After treatment by using HF-UF 10KDa membrane for 25 days experimental performance the TDS was decreased to 1590 ppm. The microbial consortia used in this process play key role in reduction of high TDS from 4220 to 1590 ppm as shown in Fig 4. MBR permeate was passed through RO membrane, TDS value was reduced from 1590 to 415, this also we can see in Fig 4. The effluent without treatment if discharged into the environment causes many problems to aquatic organisms and human health.

Turbidity

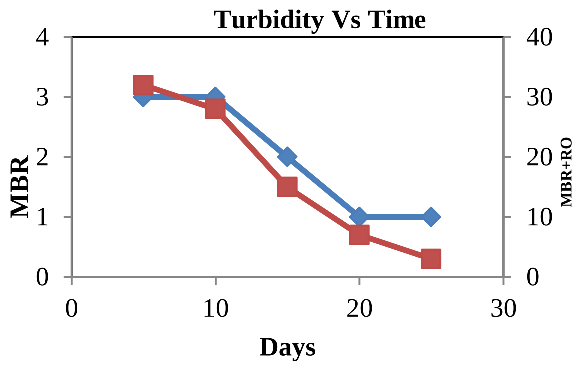

Fig. 5: Removal of turbidity

Turbidity was measured by using calorimeter DR890 with the units of FAU, mainly turbidity was depends on the strength of wastewater. The industrial wastewater (feed) initial value was 32 and filtrate turbidity value was 3 after experimental process was carried out for 25 days by using both biological treatment and membrane process as shown in Fig 5.Fig 5 also illustrates that, MBR permeate after passing through RO membrane, the turbidity value was decreased from 3 to 1.

Electrical Conductivity (EC)

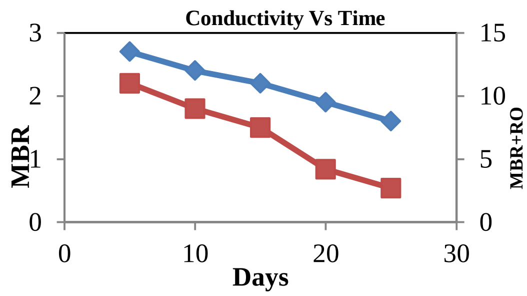

Fig. 6: Decrease in electrical conductivity

The electrical conductivity is one of the important parameter and its ability is measured based on presence of ions, concentration and temperature of wastewater. The initial value of electrical conductivity for the industrial wastewater (feed) was 11µS/cm. After 25 days of experimental performance the electrical conductivity was decreased from 11 to 2.7µS/cm. The electrical conductivity was measured in unit of Micro Siemens per cm (mS/cm) as recommended by the membrane manufactures. The permeate value was found to be 2.7 mS/cm by using HF-UF 10 KDa membrane as presented in Fig 6. MBR permeate was passed through RO membrane, the electrical conductivity was decreased from 2.7 mS/cm to 1.6 mS/cm. High electrical conductivity value shows harm to the plant growth, soil and also irrigation problems like crop yield.

Chemical Oxygen Demand (COD)

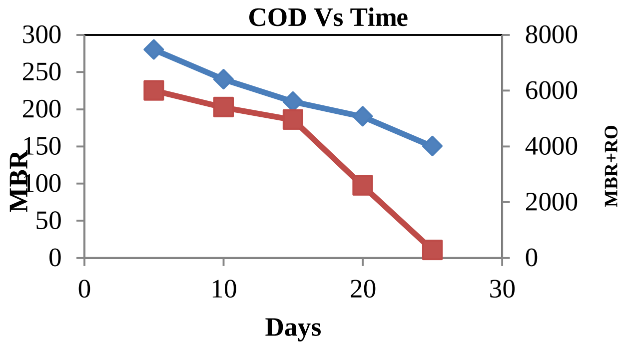

Fig. 7: Reduction of COD

Chemical oxygen demand (COD) test is used for measuring the organic strength/matter of effluents. This test is used to measure the pollutants with high levels of COD present in industrial wastewater that shows negative impact on environmental sustainability. It is measured in terms of total quality of oxygen required for oxidation of carbon dioxide and water. COD was analysed during the treatment of industrial wastewater with biological process for degradation of organic matter and it shows effectiveness for the treatment. From Fig 7, experimental graph shows that the COD is reduced from 6000 mg/L to 280 mg/L was performed for 25 days. Fig 7 also illustrates that, MBR permeate after passing through RO membrane, the COD value was reduced 150mg/L. In this COD reduction was takes places especially by biological treatment and membrane process. The removal efficiency of COD was 97.5% this is due to reduction or degradation of organic content which run through aerobic system of operation.

Colour Intensity

Fig. 8: Reduction of colour intensity

The colour of the wastewater depends upon different industrial processes. Removal of colour from wastewater is one the essential qualitative parameter for treatment. Fig 8 shows that variation of colour for initial feed effluent, MBR treated water and MBR+RO treated water. In present study, the colour of initial wastewater is blackish, after a period of experimental studies for 25 days by using HF-UF membrane process and biological treatment the water colour was changed to pale yellow. Colour is measured by comparison with standards. Permeate obtained after MBR process was further processed through RO membrane we get high quality of water.

Microbial Culture

Fig. 9: Microbial culture grown on agar plate

After collection of dairy industrial effluent which was serially diluted on nutrient agar plates for the growth of microbial culture. The serially diluted nutrient agar plates were performed from 10^0 to 10^{-6}. The colonies were isolated from 10^{-3} agar plate and were inoculated into the nutrient broth for experimental performance along with membrane process. Fig 9 shows grown mixed microbial culture on agar plate.

CONCLUSION

In this study, the treatment of dairy effluent was investigated using an efficient technology Membrane bio-reactor with an integrated Reverse-osmosis setup. The performance of experiment was assessed based on COD, TDS, Turbidity, Conductivity rejection values. The removal of both organic and in-organic pollutants was very high and good quality of permeate which is colourless has been achieved. The MBR integrated with RO system did however achieve a higher rejection of COD and TDS compared to the MBR alone, this integration revealed new insights in terms of effluent treatment compared to conventional techniques. In this spiral wound Hydrophilized Ultrafiltration (HF-UF) membrane of 10 KDa MWCO were used for the treatment of dairy effluent which exhibited a considerable reduction in TDS, COD and turbidity. MBR integrated with RO results show 90.2% TDS, 97.5% COD, 97% Turbidity and 85.5% Conductivity reductions respectively.The main advantage of MBR integrated with RO treated water can be recycled for industrial purpose in cooling systems, groundwater recharge, recreational lakes, washing plant floor's, aquaculture, cattle/poultry industry, green irrigation purposes and other indirect human uses etc.

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