

TREATMENT OF DISTILLERY WASTEWATER USING MEMBRANE TECHNOLOGIES

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ABSTRACT

The purification of waste water from various industrial processes is a world wide problem of increasing importance due to the restricted amounts of water suitable for direct use, the high price of the purification and the necessity of utilizing the waste products. Maintaining the drinking water quality is essential to public health. Although various water treatments is a common practice for supplying good quality of water from a source of water, maintaining an adequate water quality throughout a distribution system has never been an easy task.

Municipal, agricultural and industrial liquid or solid wastes differ very much in their chemical, physical and biological characteristics. The diverse spectrum of wastes requiring efficient treatment has focused the attention of researchers on membrane, ion-exchange and biological technologies. The most effective and ecological technological systems developed during the past 20 years are as a rule based on a combination of the chemical, physical and biological methods. Anaerobic digestion, anaerobic filters, lagoons, activated sludge and trickling filters have all been successfully applied to the treatment of distillery wastewater. Membrane and membrane separation techniques with immobilized microorganism or enzyme have very significant role in treatment of distillery wastewater.

1. INTRODUCTION

1.1 BACKGROUND

In recent years, membranes and membrane separation techniques have grown from a simple laboratory tool to an industrial process with considerable technical and commercial impact. Today membranes are used on a large scale to produce potable water from the sea by reverse osmosis, to clean industrial effluents (distillery wastewater) and to recover valuable constituents by electrodialysis. In many cases, membrane processes are faster, more efficient and more economical than conventional separation techniques. With membrane, the separation is usually at ambient temperature, thus allowing temperature-sensitive solutions to be treated without the constituents being damaged or chemically altered. There are two major types of waste inorganic waste and organic waste. Organic wastewaters are potent sources of water pollution.

Various organic wastewaters that are known to cause serious problems may be attributed to distillery effluents, pulp and paper effluents, textile effluents, and tannery effluents, among others. Among these types distillery wastewater is highly charged with organic matter, when dumped into water sources without treatment or with inappropriate treatment, causes serious pollution. Among the raw material sources for distillery, two very important raw materials are cane sugar molasses and beet sugar molasses. Molasses is a by-product of the extraction process and is heavily used as a raw material in many distilleries around the world. The discharge of wastewaters from wineries and distilleries is becoming increasingly restricted as pressures from environmental regulations increase and as awareness of the negative impacts of seasonal discharges of water containing high nutrient and organic loadings into water courses spreads. Raw stillage discharge has a highly deleterious effect on fish life. Stillage has been proposed for use as a fertilizer, food supplement, biomass production agent, animal feed, and potash source

1.2 OBJECTIVE AND SCOPE

Now a day's wastewater treatment is not an easy task. For distribution of water to the public it is necessary. The distillery wastewater has high amount of organic

matter so without treatment pull down in water stream is not ethical. Objective of my study is treatment of distillery wastewater using membrane technologies. The scope is to first characterize the distillery wastewater and membrane technology, then by these studies membrane techniques use for treatment of distillery wastewater.

Firstly a full description of distillery wastewater which consist of composition of distillery wastewater, source, effect, zero discharge system of distillery then about membrane technologies which describe about membrane types, membrane modules, type of membrane techniques, and also about how the membrane bioreactors are helpful for treatment of distillery wastewater. Finally there are three case studies on microorganism which are helpful for distillery wastewater and also about biofiltration how help in these treatment processes.

2. LITERATURE REVIEW

2.1 DISTILLERY WASTEWATER

Among the raw material sources for distillery, two very important raw materials are cane sugar molasses and beet sugar molasses. Distillery wastewater (stillage) is the main byproduct originating in distilleries, and its volume is approximately 10 times that of ethanol produced. It is not surprising that the utilization of the stillage raises serious problems, and that many attempts have been made all over the world to solve them. Distillery wastewater is usually comprised of a high volume of greatly acidic matter which presents many disposal and treatment problems. Waste streams generally contain high levels of both dissolved organic and inorganic materials. There has been increasing interest in the use of ethanol from biomass as a liquid fuel alternative. Ethanol fermentation is examined in relation to distillery wastes. In the year 1999, there were 285 distilleries in India producing 2.7×10^9 L of alcohol and 319 distilleries, producing 3.25×10^9 L of alcohol generating 4×10^{10} L of wastewater each year. Generating a 40.4×10^{10} L of wastewater annually. Reducing the volume of wastewater may be accomplished by fermenting higher strengths of molasses. To characterize distillery wastewater in detail so that proper insight may be gained in an attempt to treat the waste to reduce the pollution hazards. Oxygen consumption values can use to quantify the amount of

organic matter present in wastewater. However, considerable work has been reported in this field and should be taken into account with the characteristics of distillery wastewater. Some of the work done on distillery waste characterization by various parameters like: - pH, COD, BOD, phosphate, total solids, total dissolved solids, total suspended solid, ammonia, sulfate, color and iron etc as in the Table 2.1

Table 2.1 Typical characteristics of distillery spentwash (Saha *et al.*, 2005)

Parameter	Range
pH	3.8-4.4
Total solids (mg/L)	60000-90000
Total suspended solids (mg/L)	2000-14000
Total dissolved solids (mg/L)	58000-76000
Total volatile solids (mg/L)	45000-65000
COD (mg/L)	70000-98000
BOD (for 5 days at 20°C) (mg/L)	45000-60000
Total nitrogen as N (mg/L)	1000-1200
Potash as K ₂ O (mg/L)	5000-12000
Phosphate as PO ₄ (mg/L)	500-1500
Acidity as CaCO ₃ (mg/L)	8000-16000
Temperature (after heat exchanger) (°C)	70-80

2.1.1 Effect of Distillery Wastewater on Environment

To characterize distillery wastewater in detail, so that proper attempt to treat the waste to reduce the pollution hazards. In a distillery, sources of wastewater are stillage, fermenter and condenser cooling water and fermenter wastewater. The liquid residues during the industrial phase of the production of alcohol are liquor, sugar cane washing water, and from the cleaning of the equipment, apart from other residual water. This extract is extremely polluting as it contains approximately 5% organic material and fertilizers such as potassium, phosphorus and nitrogen. The amount of water used in this process is large, generating a high level of liquid residues as in the Figure 2.1

The effluents from molasses based distilleries contain large amounts of dark brown colored molasses spent wash (MSW). The molasses spent wash (MSW) is a potential water pollutant in two ways. First, the highly colored nature of MSW can block out sunlight from rivers and streams, thus reducing oxygenation of the water by photosynthesis and hence becomes problem to aquatic life. Secondly, it has a high pollution load which would result in eutrophication of contaminated water sources. Due to the presence of putriciable organics like skatole, indole and other sulfur compounds, the MSW that is disposed in canals or rivers produces obnoxious smell.

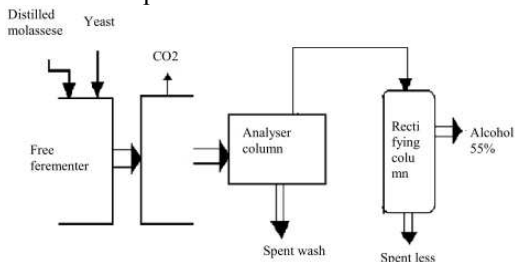


Fig. 2.1 Schematic production of distillery wastewater (Chang *et al.*, 2003)

In India, there is a number of large scale distilleries integrated with sugar mills. The waste products from sugar mill comprise bagasse (residue from the sugarcane crushing), pressmud (mud and dirt residue from juice clarification) and molasses (final residue from sugar crystallization section). Bagasse is used in paper manufacturing and as fuel in boilers, molasses as raw material in distillery for alcohol production while pressmud has no direct industrial application.

Ethanol manufacture from molasses generates large volumes of high strength wastewater that is of serious environmental problem. The effluent is characterized by extremely high chemical oxygen demand (COD) (80000 to 100000 mg/L) and biochemical oxygen demand (BOD) (40000 to 50000 mg/L), apart from low pH, strong odor and dark brown color. In India, which is the second largest producer of ethanol in Asia with annual production of about 2300 million liters in 2006–07 alcohol distilleries are rated as one of the 17 most polluting industries. Other than high organic content, distillery wastewater also contains nutrients in the form of nitrogen (1660 to 4200 mg/L), phosphorus (225 to 3038 mg/L) and potassium (9600 to 17475 mg/L) that can lead to eutrophication of water bodies. Further, its dark color hinders photosynthesis by blocking sunlight and is therefore problem to aquatic life. Studies on water quality of a river contaminated with distillery effluent displayed high BOD values.

2.1.2 Treatment and Disposal of Distillery Wastewater

During the 1970s, land disposal was practiced one of the main treatment options, since it was found to enhance yield of certain crops. In Brazil waste generated from sugarcane juice fermentation is mainly used as a fertilizer due to its high nitrogen, phosphorus and organic content. It is use to increase sugarcane productivity and also under controlled conditions the effluent is capable of replacing application of inorganic fertilizers. However, for the high strength molasses-based spentwash, the odor, putrefaction and unpleasant landscape due to unsystematic disposal are concerns in land application.

In addition, this option is subject to land availability in the vicinity of the distillery, also it is essential that the disposal site be located in a low–medium rainfall area. More recent investigations have indicated that land disposal of distillery effluent can lead to groundwater contamination. Deep well disposal is another option but limited underground storage and specific geological location limits this alternative. Other disposal methods like evaporation of spentwash to produce animal feed and incineration of spent wash for potash recovery have also been practiced.

2.1.3 Zero Discharge of Distillery Wastewater

Worldwide environment regulatory authorities are setting for discharge of wastewaters from industries. In India for instance, distillery industry had been told to achieve zero discharge of spentwash by December 2005 according to the Central Pollution Control Board as in the Figure 2.2 (CPCB, 2003). All methods of wastewater treatment such as lagooning, biodegradation wet air oxidation bio-methanation, membrane filtration evaporation composing were tried for last 25 years, and found to be techno-economically nonfeasible. The present work proposes the process-engineering approach based on experimental data on

the same and similar fluid system. The process is experimented with achievements like zero discharge of waste water, generation of distilled water to reuse in process, conservation of system energy, self refinance on utilize like steam, water and power. It further says that till 100% utilization of spentwash is achieved, controlled and restricted discharge of treated effluent from lagoons during rainy season will be allowed by CPCB in such a way that the perceptible coloring of river water bodies does not occur.

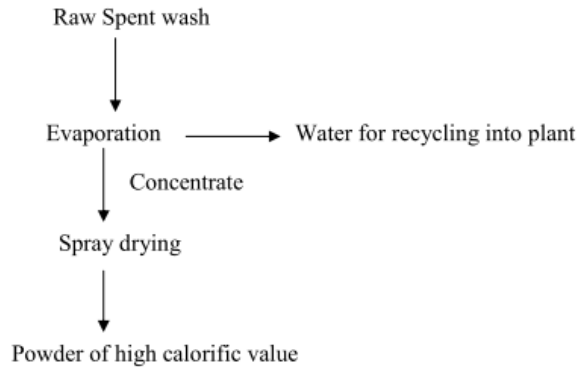


Fig. 2.2 Zero discharge system for distilleries (CPCB, 2003)

2.2 MEMBRANE TECHNOLOGIES

Physical, chemical and biological treatment approaches have been employed for the treatment of distillery wastewater. The physical methods are Sedimentation, Screening, Aeration, Filtration (Membrane Technologies), and Flotation. The chemical methods are Chlorination, Coagulation, Adsorption, and Ion Exchange. The biological methods are grouped into two types. Aerobic methods are activated sludge treatment, lagoons, trickling filtration, and oxidation ponds, and anaerobic methods are anaerobic digestion, septic tanks.

Municipal, agricultural and industrial liquid or solid wastes differ very much in their chemical, physical and biological characteristics. This diverse spectrum of wastes requiring efficient treatment has focused the attention of researchers on membrane, ion-exchange and biological technologies. The most effective and ecological technological systems developed during the past 20 years are based on a combination of the chemical, physical and biological methods. The below Figure 2.3 explain all the fundamental of the membrane technology; Feed enters into stream and by membrane separated into concentrate and permeate.

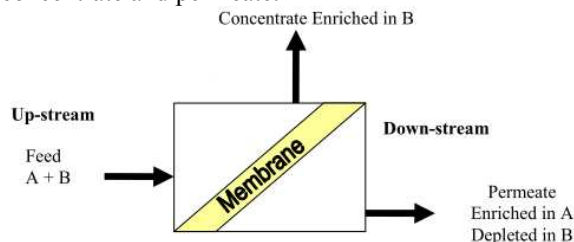


Fig. 2.3 Process fundamental of membrane technology

The fact behind the membrane technology, works without the addition of chemicals, with a relatively low energy use and easy and well-arranged process conduction. Membrane technology is a generic term for a number of different, very characteristic

separation processes. These processes are of the same kind, because in each of them a membrane is used. Membranes are now competitive for conventional techniques. Membrane filtration can be used as an alternative for flocculation, sediment purification techniques, adsorption (active carbon and sand filter), extraction and distillation.

2.2.1 The Growth of Membrane Technology

Membrane systems have been used in specialized applications for more than 30 years, largely for water treatment (distillery wastewater), including desalination of seawater and brackish water. With technical advances and corresponding cost reductions, membrane systems are now capable of decontaminating waters (including treated wastewaters) in single step processes at competitive costs. About two-thirds of the market will be for water, and one-third for wastewater. Membrane technologies are receiving special recognition as alternatives to conventional water treatment and as a means of polishing treated wastewater effluent for reuse applications. Membrane technologies are energy intensive. New membrane technologies feature the use of low pressure systems that significantly reduce energy use and operation and maintenance costs.

2.2.2 Components of a Membrane System

Typical membrane systems consist of various steps which are describe below:

1. Pre-treatment
2. Pumping
3. Cartridge filtration
4. Membranes and
5. Post-treatment.

The effluent collected from the distillery industry is highly acidic with a pH range of around 3. Hence, it is neutralized using sodium hydroxide. The neutralized solution has a lot of suspended solids, so the filtration is carried out to remove the suspended particles with a fine-pore thin cloth. This pre-filtrate is used as feed. Pretreatment of alcohol-distillery wastes with ceramic membranes is performed prior to anaerobic digestion. Ceramic membranes of different pore size are chosen based on the particle size distribution in raw wastes. In some pretreatment, chemical oxygen demand (COD) is reduced from 36000 to 18000 mg/L and suspended solids are almost completely removed. Mixed stillage exhibited higher fouling tendency than pure naked barley stillage. Several cleaning methods are attempted to recover water flux. Although lumen flushing is effective, hydrogen peroxide proved to be the most effective cleaning agent. The negative flux recovery after nitric acid cleaning could be explained by the ligand exchange theory. The performance of digester is greatly improved with membrane pretreatment, especially in the case of naked barley based stillage. Pretreatment may include the addition of chemicals to prevent organic materials or soluble salts from fouling the membrane.

Pumping is required to raise the pressure to the desired operating level and to maintain sufficient velocity across the membranes. A cartridge filter is nearly always provided by the membrane manufacturer, usually for the removal of particles.

The filter provides protection against an upset in the pre-treatment step that could cause fouling of the membrane. The membranes are the heart of the

treatment system. They may be hydraulically connected in series or parallel configurations, depending upon the feedwater composition or desired water recovery. Post-treatment may include: (1) a degasifier to remove carbon dioxide and - hydrogen sulfide and (2) the addition of lime or caustic to prevent corrosion of the subsequent piping or distribution system.

2.2.3 Design Considerations

In addition to levels of constituent removal required factors to be considered in the design of membrane systems include membrane life, membrane fouling, and disposal of concentrate. Typical membrane life is three to five years depending upon the type of service and type of membrane used. Membranes used in wastewater treatment typically have a life of four to five years. For distillery wastewater, the normal life of a membrane is three to five years, and many have been in service for more than six years. For various membrane processes different types of considerations are taken into account, some are given below into Table 2.2.

Table 2.2 Various membrane processes

Process	Function	Driving Force
Reverse Osmosis	Selective solvent transport	Pressure gradient
Electrodialysis	Selective ion transport	Electrical potential gradient
Ultrafiltration	molecular size, shape and flexibility	Pressure gradient
Dialysis	Selective solute transport	Concentration gradient

2.2.4 Type of Membrane Modules

There are four basic type of membrane modules are found in the literature which are used for various processes by doing some modification in these membrane modules. A basic guideline for selecting the right module geometry for a specific application is depends on following parameters as shown in the Table 2.3

Table 2.3 General characteristics of membrane modules (Genesis membrane, 2009)

Characteristics	Spiral Wound	Hollow Fiber	Tubular	Plate and Frame
Typical Packing Density (ft ² /ft ³)	245	1830	21	150
Required Feed Flow Rate (ft ³ /ft ² -s)	0.8-1.6	0.016	3-15	0.8-1.6
Feed Side Pressure Drop (psi)	43-85	1.4-4.3	28-43	43-85
Membrane Fouling	High	High	Low	Moderate
Ease of Cleaning	Poor	Poor	Excellent	Good
Recommended Applications	Clean dilute streams such as water for desalination. Not good for high concentration & fouling chemicals	Very clean streams such as water.	For high conc. in dirty streams or streams containing fouling chemicals, such as dye desalting & concentration	Laboratory work and membrane evaluations. Good for high viscous liquids.

Two types of membrane configuration used extensively for distillery wastewater treatment are hollow-fiber and spiral-wound. In a hollow-fiber element, fibers made of porous polymer material are bundled together and sealed in a pressure vessel. For some UF designs, feedwater enters through a perforated central tube and flows radially outward

through the fiber bundle. Under pressure, water is forced through the hollow-fiber bores and exits through one or more ports.

For RO, feedwater enters from the outside surface of the fiber and product water is removed from the bores. Spiral-wound elements usually range from 2 to 10 inches in diameter and 10 to 60 inches in length as in the Figure 2.4. They consist of two flat membrane sheets separated by a thin, mesh-like porous support or spacer and are sealed on three sides like an envelope. The fourth side is fixed onto a perforated plastic centre tube that collects the product water. The membranes are rolled up around the tube in the form of a spiral. Feedwater is pumped through the layers and product water passes through the membranes and follows the spiral configuration to the central perforated tube. Water that does not penetrate the membrane exits the element as concentrate. Spiral wound elements are used for MF, UF, and RO.

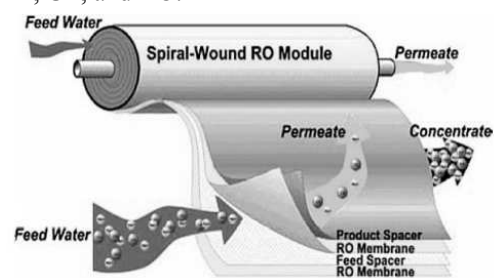


Fig. 2.4 Spiral wound membrane modules (Lenntech, 2009)

2.2.5 Types of Membrane Technology

The membrane separation process is based on the presence of semi-permeable membranes. The principle is quite simple, the membrane acts as a very specific filter that will let water flow through, while it catches suspended solids and other substances. Membranes are typically made from polymeric materials, although ceramic and metal oxide membranes are also available. Cellulose polymers are inexpensive and widely used.

More recent polyamide thin-film composite membranes are more chemically robust, have longer life, possess greater rejection of dissolved salts and organics, and operate at lower pressures. They are more expensive than cellulose membranes. Ceramic and metal oxide membranes are traditionally used for UF and are commonly available in tubular form. Although ceramic and metal oxide membranes are more costly than other types, they are used for many industrial processes because they can withstand very high temperatures. There are two basic types of membrane separation processes; pressure-driven and electrically-driven.

2.2.5.1 Pressure-driven membranes

Pressure-driven technologies include, in order of decreasing permeability, microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO). MF and UF often serve to remove large organic molecules, large colloidal particles, and many microorganisms. MF performs as a porous barrier to reduce turbidity and colloidal suspensions. UF offers higher removals than MF, but operates at higher pressures. In wastewater reclamation, MF or UF might provide a suitable level of treatment. In drinking-water treatment, MF or UF might be used in tandem with NF or RO to remove coarser material so that fouling of the less permeable membranes is minimized.

The most commonly used process for the production of drinking water is RO, but NF is now emerging as a viable alternative to conventional water treatment because it can operate at lower pressures and higher recovery rates than RO systems. NF is also cost-effective in many groundwater softening applications where the incoming turbidity is low.

2.2.5.2 Classes of pressure driven membranes

Pressure driven membranes have been classified into four categories based on the membrane rejection properties as follows

- 1) Microfiltration (MF) membranes: - have the largest pore size (0.1 to 3 micron), require low transmembrane pressure (1 to 30 psi), and are used for turbidity reduction, removal of suspended solids, parasites like bacteria and some viruses.
- 2) Ultrafiltration (UF) membranes: - have a smaller range of pore sizes than MF membranes (0.01 to 0.1 micron) require low transmembrane pressure (1 to 30 psi), and are capable of removing viruses as well as some color, odor, and organics removal, along with everything that the MF process can remove.
- 3) Nanofiltration (NF) membranes : - are relatively new porous membranes that have a pore size less than 0.002 micron require moderate transmembrane pressure (75- 150 psi), and are primarily used for natural organic matter removal for controlling disinfection byproduct precursor, water softening and sulfate removal.
- 4) Reverse osmosis (RO) membranes: - are effectively non-porous membranes that require high transmembrane pressure (150-500 psi) and are used for monovalent salt removal like Na^+ , K^+ .

Table 2.4 Classes of pressure driven membranes (Kalyuzhnyi *et al.*, 2005)

Process	Driving Force	di (nm)	Species Rejected
Microfiltration < 50 nm	10-25 psi	100-20,000	TSS, Protozoa, Bacteria, Viruses
Ultrafiltration 2-50 nm	10-100 psi	2-10	Macromolecules, Colloids, Proteins
Nanofiltration < 2 nm	100-500 psi	0.5-2	Small molecules, Hardness, Viruses
Reverse Osmosis < 2 nm	100-1500 psi	0.3-0.5	NaCl , Mg^{2+} , Ca^{2+} , SO_4^{2-} , NO_3^- , Colour

Reverse osmosis technique generate about 50% clean colorless reusable water & the balance 50% concentrate can be easily composted by available pressmud. This method thus creates an opportunity to arrive at zero discharge status. Thus it can be concluded that the above mentioned specific membrane configuration has the distinct ability of processing both the raw & biogas treated distillery spentwash, to obtain two streams, one containing clear & colorless water & the other a concentrated spentwash. Their quantitative proportion was average 50: 50.

Thus the processing of the spentwash by this technique offers an opportunity to reduce the volume by 50%, facilitating its convenient composting. The

overall pressmud & land requirement also is reduced to 50%, thus saving operating cost. The clear & colorless water may offer another opportunity to recycle the same, which could be a great boon to distilleries operating in water scarce areas or those spending large amounts of money for their water supply. Alternatively it can simply be given to irrigation to benefit the farmers.

Table 2.5 Results of spentwash decolorization by RO (Mohammad, *et al.*, 2006)

Parameters	Spentwash
INPUT	
Color	Black brown
Volume (L/hr)	450
Feed COD (ppm)	30000
Feed TDS Inorganic (ppm)	25000
OUTPUT	
Color	Colorless
Volume (L/hr)	225
Permeate COD (ppm)	< 750
Permeate TDS Inorganic (ppm)	< 1000
RECOVERY	50 %

2.2.5.3 Electrically-driven membranes

Electrodialysis reversal (EDR) is an improvement over the original electrodialysis process. Electrodialysis reversal (EDR) is an electrochemical separation process that removes ions and other charged species from water and other fluids. EDR uses small quantities of electricity to transport these species through membranes composed of ion exchange material to create a separate purified and concentrated stream. Ions are transferred through the membranes by means of direct current voltage and are removed from the feed water as the current drives the ions through the membranes.

This innovation improves both efficiency and the operating life of membranes. Ion exchange membranes are the heart of the membrane process. Cation selective and anion-selective membranes are alternately placed in a membrane. Distillery wastewater flows between the membranes, and when direct current is applied across the stack of membrane, positive ions move toward the cathode and negative ions move toward the anode as shown in Figure 2.5 (Genesis membrane, 2009).

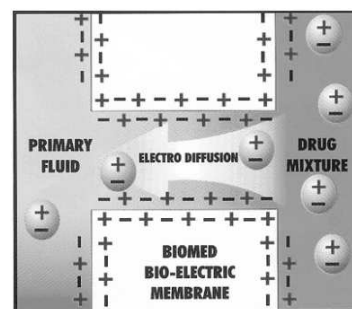


Fig. 2.5 Electrically driven membrane (Genesis membrane, 2009)

2.2.6 Use of Membrane

As the cost of wastewater disposal increases, more emphasis is being placed upon the recovery and recycling of the valuable chemicals contained within these streams. Membranes are commonly used for the removal of dissolved solids, color, and hardness in drinking water. Membrane technologies have also been proposed by the USEPA for particle removal, reducing disinfection by-products such as trihalomethanes (THMs) and haloacetic acids (HAAs) and eliminating illness-causing microorganisms such as *Giardia* and

Cryptosporidium in drinking water applications. In wastewater reclamation and reuse, Water quality requirements may call for reductions in suspended solids, total dissolved solids, and selected constituents such as nitrates, chlorides, and natural and synthetic organic compounds. Membrane treatment, applied to the end of conventional wastewater treatment systems, is a viable method of achieving desired effluent quality levels at reasonable costs.

A hybrid nanofiltration (NF) and reverse osmosis (RO) pilot plant was used to remove the color and contaminants of the distillery spent wash. The feasibility of the membranes for treating wastewater from the distillery industry by varying the feed pressure (0–70 bar) and feed concentration was tested on the separation performance of thin-film composite NF and RO membranes. Color removal by NF and a high rejection of 99.80 % total dissolved solids (TDS), 99.90 % of chemical oxygen demand (COD) and 99.99 % of potassium was achieved from the RO runs, by retaining a significant flux as compared to pure water flux, which shows that membranes were not affected by fouling during wastewater run. The pollutant level in permeates were below the maximum contaminant level as per the guidelines of the World Health Organization and the Central Pollution Control Board specifications for effluent discharge (less than 1000ppm of TDS and 500ppm of COD).

2.2.7 Economic Importance of Membrane Technology

Engineers designing cross flow membrane equipment into process flow-sheets must balance capital cost and operating expense just as they do for other process equipment. For membrane equipment, the capital contributions and typical fraction of the total are as in the Table 2.6

Table 2.6 Economic importance of membrane technology

Capital item	% of total capital
Pumps	30
Replaceable membrane element	20
Housings for membranes	10
Pipes, valves and framework	20
Controls	15
Other	5

US membrane material demand will rise 8.2 percent annually through 2012, driven by on going interest in higher purity process fluids and increasingly strict water/wastewater quality rules. The best opportunities will emerge in pharmaceutical and medical markets, while water and wastewater treatment remain the largest markets. This study analyzes the \$2.9 billion US membrane industry, with forecasts for 2012 and 2017 by type (e.g., cellulosic membranes, polysulfone and nylon membranes, ceramic membranes); application (e.g., microfiltration, reverse osmosis, ultrafiltration); and market (e.g., water and wastewater treatment, food and beverage processing, pharmaceuticals and medical uses, chemical processing, industrial gas processing).

2.2.8 Energy Requirement in Membrane Treatment Process

Membrane processes use a significant amount of energy. Even low pressure membranes use approximately 100 kwh per million gallons (3.785 million liters) of water produced. The development of new composite membranes has reduced the operating pressures considerably. Lower pressure operation means lower energy consumption.

2.2.9 Problems with Membrane Technology

Various type of membrane problem are occurs during operation of membrane the some important specific membrane related problems such as membrane fouling, clogging, scaling and cleaning.

Fouling of membranes can be broken into four distinct categories. They are fouling by particulate matter, organic fouling, biological fouling, and inorganic scaling. Fouling with particulate matter and suspended solids, If not properly dealt with, particulate matter and fine suspended solids present in the feed water are problematic and will reduce the water throughput of the membranes with time. Depending on the feed water quality, a filtration system needs to be designed to reduce the influent suspended solids and particulate matter before feeding the water. Fouling with organic materials, membranes are susceptible to organic fouling depending on the source water quality.

ED anion-exchange membranes are particularly susceptible to organic fouling due to the negative charge associated with natural organic matter. This can lead to process failures. Large organic anions cannot penetrate the anion exchange membrane and will accumulate and adsorb to the membrane surface, increasing the stack resistance. Small organic molecules can also be problematic because they penetrate the membrane, but their electro mobility is low and they remain inside the membrane. Fouling of this kind can make it quite difficult to clean and restore these membranes to their original electrical resistance. NF and RO membranes are fouled by organic adsorption as the membrane rejects these materials and membrane permeates are produced. It is difficult to determine the organic fouling potentials using aggregate organic measurements in the feedwater.

Biological Fouling, biofilm control is important in virtually every unit process, which sets out to accomplish mass transfer in an aqueous system. Membrane manufacturers have come a long way in reducing the biodegradability of the membranes themselves, but most modern RO and NF membranes are sensitive to oxidants. Without the use of oxidizing disinfectants, it is unlikely that biofilm control will ever be adequately achieved. Although turbulent cross-flow is maintained in all membrane systems, bacteria are still capable of adhering to the membrane surface and excreting extracellular polymeric substances (EPS) to create a strong bond to the membrane surface.

Once attached to the membrane, a complex community of microorganisms is created that is held together and fixed to the membrane with EPS. Biofilm result in decreased membrane permeability in pressure driven applications and increased electrical resistance in potential driven processes, increasing the operational and maintenance costs of membrane processes. The rejection of targeted contaminants can also be adversely affected. Fouling from the formation of inorganic scale, rejection of dissolved solids with membranes segregates salts into a waste stream

commonly referred to as concentrate or brine. If the concentrations of these salts exceed their solution saturation, precipitates will form a scale of inorganic salts (e.g. Fe_2O_3 , CaCO_3 , CaSO_4 , SiO_2 , CaF_2 , BaSO_4 , etc.) on the membrane surface. Scaling usually develops in the final stage of the RO or EDR process at the membrane surface because this is the active point of ion separation where concentrations are highest. By adjusting the feedwater recovery, the design engineer can estimate the concentrations of the dissolved solids and specify a system that does not suffer from inorganic scaling. Inorganic scaling, like other forms of fouling, will increase the operational costs and require operator attention to clean and restore the membrane system.

Membrane fouling mechanisms during the longtime operation of a membrane coupled anaerobic bioreactor (MCAB) system designed for the treatment of alcohol-distillery wastewater. This system provided interesting information on anaerobic digestion and membrane performance associated with the fouling mechanisms in the membrane bioreactor. Enhanced COD removal was achieved with the complete retention of biomass either inside the anaerobic reactor or on the membrane surface. Membrane fouling was mainly attributed to external fouling, which was closely related to the movement of cell population to the membrane surface and inorganic precipitation at the membrane surface. There are two factors that determine the affectivity of a membrane filtration process; selectivity and productivity. Selectivity is expressed as a parameter called retention or separation factor. Productivity is expressed as a parameter called flux. Selectivity and productivity are membrane-dependent.

2.3 Treatment of Distillery Using Wastewater Membrane Bioreactor

Membrane bioreactors (MBRs) are being increasingly recognized as an effective method for the treatment of industrial (distillery) wastewaters. MBRs offer the advantages of total solids retention at all biomass concentration, low sludge yield and better treated effluent quality. In addition, the high mixed liquor suspended solids (MLSS) concentration encourages the treatment of high strength wastewater. The widespread application of MBRs is however, limited by two reason high initial membrane cost and progressive membrane fouling, which leads to frequent membrane cleaning and eventual replacement, thus contributing to the high operating costs. There are very few investigations on distillery wastewater treatment in an MBR. The COD removal efficiency was 94.7%. Membrane coupled anaerobic bioreactor (MCAB) using $0.2\mu\text{m}$ polypropylene and $0.14\mu\text{m}$ zirconia skinned inorganic tubular membranes has also been investigated for the treatment of 40000 mg/L COD distillery wastewater at 55°C . High COD removal (90%) was observed in both the anaerobic MBRs as in the Figure 2.6.

Anaerobically treated spentwash from sugarcane molasses based distilleries has a high COD and requires further aerobic treatment. So the objective to investigate the optimum start up method and continuous operation of aerobic MBR using anaerobically treated spentwash as feed. The main objective behind using MBR was to provide long

SRT (sludge retention time) so that the degradation of high molecular weight compounds could be achieved in the reactor. Nylon mesh was used instead of commercial microporous membranes to decrease the cost. During MBRs study, the initial sludge acclimatization phase where the focus was on biomass growth and sludge properties, followed by continuous operation that mainly deals with reactor operation and filtration performance.

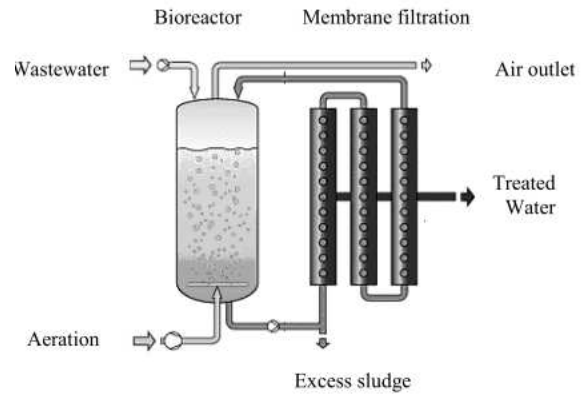


Figure 2.6 Process of Wastewater Treatment Using Membrane bioreactors (Satyawali *et al.*, 2008)

3. CASE STUDY

3.1 CASE STUDY ON TREATMENT OF DISTILLERY WASTEWATER USING MICROORGANISMS

The microorganisms used for distillery wastewater treatment are given below which may directly immobilized on the membrane or their enzyme is immobilized on the membrane as in the Table 3.1. Major finding of this work is the microorganism used for decolorization is identified, which includes both bacterial and fungal microorganisms.

Table 3.1 Microorganism employed for the decolorization of distillery effluent (Pant *et al.*, 2007)

Name	Color Removal (%)
BACTERIA	
<i>Xanthomonas fragariae</i>	76
<i>Bacillus cereus</i>	82
<i>Acetobacter acetii</i>	76.4
<i>Pseudomonas putida</i>	60
<i>Pseudomonas fluorescens</i>	94
<i>Pseudomonas aeruginosa</i>	67
FUNGI	
<i>Trametes versicolor</i>	82
<i>Geotrichum candidum</i>	80
<i>Aspergillus niger</i>	80
<i>Mycelia sterilia</i>	93
<i>Rhizopus sp.</i>	90
<i>Aspergillus oryzae</i>	75

3.2 IMPROVING INDUSTRIAL WATER USE

Alcohol distilleries are highly water intensive units generating large volumes of high strength wastewater that poses a serious environmental concern. This case study aimed at identifying options for improved water use in this sector through a case study in a local distillery. It emerged that optimization of cooling tower operation, innovative ways to reuse wastewater streams like spent lees and spentwash and employing semi-continuous/continuous fermentation could reduce water use in distilleries.

In general, reduction in industrial wastewater can be achieved through one or a combination of the following measures.

- 1) Process modification or change in raw materials to reduce water consumption,
- 2) Direct reuse of wastewater,
- 3) In-plant reuse of reclaimed wastewater, and
- 4) Use of treated wastewater for non-industrial purposes.

3.2.1 Water Balance

The unit uses 1133.5 kilolitres water/day and generates around 668 kilolitre/day of effluent. The effluent volume has been calculated on the basis of contributions from water used for molasses dilution, yeast preparation, steam generation, fermenter washing and effluent treatment. It has been assumed that other processes do not contribute to effluent generation. Molasses dilution, cooling requirement and steam generation in the boiler are the most water intensive processes. Thirty-four percent of total daily water input to the distillery is in the form of cooling tower make-up volume that is a consequence of evaporative loss, drift loss and blow down. Optimization of the cooling tower operation and maintenance can contribute significantly to makeup water requirement as shown in Fig. 3.1.

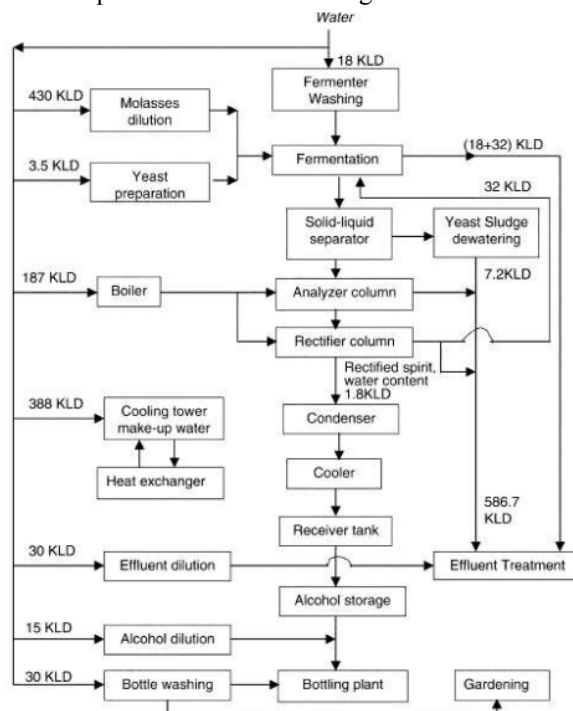


Fig. 3.1 Water balance (Saha *et al.*, 2005)

There is significant scope to improve water utilization in Indian distilleries through conservation and reuse. Though good housekeeping measures such as proper metering of water flow in individual units and maintenance of piping contribute to water savings, specific interventions should also be targeted. Our study identified optimization of cooling tower operation, innovative ways to reuse segregated wastewater streams and replacing batch with semi-continuous/continuous fermentation to be appropriate interventions to reduce water use in distilleries.

3.3 CASE STUDY ON BIOFILTRATION

In common biological treatments, microorganisms are mixed with the waste material. The microorganisms decompose the waste material and convert it to microbial biomass and energy. There is no separation between the microorganisms and the treated waste. One such treatment system is the

activated sludge in waste treatment, in which the microorganisms are suspended within the treated liquid. A second step of treatment is needed in this system to separate the microbial biomass from the treated fluid. To overcome from these problem biofiltration a technique is applied.

Biofiltration is distinguished from other biological waste treatments by the fact that there is a separation between the microorganisms and the treated waste. In biofiltration systems the microorganisms are immobilized to the bedding material, while the treated fluid flows through it. Recently, a vast amount of literature has been written on single experiments involving the treatment of fluids by immobilized microorganisms. Several artificial immobilization methods have been examined and impressive results have been achieved in the treatment of fluids with one of the artificial immobilization methods - the entrapment of microorganisms within polymer beads. This method, even though it needs to be improved, seems to have a future potential in commercial biofiltration systems.

The methods of artificial immobilization of microorganisms within biofiltration systems have several advantages, but also suffer from several disadvantages in comparison to the treatment of fluids by naturally attached microorganisms. Understanding the mechanisms and forces responsible for the attachment of microbes to the bedding material, in attempt to improve this attachment is important.

Further improvement of the artificial entrapment of microorganisms within polymers will allow the exploitation of the advantages of this method in the treatment of fluids. There are two methods of immobilization processes – the self-attachment of microorganisms to the bedding material and the artificial entrapment of microorganisms within polymer beads. Apart from the immobilization process, biofiltration systems can be divided into two different treatment systems based on the phase of the treated fluid, i.e., systems treating gas and those treating liquids. There is a considerable difference in the operation of systems treating different phases of fluid, even though based upon the same bedding material.

In biofiltration systems the pollutants may be removed from the fluid in several ways. They can be adsorbed to the microbial film or to the bedding material. In biofilters treating gas, the pollutants might be adsorbed to the water that clings to the bedding material. The main way of pollutant removal in biofiltration systems, however, is the biological degradation of the waste. In this way the contaminants are incorporated into the microbial biomass or used as energy sources.

4. SUMMARY

Drinking water quality is essential to public health. Although water treatment is a common practice for supplying good quality of water from a source, maintaining an adequate water quality throughout a distribution system is never an easy task. Municipal, agricultural and industrial liquid or solid wastes differ very much in their chemical, physical and biological characteristics. There are two type of waste like inorganic waste and organic waste are potent source of water pollution. Organic wastewater that is known to cause serious problems may be contributed by distillery effluent, pulp and paper effluent and textile effluent

etc. Among the raw material sources for distillery, two very important raw materials are cane sugar molasses and beet sugar molasses. Distillery wastewater is usually composed of a high volume of acidic matter which presents many disposal and treatment problems.

Waste streams of distillery wastewater generally contain high levels of both dissolved organic and inorganic materials. There has been increasing interest in the use of ethanol from biomass as a liquid fuel alternative. Ethanol fermentation is examined in relation to distillery wastes. Reducing the volume of wastes may be accomplished by fermenting higher strengths of molasses. There are various methods used in the treatment of distillery wastewater. Physical-chemical treatment of distillery wastewater has little success. Anaerobic digestion, anaerobic filters, lagoons, activated sludge and trickling filters have all been successfully applied to the treatment of distillery wastewater. This diverse spectrum of wastes requiring efficient treatment has focused the attention of researchers on membrane, ion-exchange and biological technologies. Membrane and membrane separation techniques with immobilized microorganism or enzyme have very significant role in treatment of distillery wastewater.

Nomenclature

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
DWW	Distillery Wastewater
EPS	Extracellular Polymeric Substances
EDR	Electrodialysis Reversal
MBR	Membrane Bioreactor
MLSS	Mixed Liquor Suspended Solids
MCAB	Membrane Coupled Anaerobic Bioreactor
MSW	Molasses Spent Wash
MF	Microfiltration
NF	Nanofiltration
RO	Reverse Osmosis
TSS	Total suspended solids
TDS	Total dissolved solids
TVS	Total volatile solids
UF	Ultrafiltration

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