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Advance Methods for Treatment of Textile Industry Effluents



CENTRAL POLLUTION CONTROL BOARD
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FOREWORD

The textile units use a number of dyes, chemicals and other materials to impart desired quality to the fabrics. These units generate a substantial quantity of effluents, the quality of which in most of the cases is unsuitable for further use and can cause environmental problems, if disposed of without proper treatment. At present, due to the increasing resource constraints and the environmental requirements, these textile units need to adopt a sustainable approach, and wastes need therefore to be viewed as unutilised resources. Ways and means must be found to recover water and chemicals from these “waste” resources. Advanced treatment methods, like membrane filtration, appear to be promising because these methods not only help in reducing the pollution but also provide a scope for recovery and recycling of water and chemicals.

This Report seeks to give an overview of the different advanced methods for treatment of textile industry effluents as well as for recovery of water/salt in the process. The performance of these advanced treatment methods as also their economic analysis, benefits and constraints have been discussed in the Report.

While the cooperation extended by Textile Industry in the CPCB studies is gratefully acknowledged, we do hope that this Report would be useful to the Textile units, the regulatory agencies and all those concerned with pollution control and sustainable industrial development.

(J.M. Mauskar)

New Delhi
March, 2007

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Contents

S. No.	Title	Page No.
1.0	Introduction	1
2.0	Pollution Problems in Textile Industry	2
2.1	Colour	2
2.2.	Dissolved Solids	2
2.3	Toxic Metals	2
2.4	Residual Chlorine	2
2.5	Others	3
3.0	Effluent Treatment	3
3.1	Primary and Secondary Treatment	3
3.2	Tertiary Treatment	5
4.0	Advance Methods for Treatment	5
4.1	Adsorption	5
4.2	Ion Exchange	6
4.3	Membrane Filtration	6
	Reverse Osmosis	6
	Ultrafiltration	7
	Nanofiltration	8
4.4	Ozonation	10
4.5	Evaporation	10
	Multiple Effect Evaporation	10
	Mechanical Vapour Compression	13
	Direct Contact Evaporation	13
4.6	Crystallisation	13
4.7	Specific Treatments	14

5.0	Selection of Advance Methods for Treatment	14
5.1	Recovery of Water and Glauber Salt	15
	Treatment Scheme	15
	Results	21
	Economics of Treatment Scheme	22
	Findings	25
5.2	Recovery of Water and Common Salt	27
	Treatment Scheme	28
	Results	31
	Economics of Treatment Scheme	32
	Findings	32
5.3	Recovery of Water	33
	Treatment Scheme	34
	Results	37
	Economics of Treatment Scheme	37
	Findings	38
6.0	Treatment Methods and Their Suitability for Process Water	
	Requirements	39
7.0	Benefits of Advance Treatment Methods	43
8.0	Limitations of Advance Treatment Methods	44
9.0	Conclusions	44
10.0	Recommendations for Effluent Management in Textile Industries	45

List of Tables

Table No.	Title	Page No.
1.1	State-wise distribution of textile industries	1
4.1.	Properties of typical activated carbon	5
4.2.	Filtration spectrum of different membranes	8
4.3	Operating condition of a typical multiple effect evaporator	11
5.1	Performance of treatment scheme for waste water	20
5.2	Performance of treatment scheme for dye bath effluent	22
5.3	Capital operation and maintenance costs of treatment system	23
5.4	Economics of treatment system for recovery of water and glauber salt.	24
5.5	Details of recovery and savings	24
5.6	Performance of treatment scheme for wash water	31
5.7	Performance of treatment scheme for dye bath effluent.	32
5.8	Economics of scheme for recovery of water and common salt	33
5.9	Performance of treatment scheme for recovery of water	37
5.10	Capital and recurring costs of treatment scheme for recovery of water.	38
5.11	Economics of treatment scheme for recovery of water	39
6.1	Treated effluent quality and standards for process water	41
10.1	Some options for effluent management in textile industry	47

List of Figures

Figure No.	Title	Page No.
5.1	Treatment Scheme for recovery of water and glauber Salt.	16
5.2	Mass balance of treatment system for recovery of water and glauber salt.	19
5.3	Treatment scheme for recovery of water and common slat.	29
5.4	Mass balance of treatment scheme for recovery of water and common salt.	30
5.5	Treatment scheme for recovery of water	35
5.6	Mass balance of scheme for recovery of water	36

1.0 INTRODUCTION

Textiles are among the basic needs of human being. The textile industries therefore have great economic significance by virtue of its contribution to overall industrial out put and employment generation. This sector has wide spectrum of industries ranging from small scale units that use traditional manufacturing process, to large integrated mills using modern machineries and equipment. There are 2324 textile industries in the country including composite and process houses. State-wise distribution of these units is given in **Table 1.1**. It can be seen from these data that there are 83 composite mills in the country. Rest 2241 is semi composite and processing units. Tamil Nadu, Gujarat, Punjab and Maharashtra are among the states which have large number of textile industries amounting to 1895 i.e. about 81 per cent of total industries.

Table 1.1: State-wise distribution of textile industries

State/UT	Composite mills	Semi composite/ processing units	Total
Andhra Pradesh	-	54	54
Assam	1	1	2
Bihar	-	4	4
Delhi	-	61	61
Gujarat	17	506	523
Haryana	1	74	75
Himachal Pradesh	-	4	4
Jammu & Kashmir	1	2	3
Karnataka	8	33	41
Kerala	3	11	14
Madhya Pradesh	3	9	12
Maharashtra	27	222	249
Orissa	1	1	2
Punjab	4	378	382
Rajasthan	2	30	32
Tamil Nadu	2	739	741
Uttar Pradesh	4	76	80
West Bengal	8	32	40
Pondicherry	1	4	5
Total	83	2241	2324

Textile industries transform fibres into yarn; convert the yarn into fabrics or related products, and dye and finish these materials at various stages of production. In processing of textiles, the industry uses a number of dyes, chemicals, auxiliary chemicals and sizing materials. As a result, contaminated waste water is generated which can cause environmental problems unless properly treated before its disposal. The waste water treatment is mostly by

primary and secondary processes. However, these conventional treatment systems are not very effective in removal of pollutants such as dissolved solids, colour, trace metals etc. The advance treatment methods, while reducing these pollutants also give scope for recovery and recycling of water and chemicals.

2.0 POLLUTION PROBLEMS IN TEXTILE INDUSTRY

2.1 Colour

Presence of colour in the waste water is one of the main problems in textile industry. Colours are easily visible to human eyes even at very low concentration. Hence, colour from textile wastes carries significant esthetic importance. Most of the dyes are stable and has no effect of light or oxidizing agents. They are also not easily degradable by the conventional treatment methods. Removal of dyes from the effluent is major problem in most of textile industries.

2.2 Dissolved Solids

Dissolved solids contained in the industry effluents are also a critical parameter. Use of common salt and glauber salt etc. in processes directly increase total dissolved solids (TDS) level in the effluent. TDS are difficult to be treated with conventional treatment systems. Disposal of high TDS bearing effluents can lead to increase in TDS of ground water and surface water. Dissolved solids in effluent may also be harmful to vegetation and restrict its use for agricultural purpose.

2.3 Toxic Metals

Waste water of textiles is not free from metal contents. There are mainly two sources of metals. Firstly, the metals may come as impurity with the chemicals used during processing such as caustic soda, sodium carbonate and salts. For instance, caustic soda may contain mercury if produced using mercury cell processes. Secondly, the source of metal could be dye stuffs like metalised mordent dyes. The metal complex dyes are mostly based on chromium.

2.4 Residual Chlorine

The use of chlorine compounds in textile processing, residual chlorine is found in the waste stream. The waste water (if disposed without treatment) depletes dissolved oxygen in the receiving water body and as such aquatic life gets affected. Residual chlorine may also react with other compounds in the waste water stream to form toxic substances.

2.5 Others

Textile effluents are often contaminated with non-biodegradable organics termed as refractory materials. Detergents are typical example of such materials. The presence of these chemicals results in high chemical oxygen demand (COD) value of the effluent.

Organic pollutants, which originate from organic compounds of dye stuffs, acids, sizing materials, enzymes, tallow etc. are also found in textile effluent, Such impurities are reflected in the analysis of bio-chemical oxygen demand (BOD) and COD. These pollutants are controlled by use of biological treatment processes. In many textile units, particularly engaged in synthetic processing, low BOD/COD ratio of effluent is observed which makes even biological treatment not a ready proposition.

The waste water of cotton based textile units is usually alkaline, whereas synthetic and woolen fabric processing generates acidic effluent.

3.0 EFFLUENT TREATMENT

3.1 Primary and Secondary Treatment

The conventional treatment systems like physico-chemical treatment and physoco-chemical treatment followed by biological treatment system are installed in majority of textile industries. The first step in the waste water treatment, is to mix and equalize the waste water streams that are discharged at different time, and different intervals from different stages in the processes. Some industries also prefer screening, oil trap prior to equalization for removal of solids and oil and grease. Equalization ensures that the effluent have uniform characteristics in terms of pollution load, pH and temperature. The effluent is then subject to flash mixing for the addition of coagulants such as lime, alum, ferrous sulphate, ferric chloride, polyelectrolyte and processed through clariflocculator or flocculator and settling tank. Selection of appropriate coagulants and doses of chemicals are determined on the basis of treatability study of effluent samples. The chemical treatment helps in reduction of colour and suspended solids. A significant reduction in BOD and COD values is also observed. This physico-chemical treatment is followed by biological treatment process, with settling which further reduces BOD and COD values. The textile process houses which undertake chemical processing, do not have much organic load in their effluents. In such cases, the recent trend is to set up an activated adsorption system or an ozonation unit instead of biological treatment process.



Dyeing of Fabrics



Fabrics after Dyeing

3.2 Tertiary Treatment

Textile effluents may require tertiary or advance treatment methods to remove particular contaminant or to prepare the treated effluent for reuse. Some common tertiary operations are removal of residual organic colour compounds by adsorption and removal of dissolved solids by membrane filtration. The waste water is also treated with ozone or other oxidizing agent to destroy many contaminants. Evaporation and crystallization are other methods to minimize effluent disposal problems.

4.0 ADVANCE METHODS FOR TREATMENT

4.1 Adsorption

The adsorption process is used to removes colour and other soluble organic pollutants from effluent. The process also removes toxic chemicals such as pesticides, phenols, cyanides and organic dyes that can not be treated by conventional treatment methods. Dissolved organics are adsorbed on surface as waste water containing these is made to pass through adsorbent. Most commonly used adsorbent for treatment is activated carbon. It is manufactured from carbonaceous material such as wood, coal, petroleum products etc. A char is made by burning the material in the absence of air. The char is then oxidized at higher temperatures to create a porous solid mass which has large surface area per unit mass. The pores need to be large enough for soluble organics compounds to diffuse in order to reach the abundant surface area. Typical properties of commercially available activated carbon are given in **Table 4.1**.

Table 4.1: Properties of typical activated carbon

Parameter	Value
Base material	Lignin
Real density	1.9 g/cm ³
Apparent density	0.244 g/cm ³
Surface area	750 m ² /g
Iodine value	93
Effective pore size	2 μ

The activated carbon once it is saturated needs replacement or regeneration. Regeneration can be done chemically or thermally. The chemical regeneration can be done in within the column itself either with acid or other oxidizing chemicals. This normally effects partial recovery of activity and necessitate

frequent recharging of carbon. For thermal regeneration, the exhausted carbon is transported preferable in water slurry to regeneration unit where it is dewatered and fed to furnace and heated in a controlled conditions. This process volatilize and oxidize the impurities held in carbon. The hot reactivated carbon is then quenched with water and moved back to the site. This results in almost complete restoration of its adsorption.

There are some other materials such as activated clay, silica, flyash, etc are also known to be promising adsorbents.

4.2 Ion Exchange

Ion exchange process is normally used for the removal of inorganic salts and some specific organic anionic components such as phenol. All salts are composed of a positive ion of a base and a negative ion of an acid. Ion exchange materials are capable of exchanging soluble ions and cations with electrolyte solutions. For example, a cation exchanger in the sodium form when contacted with a solution of calcium chloride, will scavenge the calcium ions from the solution and replace them with sodium ions. This provides a convenient method for removing the hardness from water or effluent. Ion exchange resin are available in several types starting from natural zeolite to synthetics which may be phenolic, sulphonic styrenes and other complex compounds. The divalent ions such as calcium and magnesium in general have high affinity for the ion exchange resins and as such can be removed with high efficiencies.

In the ion exchange process the impurities from the effluent streams is transformed into another one of relatively more concentrated with increased quantity of impurities because of the addition of regeneration chemicals. The process can not be used for removal of non-ionic compounds.

4.3 Membrane Filtration

4.3.1 Reverse Osmosis

The process of reverse osmosis is based on the ability of certain specific polymeric membranes, usually cellulose acetate or nylon to pass pure water at fairly high rates and to reject salts. To achieve this, water or waste water stream is passed at high pressures through the membrane. The applied pressures has to be high enough to overcome the osmotic pressure of the stream, and to provide a pressure driving force for water to flow from the reject compartment through the membrane into the clear water compartment.

In a typical reverse osmosis system, the feed water is pumped through a pretreatment section which removes suspended solids and if necessary, ions such as iron and magnesium which may foul the system. The feed water is then

pressurised and sent through the reverse osmosis modules. Clear water permeates through the membrane under the pressure driving force, emerging at atmospheric pressure. The pressure of reject stream is reduced by a power recovery, which helps drive the high pressure pump and then is discharged.

Reverse osmosis can be used as end-of-pipe treatment and recycling system for effluent. After primary, secondary and/or tertiary treatment, further purification by removal of organics and dissolved salts is possible by use of reverse osmosis. RO membranes are susceptible to fouling due to organics, colloids and micro-organism. scale causing constituents like hardness, carbonate. Silica, heavy metals, oil etc has to be removed from the feed. As the membranes are sensitive to oxidizing agents like chlorine or ozone, they should also be absent.

Reverse osmosis membranes are available in different configurations. In spiral wound system, membrane and supporting material are placed in alternate layers, rolled into a cylindrical shape and in housed in tube of suitable material. The support material is porous and serves as transport medium for permeate. Tubular systems are available in which the membrane and its support are wound to fit inside a containment tube. Permeate is withdrawn from the support medium, while reject passes through the core of the membrane. Hollow fiber membranes are extremely small tubes. These fibres can be suspended in the fluid without the use of support medium. The feed water is usually on out side of fibre, while the permeate is withdrawn through the centre. The disc module is relatively new in the reverse osmosis application. Unlike conventional membrane modules such as spiral wound, the design of disc module facilitates an open feed flow path over membrane element. The membrane is housed in hydraulic disc which works as membrane spacers.

4.3.2 Ultrafiltration

This process is similar to reverse osmosis. The difference between reverse osmosis and ultrafiltration is primarily the retention properties of the membranes. Reverse osmosis membranes retain all solutes including salts, while ultrafiltration membranes retain only macro molecules and suspended solids. Thus salts, solvents and low molecular weight organic solutes pass through ultrafiltration membrane with the permeate water. Since salts are not retained by the membrane, the osmotic pressure differences across ultrafiltration membrane are negligible. Flux rates through the membranes are fairly high, and hence lower pressures can be used.

Ultrafiltration membranes may be made from cellulose acetate, polyelectrolyte complexes, nylon and inert polymers. Hence, acidic or caustic streams may also be processed and the process is not usually limited by chemical attack of the membranes.

4.3.3 Nanofiltration

Nanofiltration can be positioned between reverse osmosis and ultrafiltration. Nanofiltration is essentially a lower pressure version membrane where the purity of permeate water less important. This process is used where the high salt rejection of reverse osmosis is not necessary. The nanofiltration is capable of removing hardness elements such as calcium or magnesium together with bacteria, viruses, and colour. Nanofiltration operated on lower pressure than reverse osmosis and as such treatment cost is lower than reverse osmosis treatment.

Nanofiltration is preferred when permeate with TDS but without colour, COD and hardness is acceptable. Feed water to nanofiltration should be of similar qualities as in case of reverse osmosis. Turbidity and colloids should be low. Disinfection of feed may also necessary to remove micro-organism.

The filtration spectrum indicating size and weight of molecules, operating pressure etc. in respect of reverse osmosis, ultrafiltration and nanofiltration, is shown in **Table 4.2**.

Table 4.2: Filtration spectrum of different membranes

Process	Pore size (micron)	Molecular weight	Examples/use for removal of
Microfiltration	0.007- 2.00	> 100000	Bacteria, pigments, oil etc.
Ultrafiltration	0.002- 0.10	1000-200000	Coloids, virus, protein, etc.
Nanofiltration	0.001- 0.07	180-15000	Dyes, pesticides, divalent ions etc.
Reverse osmosis	< 0.001	< 200	Salts and ions

It has to be noted that in most of the filtrations, membranes are prone to fouling unless feed quality is properly maintained. Fouling may result in increased pressure difference and reduced flux. Dissolved minerals such as calcium, silica, barium, strontium and iron may precipitate on the membrane surface and foul the membrane. Fouling can also be caused by bacteria, which may be present in effluent and proliferate in the warm membrane operational environment. Selection of suitable chemical dose to cope with fouling, deposition and precipitation can avoid fouling. Mineral scales are prevented by removal of minerals from effluent or use of anti-scalants. Bacterial fouling can be prevented through control of organism in effluent and routine cleaning and/or use of biocides.



Ozone Manufacturing Plant



RO Membrane Filtration Plant

4.4 Ozonation

Ozone is one of the strongest oxidizers commercially available and popular for disinfection of potable water. Besides this it has multiple applications. Large, complex organic molecules, detergents, phenols etc. can be broken into simpler compounds by ozonation. Among the industrial applications, oxidation of organics and inorganics, deodorisation, and decolourisation are the main usages.

Ozone is an unstable gas at temperature and pressure encountered in water and waste water treatment plants. For most industrial applications ozone has to be produced at the site. Although, there are several methods by which ozone can be generated, the corona discharge method is widely used procedure. An ozone generation unit incorporates a series of electrodes fitted with cooling arrangements mounted in a gas tight container. When the source gas (air or oxygen) is passed through narrow gap separating electrodes, the oxygen gets converted into ozone.

Ozone is applied to waste water by means of diffuser tubes or turbine mixers. Ozone doses in level of 2 mg/l have been reported to result in virtually complete removal of colour and hard pollutants such as detergents. The treated water after sand filtration becomes clean and sparkling.

4.5 Evaporation

4.5.1 Multiple Effect Evaporation

Multiple effect evaporator is generally a vertical cell in which stainless steel tube is mounted. Some evaporator systems work on falling liquid film theory which means that the tubes are not filled up with liquid but a liquid film on inner surface of tube is established. To develop such film, the liquid is trickled in the form of drops through a perforation plate in such a way that the drops fall on the internal periphery of tubes and make a liquid film which moves down throughout the length of the tube. The tube is heated with the help of steam. This technique is reported to enhance evaporation efficiency.

In the evaporation process concentrated liquid is collected at the bottom of evaporator, which is sent to next stage evaporator. Thus the fresh liquor is added

only to the first stage evaporator. Similarly steam is also applied to the first evaporator. The next stage evaporator gets steam from previous one. During evaporation, the liquid is recirculated till it achieves desired concentration of salt or specific density. The vapors and spent steam are connected to condenser. Because of the vacuum in evaporators created by condenser, liquid evaporates at low temperature. The operating temperature of a typical Multiple Effect Evaporator are given in **Table 4.3**. Use of evaporators reduces effluent volume. Also, the evaporation leads into increased concentration of salts in the stream making their recovery more viable wherever intended.

Table 4.3: Operating conditions of a typical multiple effect evaporation system

Parameter	Stage I	Stage II	Stage III	Stage IV
Temperature, °C	82	72	62	55
Length of tube, meters	6	6	4.5	4.5
Diameter of tube, mm	90	90	45	45

In the evaporation process, scaling takes place in the tubes as the evaporation proceeds. Higher the scale formation, lower is the heat transfer rate and the evaporation rate is therefore also reduced. After operation of the system for few weeks scale formation reaches at a stage when cleaning appears necessary. Cleaning process involve both chemical and mechanical operations. The inner surface of tube is wetted with cleaning agent usually acid, to loosen the scale. Then a scale cutter, which is mounted on flexible shaft, is used for scaling off the deposition. The cutter is inserted from top end of the pipe and moved down up to bottom which removes scale in the entire length of tube. Then the scale cutter is replaced with a polishing wire brush for giving final cleaning and making tube surface smooth. This process is repeated for descaling of other tubes. Once the entire set of tubes has been cleaned, the evaporator is closed and tested for leaks etc. In the first stage leak test is performed with the soap solution. Then if needed, the evaporator is filled up with water for further leak test. In case any leak is detected it is rectified with refitting of covers and or seal.



Activated Carbon Adsorption Plant



Multiple Effect Evaporator

4.5.2 Mechanical Vapour Compression

Mechanical vapour compression technique is also used for concentration of effluents. The system is basically a heat exchanger that is an evaporator/condenser. The heat required to evaporate water which flows on one side of a heat transfer surface is supplied through the simultaneous condensation of the distillate-producing vapor on the other side of the surface. That is, the latent heat is exchanged in the evaporation-condensation process within the system. A compressor is the driving force for this heat transfer and provides the energy required separating the solution and overcoming dynamic pressure losses and other irreversibilities.

4.5.3 Direct contact Evaporation

In direct contact evaporation, a heated gas is used as a heating fluid for bringing about vaporization of liquid (effluent). The gas stream is injected at bottom of the equipment by means of adequate distribution system usually perforated plate or a set of pipes. Since both mass and heat transfer takes place at the gas-liquid interface, the available area in direct contact evaporation fundamentally depends on the bubble size in case gas is inject directly into liquid and the droplet size in case liquid is sprayed into the stream of heated gas. Spraying of liquid in air such as mist evaporation is also used for volume reduction. In the mist evaporation system a mist of small droplets is created by pumping liquid through nozzles mounted around periphery of a duct though which air is blown. The large surface area of the mist results in enhanced evaporation of liquid.

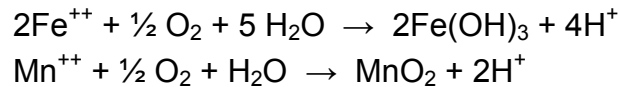
4.6 Crystallization

Crystallization refers to the formation of solid crystals from a homogeneous solution. It is essentially a solid-liquid separation technique. In order for crystallization to take place a solution must be 'supersaturated'. Supersaturation refers to a state in which the liquid (solvent) contains more dissolved solids (solute) than can ordinarily be accommodated at that temperature.

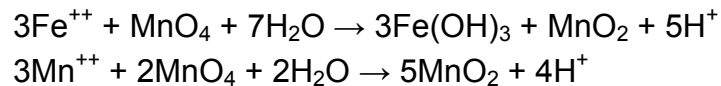
This method is used to crystallise salts and recover them from its mother. The crystallizers may be single stage or multi-stage for extracting useful chemicals like sodium sulphate, calcium sulphate, sodium chloride, calcium chloride etc. from process solutions and effluents.

4.7 Specific Treatments

Textile industry effluent may require specific treatment to remove undesired pollutants based on its end use. For instance, manganese and iron salts are detourous in textile processing. Iron and manganese are expected to be present in effluent which may be due to source of water supply, dyes stuff, chemicals etc. The textile industry are required to provided aeration system at equalization tanks or holding tank prior to RO system. Iron in the form of ferrous bicarbonate may be removed by aeration when ferric hydroxide is precipitated and carbon dioxide is released into atmosphere. Aeration also helps to raise pH by reducing the content of dissolved carbon dioxide. Manganese bicarbonate also react in the same way for which pH of more then 10 is achieved by addition of lime in physico-chemical treatment plant. If ferrous sulphate is present in waste water, the insoluble hydroxide of iron or manganese may be formed due to addition of lime. The iron precipitation will occur at 8.5 pH, but the manganese will be precipitated at pH of 9.0 is reached.



The iron removal filter can be provided prior to RO to further reduce iron and manganese content. In the filter, manganese zeolite is formed by treating sodiumzeolite with manganous sulphate, and then oxidizing by treatment with potassium permanganate. Higher insoluble oxides of manganese are formed on the surface of zeolite grains, thereby making available oxygen capable of converting the ferrous and manganous ions in water to insoluble oxidized form which can be filtered out using multi-grade filter column.



5.0 SELECTION OF ADVANCE TREATMENT METHODS

Proper selection and application of individual or combination the advance treatment methods in textile industry can effectively make recovery of water and/or salts from effluent streams for their reuse in production process. Along with the recovery and reuse of water and salt, the advance methods can also be applied to meet stringent environmental or regulatory requirements such as zero effluent discharge. Membrane filtrations can produce treated water with high purity. Treatment system like activated carbon adsorption and ozonation can be

used to make the effluent suitable for use in membrane filtration. Evaporation system can be used for minimizing effluent volume or achieving desired concentration of target pollutant. The evaporation system and crystallizer combination can recover salt. Nanofiltration on other hand allows passage salt with the permeate, which when used in dyeing process, requires less addition of salt.

5.1 Recovery of Water and Glauber Salt

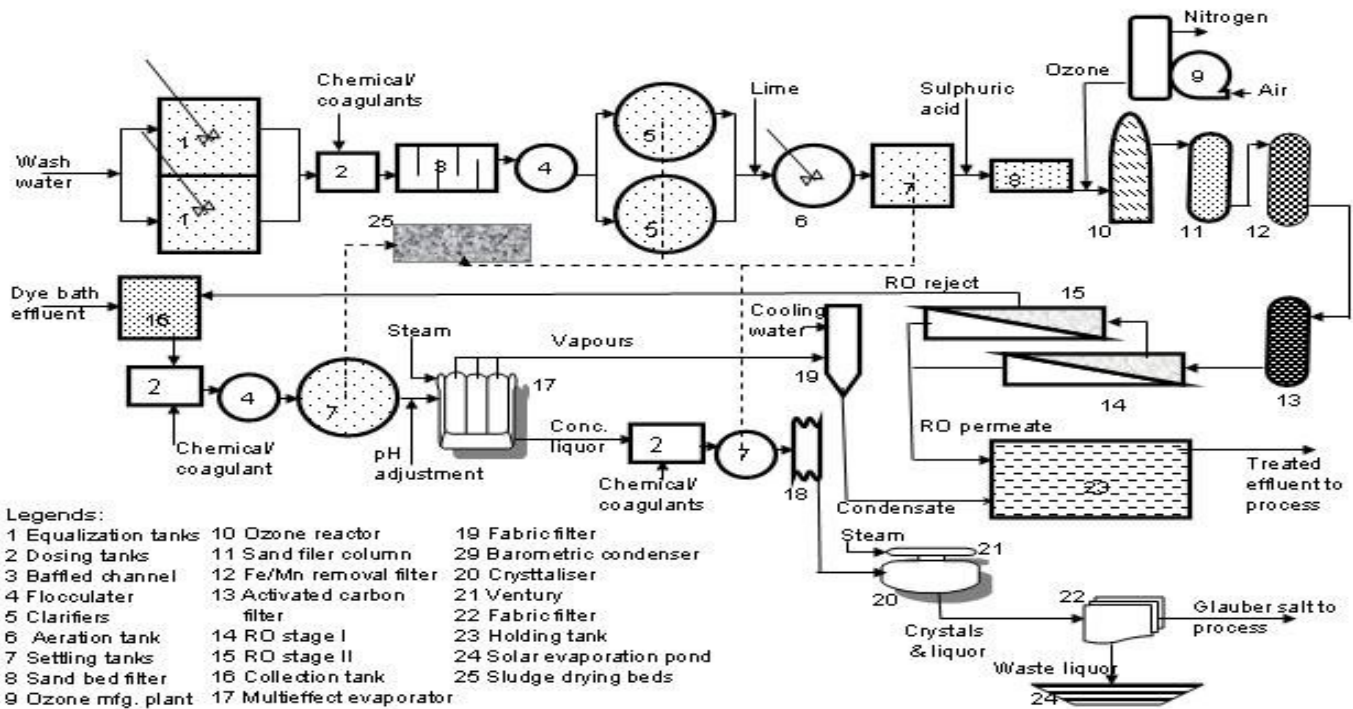
The effluent stream bearing high salt i.e. the spent dye bath is segregated and treated with recovery of salt. This effluent stream has low volume and can be treated using a chemical treatment followed by multi-effect evaporation and crystallization. Glauber salt (Sodium Sulphate decahydrate $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$) based dyeing enables recovery of the salt. The other effluent stream i.e. wash water can be treated separately by primary/secondary treatment methods followed by RO system to recover water.

A case study of treatment scheme based on above concept is presented in this section which is installed by an industry engaged in processing of hosiery fabrics and yarns with an average production of 5 tonnes of hosiery cloths and yarns per day. During processing i.e. scouring, bleaching and dyeing contaminated waste water is generated which is about 500 KLD. The treatment of waste water in the are primary treatment, ozonation, reverse osmosis membrane filtration, multiple effect evaporators and crystalliser. These measure enable industry to recover water and glauber salt (sodium sulphate) for recycle in the production process.

5.1.1 Treatment Scheme

Schematic of treatment system is given in **Fig. 5.1**. Treatment system starts with effective segregation of highly polluting effluent stream from the less polluted waste water. Fabric dyeing machines are provided with two outlet pipes which can be closed or opened depending upon types of discharge. These discharge pipes let out waste water into two different drains. The highly polluted wastewater mainly comprises of spent dye bath and the first wash. The other wastewater stream which is less polluted is the discharge of wash water followed by dyeing and other production processes. The industry has provided different set of treatment units for these two waste streams.

Fig. 5.1: Treatment scheme for recovery of water and glauber salt



The wash water volume is 450 KLD, which is collected in two rectangular equalization tanks equipped with diffused air aeration system. Aeration system helps in homogenization of waste water and at the same time it also helps in preventing odorous condition. The waste water from equalization tanks is pumped to physico-chemical treatment plant. The physico-chemical treatment system consists of lime dosing, coagulant dosing, flocculation, first stage settling, second stage settling, sand bed filtration and acid dosing. The waste water from equalization tanks has pH of about 9. Lime and ferric chloride are added as per the requirement and the wastewater is allowed to pass through baffled channel. Polyelectrolyte is added to enhance flocculation. From the baffled channel, the waste water with above coagulants and chemicals goes to flocculator and then to settling tanks. The overflow of first settling tank is added with lime to raise the pH value to treat iron/manganese. Finally, wastewater is settled in second stage settling tank. In an effort to arrest remaining suspended solids, the effluent is passed through sand bed filter. The effluent at this stage has pH of about 9 to 11. For further treatment, pH is reduced to a neutral level by adding sulfuric acid. The suspended solids are removed and the colour content also goes down considerably in this process. Sludge generated in the primary treatment plant is sent to sludge drying beds. There is no secondary treatment system.

The effluent is given ozone treatment followed by activated carbon system to further reduce colour content and removal of other organic impurities,. The effluent after primary treatment is collected in a collection sump from where it is pumped ozone reactor and then to sand filter column. At the entrance of the reactor, there is arrangement to inject ozone gas in the form of fine bubbles. To effect thorough mixing of effluent with gas pebbles, a tube with baffles is fitted at the inlet of the reactor. Ozone being a strong oxidizer destroys organic impurities, colour and odours. Reaction time in ozone reactor is very quick. Onsite ozone plant is installed for the purpose. At this stage almost all suspended and colloidal impurities are removed. The effluent is then taken to a tank where aeration is effected with the help of compressed air diffuser system. This ensures maintaining odour free environment and removes dissolve gases if any in the effluent prior to further treatment in reverse osmosis system.

Reverse osmosis plant consists of units such as holding tank, iron/manganese removal filter, activated carbon filter, micro cartridge filter reverse osmosis stage

I and reverse osmosis stage II. Effluent enters to reverse osmosis unit at high pressure.. In the effluent anti-scaling agents and acid is mixed before entry into the reverse osmosis unit. Like other filtration system, reverse osmosis membranes are also required to be cleaned by backwash. For developing required pressure, multi stage centrifugal type of pump is used. The pump in first stage develops a maximum pressure of 16.5 kg/cm^2 , which can be raised to up to 25 kg/cm^2 in second stage. The permeate i.e. purified water (which is about 75% of feed) is collected in overhead tank for recycle in the process. Remaining portion 25 % is the reject and is sent to the reverse osmosis stage II plant. Permeate of this plant is 50%. Remaining portion i.e. reject is also 50 %. The permeate is collected in the overhead tank along with permeate of RO stage for use in process. Reject of reverse osmosis II is mixed with dye bath waste water.

The combined quantity of spent dye bath, other process effluents and reject of reverse osmosis stage II is 71.5 KLD. The effluent is collected in a tank and is subject to chemical treatment, which includes lime, ferric chloride and polyelectrolyte dosing and setting. The settled sludge is collected separately. Supernatant is sent to filter press. Then the effluent is processed in multi-effect evaporation system consisting of 4 stages till it attains the desired specific density. The concentrated liquid has sodium sulphate with other salts and colour. For removal of colour, the concentrate is subjected to further treatment which includes chemical dosing. After reaction, effluent liquid is settled in a tank. Sludge settled forms solid wastes. The supernatant liquid is processed in crystallizer for recovery of glauber salt.

There single stage static tank type crystallizer. To effect the crystallization of dissolved sodium sulphate, required conditions are created in the tank for which a steam jet is passed through the ventury so that a vacuum developed. Because of the vacuum the evaporation rate increases. The process is so controlled that the temperature of liquid remains at $12 \text{ }^\circ\text{C}$. At the temperature of $12 \text{ }^\circ\text{C}$, (which is ideal condition) sodium decahydro sulphate precipitates from the liquid. The liquid with sodium decahydro sulphate crystals are transferred to a filter tank. In the tank, sodium decahydro sulphate is separated with fabric filter and utilized in the process mainly in dyeing. The permeate is sent to solar evaporation ponds.

Mass balance of the treatment scheme is given in **Fig. 5.2**.

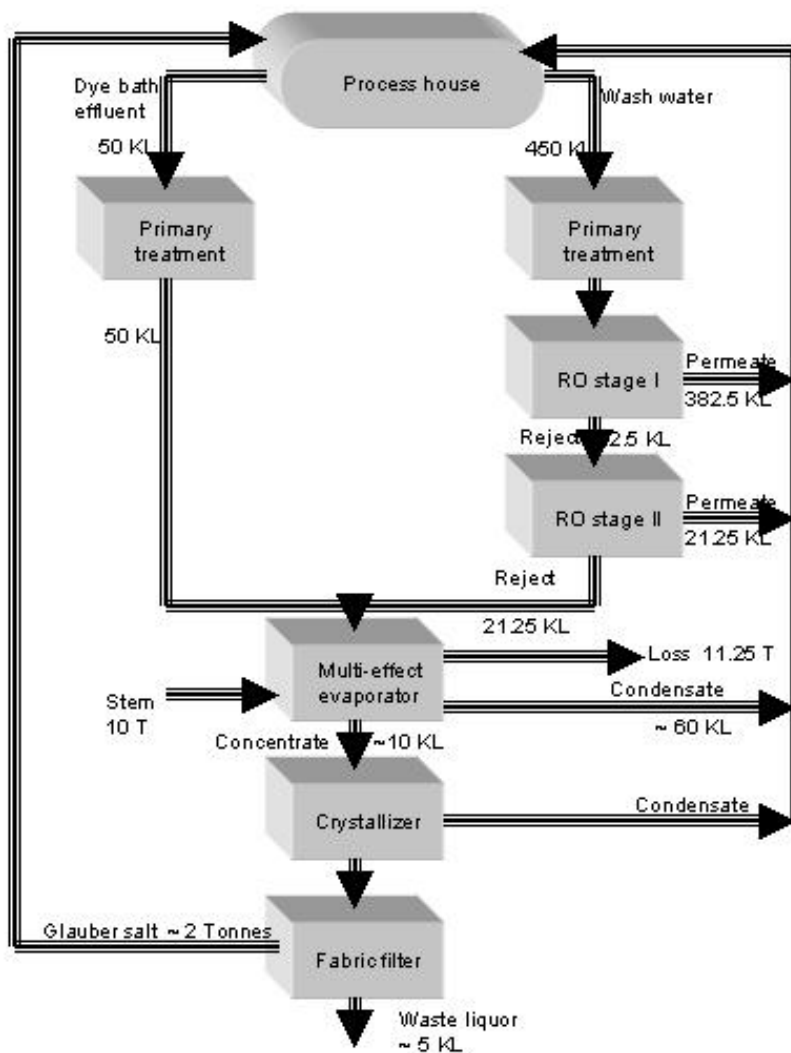


Fig. 5.2: Mass balance of treatment scheme for recovery of water and glauber salt

Table 5.1: Performance of Treatment System for Wash Water

Parameter	Influent	Primary Treatment	Ozonation	RO Stage I		RO Stage II	
				Permeate	Reject	Permeate	Reject
pH	9.88	9.61	6.92	6.03	6.72	5.76	7.04
Total suspended solids, mg/l	167	56	19	6	70	6	124
Total dissolved solids, mg/l	3104	1946	3256	922	9830	196	17828
Chemical oxygen demand, mg/l	586	166	130	26	327	17	754
Biochemical oxygen demand, mg/l	190	41	41	1	16	02	208
Total Hardness, mg/l	96				60	Nil	1080
Chlorides, mg/l	334	636	692	314	108	34	4416
Colour, % purity	<10	<10	Colourless	Colour less	<10	Colour less	10-20

5.1.2 Results

Performance of treatment system for wash water is given in **Table 5.1**. The primary treatment system along with ozonation effectively reduce organic contaminants, i.e. BOD and COD. The levels of COD and BOD in wash water were observed to be 586 mg/l and 190 mg/l respectively. After treatment, COD concentration was measured to be 166 mg/l in physico-chemical treatment and 130 after ozonation. As such there is 77.8 % reduction in COD. Concentration of BOD after primary treatment and ozonation is 41 mg/l, which shows 78.4% reduction. The primary treatment and ozonation have been effective for removal of colour content. It goes colourless from 10% purity in raw wash water effluent.

In the RO influent pH level is 6.92 In RO stage I permeate pH level was observed to be 6.03 whereas pH in RO stage II permeate was found 5.76. Suspended solid concentration in the permeate of both stages of RO is 6 mg/l. There is substantial increase in TSS level on reject streams. From 19 mg/l of TDS in influent goes up to 70 mg/l and 124 mg/l in the rejects of RO stage I and RO stage II respectively. Concentration of COD in influent is 130 mg/l and after RO stage I and RO stage II, its value were measured 26 mg/l and 17 mg/l. Reject streams of RO stage I and RO stage II contains COD values of 327 mg/l and 754 mg/l i.e. 480% increase from its inlet value of 130 mg/l. As regards the BOD content, inlet value of 41 mg/l reduce to 1 mg/l and 2 mg/l in the permeate of RO stage I and RO Stage II permeates. On the other hand, BOD content in the rejects of RO stage I and RO stage II were found to be 16 mg/l and 208, which shows 407% increase of BOD. Colour content after treatment goes up to 10 and 20 percent purity in rejects of RO stage I and RO stage II. In the permeate streams no colour content was observed.

The TDS is the important parameter for RO system The TDS content of RO stage I and RO stage II permeates were observed to be 922 mg/l and 196 mg/l. Net reduction of TDS pollution from its inlet value of 3256 mg/l in RO systems is therefore works out to be above 94%. Separated TDS portion of RO stage I is treated in RO stage II. TDS level in RO stage I is 9830 mg/l whereas its level in reject of RO stage II is 17828 mg/l. After the RO treatment, concentrated TDS bearing reject stream is subject to further treatment along with dye both waste water.

Performance of dyebath waste water treatment is given in **Table 5.2**. This stream contains high level of all the parameters. TSS, TDS, BOD, COD and hardness were observed to be 4669 mg/l, 17000 mg/l, 1823 mg/l, 9366 mg/l and 1060 mg/l respectively. Initially, the waste water is treated in physico-chemical treatment, which reduces all the parameter considerably. Colour content goes from 80 per cent purity to 10 per cent purity. The effluent treatment is essential considering the fact that i.e. sodium sulphate is to be recovered from the waste stream. Better the treatment result more pure will be the sodium sulphate. The treated

Table 5.2: Performance of treatment scheme for dye bath effluent

Parameters	Influent	Multiple effect evaporation		Condensate	Crystallizer waste
		Primary Treatment	Conce-ntrate		
pH	9.34	8.88	9.38	8.35	9.13
Total suspended solids, mg/l	4669	319	2516	8	1993
Total dissolved solids, mg/l	17000	18340	212384	1426	21700
Chemical oxygen demand, mg/l	9366	655	1382	81	668
Biochemical oxygen demand, mg/l	1823	279	801	30	295
Total Hardness, mg/l	1060	640	Nil	Nil	800
Chlorides, mg/l	28453	4539	31897	19	34289
Colour, % purity	60-80	10	81-100	Colourless	40-60

dye bath waste is evaporated to make more concentrated liquor. As per the analysis results, the concentrated liquor after evaporation contains 212384 mg/l of TDS, the value of which before evaporation is 18340 mg/l. Evaporation process is continued till the liquid attends specific gravity of 1.24. The desired composition of the liquor is 20% sodium sulphate, 10% other salts and remaining 70% water. The condensate obtained from evaporation system is pure water with low TDS, COD and BOD contents. Colour content and hardness were found to be zero in the condensate. TDS of condensate is reported to be 50 mg/l. However, it was observed to be 1426 mg/l which may be due to mixing of condensate water in barometer with cooling water.

5.1.3 Economics of Treatment Scheme

Total waste water discharge is estimated (**Fig. 5.2**) to 500 KLD. Out of this 50 KLD is dye bath waste water and the first wash, and remaining 450 KLD is wash water effluent. In the RO stage I, about 75% of wash water effluent i.e. 382.5 KLD is recovered, and remaining 25% (42.5 KLD) reject is treated in RO stage II. The water recovery in RO stage II is 50% i.e. 21.25 KLD. Water recovery by RO system is 403.75 KLD which is 80.75 % of the entire effluent generated. Water

recovery is also done by condensation of vapors, which was reported to 60 KLD. Therefore, total water recovery in the system is 463.75 KLD which is 92.75 % of total waste water discharge of industry. Besides the water recovery, the system facilitates salt recovery which is estimated to be about 2000 kg per day.

The capital cost and operation and maintenance cost of different units as obtained from the industry is presented in **Table 5.3**. Based on these figures, economics has been worked out and presented in **Table 5.4** and **Table 5.5**.

Table 5.3: Capital cost, operation and maintenance costs of treatment scheme

Treatment units	Capital cost, Rs. Lakhs	Operation cost, Rs. Lakh/m	Maintenance cost, Rs. Lakh/m
Primary treatment	45	1.5	0.25
R.O. System	92	1.0	0.25
Evaporators and Crystalliser	55	1.9	0.50

It can be seen that annual burden on account of primary treatment alone is Rs. 29.93 lakh/year. Annual burden goes up to Rs. 63.29 lakhs/year with primary and RO system. The entire treatment system i.e. primary, RO evaporation and crystallization puts annual burden of Rs. 103.05 lakh per year. Annual burden/annual turnover ratios in respect of these three sets of treatment works out to be 2.99%, 6.33% and 10.30% respectively. Recurring cost for treatment of waste water using primary treatment comes to be Rs. 13.06 per KL. When primary treatment and RO system are put together, the recurring cost goes up to Rs. 23.07 per KL. With all the treatment units (primary + RO + Evaporation crystallizer) this cost comes to be Rs. 41.53 per KL of waste water.

The industry recovers water and sodium decahydro sulphate, which gives returns of Rs. 76.54 lakhs per year. Whereas the annual burden is Rs. 103.45 lakhs per year. As such there is a net loss of Rs. 26.51 lakh per year when interest and depreciation cost of treatment system are taken into account. Total recurring cost is Rs. 64.8 lakh per year. When interest and depreciation is not taken into account a profit of Rs. 11.74 lakh per year is has been worked out.

Table 5.4: Economics of treatment scheme for recovery of water and glauber salt

Particulars	Primary treatment	Primary + Reverse osmosis	Primary + Reverse osmosis + multiple effect evaporator crystalliser
Capital cost (Rs. Lakhs)	45	137	192
Annualized capital cost [@ 15% p.a. interests& depreciation, plant life 10 years] (Rs. Lakh)	8.96	27.29	38.25
Operation and maintenance cost (Rs. Lskh/annum)	21.0	36.0	64.8
Annual burden (Annualised cost + O&M cost) Rs. Lakh	29.96	63.29	103.05
Annual burden /annual turnover ratio (%)	2.99	6.33	10.30
Treatment cost Rs./KL (without interest & depreciation)	13.46	23.07	41.53
Treatment cost Rs./KL (with interest & depreciation)	19.18	40.57	66.05

Table 5.5: Details of recovery and savings

Quantity of water recovered	=	382.05 + 21.25 + 60
	=	463.75 KLD
	=	12057.5 KL per month
	=	144690 KL per year
Cost of water @ Rs. 50/KL	=	Rs. 72,34,500/ per year
Cost of recovered salt (as reported by industry)	=	Rs. 0.35 lakh per month = Rs. 4.20 lakhs per year
Total recovery	=	72.34 + 4.20 = Rs. 76.54 lakhs/year
Loss / Saving	=	Rs. 103.05 – 76.54 = 26.51 lakh/year (Loss)
Saving (without taking into interest and depreciation)	=	76.54 – 64.8 = Rs. 11.74 lakhs per year

5.1.4 Findings

- The dye bath effluent is 10 % of the total waste generated and the remaining 90 % is wash water.
- The pollution load in terms of BOD, COD and TDS in dye bath effluent was measured as 1823 mg/l, 9366 mg/l and 17000 mg/l respectively. The values of BOD, COD and TDS in wash water effluent is 190 mg/l, 586 gm/l and 3104 mg/l.
- The wash water effluent after primary treatment and ozonation achieves 77.8 % COD reduction and 78.4 % reduction in BOD.
- The further treatment of the effluent in two stage RO system gives a permeate having BOD,COD and TDS levels of 6 mg/l, 17-26 mg/l and 196-922 mg/l respectively. Colour content and hardness were also completely removed.
- The reject stream of RO system contains TSS 124 mg/l, COD 754 mg/l and TDS of 17828 mg/l.
- The liquid after evaporation in multi-effect evaporators contains 212384 mg/l of TDS, the value of which before evaporation is 18340 mg/l. Evaporation process is continued till the liquid attends specific gravity of 1.24.
- The condensate of evaporation is pure water with TSS, COD and BOD contents of 8 mg/l, 81 mg/l and 30 mg/l. Colour content and hardness were found to be zero in the condensate.
- The RO stage I gives permeate water which was found to 76.5 % (382.5 KLD) of the total waste water This water is recycled in the production process.
- The total recovery of permeate water with the use of RO stage II, comes to be 80.75 % (403.75 KLD) of the total effluent generation.
- The estimated condensate from multiple effect evaporator comes to be 60 KLD and as such the total recovery of water for the entire system works out to be 92.75 % (463.75 KLD)
- The capital cost of primary treatment, RO technology and, evaporators and crystalliser is Rs. 45 lakhs, 92 lakhs 55 lakhs respectively. When expressed as Rs./KL, the capital cost comes to be, (i) Rs. 9000/Kl, for primary treatment, (ii) Rs 27,400/KL for the primary and RO system, and (iii) Rs. 38,400/KL for the entire treatment and recycling system.



Crystallizer



Filtration of Crystals

- The estimated annual burden on account of primary treatment alone is Rs. 29.93 lakh/year. Annual burden goes up to Rs. 63.29 lakhs/year with primary and RO system. The entire treatment system i.e. primary, RO evaporation and crystallization puts annual burden of Rs. 103.05 lakh per year.
- Annual burden to turnover ratios in respect of the three sets of treatment works out to be, (i) 2.99% for primary treatment, (ii) 6.33% for primary and RO system, and (iii) 10.30% for the entire treatment and recycling plant.
- Recurring cost for treatment waste water using primary treatment comes to be Rs. 13.46 per KL. When primary treatment and RO system are put together, the recurring cost goes up to Rs. 23.07 per KL. With all the treatment units (primary + RO + Evaporation crystallize) this cost comes to be Rs. 41.53 per KL of waste water.
- The industry recovers water and glauber salt, which gives returns of Rs. 76.54 lakhs per year.

5.2 Recovery of Water and Common Salt

This scheme also require segregation of spent dyebath effluent from wash water stream. Dye bath effluent is to be treated using a nanofiltration system and wash water effluent with RO system. Nanofiltration allows maximum passage of the salt with no colour in the permeate. As such the permeate can be directly recycled back to dye bath so that fresh addition of salt can be reduced drastically. For this option common salt is used in dyeing process.

Information about the treatment scheme given in the report corresponds to the systems installed in a yarn processing units of 2 to 2.5 tonnes per day production. Grey yarn received in industry is first subjected to chemical treatment

such as scouring, mercerizing and bleaching and then dyeing is performed. Cotton yarns are dyed with reactive dyes, whereas polyester yarns are dyed using disperse dyes. Processing of yarns generates about 220 KLD of effluent.

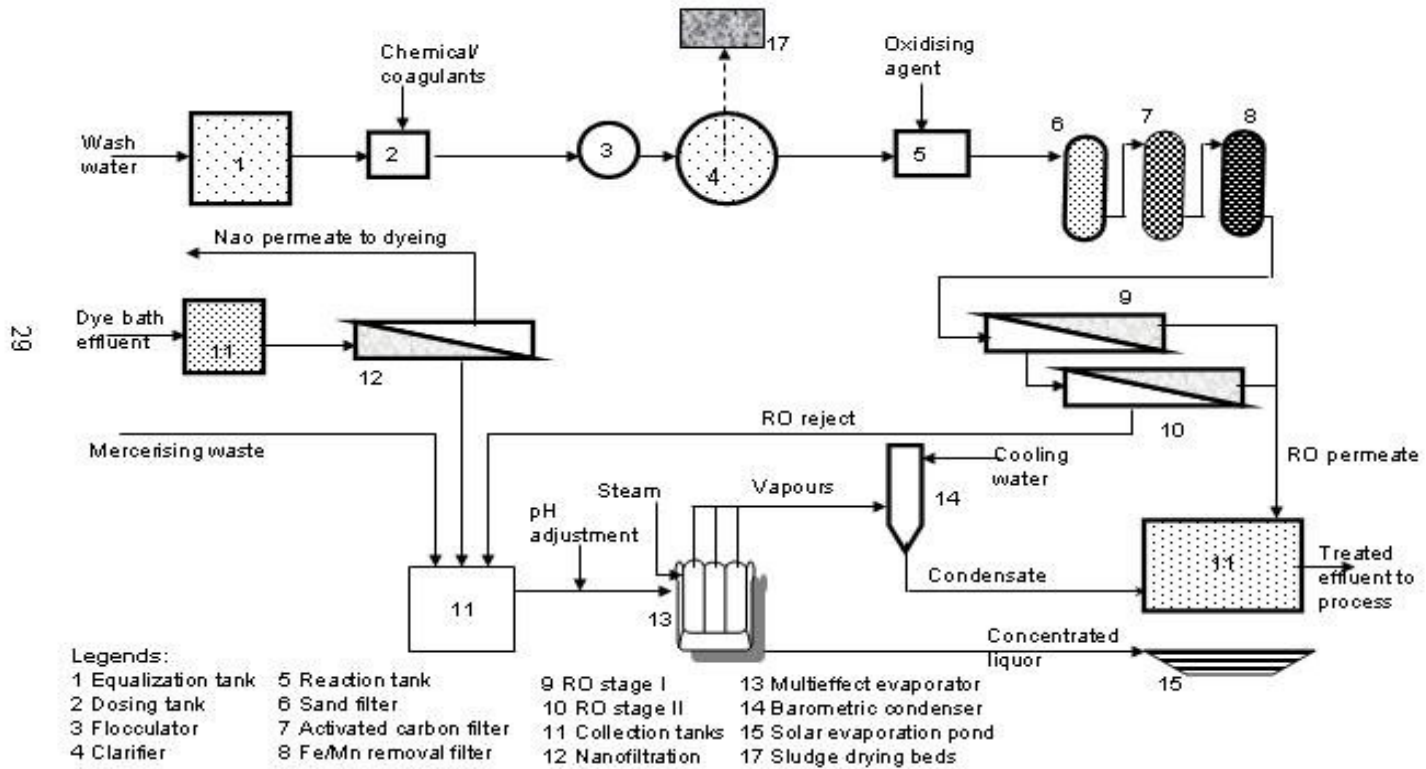
5.2.1 Treatment Scheme

The effluent streams are properly segregated for further treatment and reuse. Schematic of treatment scheme is shown in **Fig. 5.3**. The spent dye bath effluent amounting to 20 KLD is segregated. Out of the remaining discharge 180 KLD is the wash water i.e. dilute waste and 20 KLD is mercerizing waste. Wash water is first treated in primary treatment unit, where lime, ferrous sulphate and polyelectrolyte are added. The primary treated effluent is further treated with oxidizing agent. Next stage of treatment includes sand filtration and activated adsorption process. The effluent is then purified in two stage RO system. The first stage of RO unit gives permeate of high purity which is 70% of feed. The reject of RO stage I is further pumped to RO stage II which produce permeate about 65% of feed and 35% reject. The permeates of RO stage I and stage II are collected recycled in process plant. The rejects of these RO are treated in evaporation system.

As regard the spend dye bath and mercerizing effluents are concerned, no treatment is given except pH adjustment. The spend dye bath effluent along with reject of RO stage II and mercerizing waste is directly sent to multi-effect evaporation system. The vapours arising out of the evaporation is condensed and re-used. The concentrated liquor of evaporation system which is about 10 per cent of the feed is subjected to solar evaporation.

Mass balance of treatment scheme is given in **Fig. 5.4**.

Fig. 5.3: Treatment scheme for recovery of water and common salt



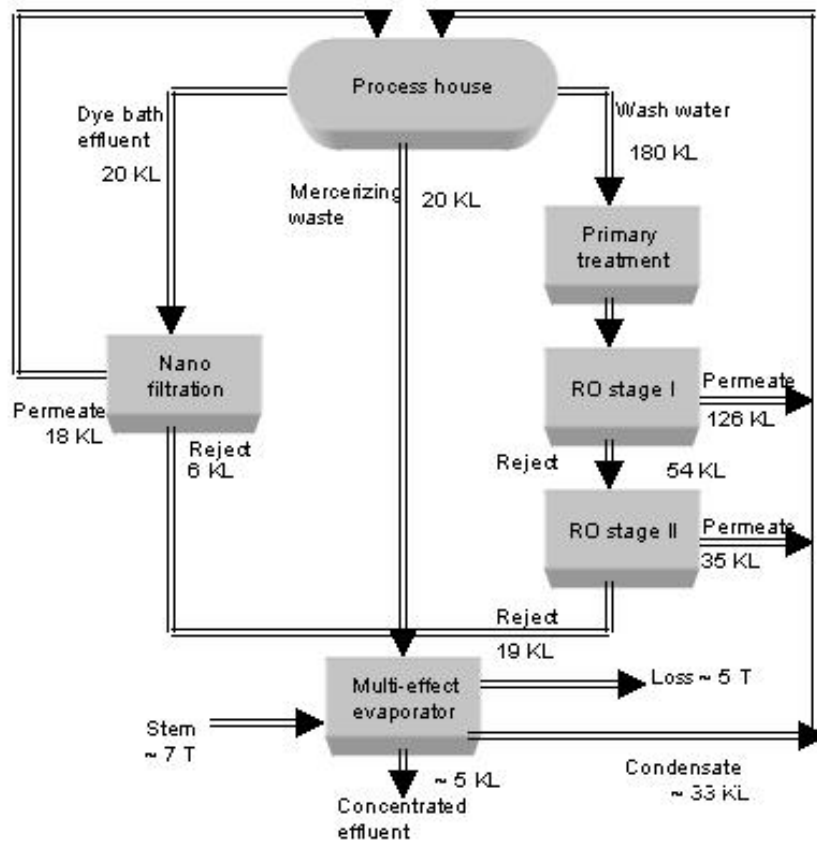


Fig. 5.4: Mass balance of treatment scheme for recovery of water and common salt

5.2.2 Results

The characteristics of waste water is presented in **Table 5.6**. It can be seen that values of TSS TDS, COD and BOD in raw wash water are 57 mg/l, 3690 mg/l, 342 mg/l and 70 mg/l, which after primary treatment measure 23 mg/l, 3608 mg/l 212 mg/l and 50 mg/l respectively. As such there is about 59.6% reduction in TSS, 38% reduction in COD and 28.5% reduction in BOD. In the permeate of RO system, TSS of 3 mg/l, TDS of 462 mg/l, COD of 21 mg/l, BOD of 6 mg/l and zero hardness was found. The permeate is reused in production process. The reject stream of RO System contains TSS, TDS, COD and BOD values as 48 mg/l, 19548 mg/l, 1014 mg/l and 280 mg/l which is further processed in multi-effect evaporation system.

Performance data of nano-filtration system for dye bath effluent is given in **Table 5.7**. Analysis results of dye bath effluent reveal that TDS values remain more or less same after nano-filtration as nano-filtration allows passage of common salt. The organic pollution in terms of COD and BOD in influent are 909 mg/l and 200 mg/l. In the permeate COD and BOD were found 364 mg/l and 65 mg/l. The permeate i.e. brine water having chloride 28069 mg/l is recycled in dyeing process.

Table 5.6: Performance of treatment scheme wash water

Parameter	Influent	Primary treatment/ ozonation/ adsorption	RO Stage I & II	
			Permeate	Reject
pH	9.93	9.69	7.51	8.12
Total suspended solids, mg/l	57	23	3	48
Total dissolved solids, mg/l	3690	3608	462	19548
Chemical oxygen demand, mg/l	342	212	21	1014
Biochemical oxygen demand, mg/l	70	50	6	280
Chlorides, mg/l	1771	1724	190	10054
Total hardness, mg/l	182	141	Nil	687

5.2.3 Economics of Treatment System

Based on the quantity and cost of water and salt, an attempt has been made to work out economics of treatment and recycling system and presented in **Table 5.8**. It can be seen that benefits on account of recovery water and salt can completely off set operating cost of RO system, nano-filtration and multiple effect evaporator.

5.2.4 Findings

- TDS level in wash water influent 3690 mg/l. After primary treatment, the value was observed to be 3608 and after reverse osmosis 462 mg/l. Cod and BOD concentrations were observed as 21 and 6 mg/l respectively in the permeate .
- The other treated effluent stream is nanofiltration permeate with which contains COD BOD and hardness as 364 mg/l, 65 mg/l and 51 mg/l. respectively. Chloride content is 28069 mg/l.
- The total recovery is about 254 KLD from reverse osmosis system and multiple effect evaporator. In addition 35 KLD of brine water is collected for nanofiltration for recycle in dyeing process.

Table 5.7: Performance of treatment scheme for dye bath effluent

Parameter	Influent	Nano filtration (Brine water)
pH	10.43	8.19
Total suspended solids, mg/l	95	105
Total dissolved solids, mg/l	44418	45680
Chemical oxygen demand, mg/l	909	364
Biochemical oxygen demand, mg/l	200	65
Chlorides, mg/l	21284	28069
Hardness, mg/	101	51

- The returns on account of recovery of water and salt works out to Rs. 14277/- per day whereas the recurring cost on entire treatment system comes to Rs. 20250/- per day. Therefore, the net expenses on operation and maintenance is Rs. 8529/- per day.

- It may be noted that the operating cost of multiple effect evaporator alone is Rs. 11250/- per day. The treatment system excluding evaporation system may be managed with returns on recovery of water and salt.

5.3 Recovery of Water

The effluent steams can be collectively treated using RO system. In this case recovery of water is possible but salt recovery is not feasible.

Study of a scheme installed in a large textile industry situated in Rajasthan was selected for study. The industry is engaged in production of towels, which is 65 tones per month. Production activities involve weaving, dyeing and finishing. Processing activities generate about 575 KLD of waste water, which is treated in treatment and recycling plant consisting of primary treatment, ion exchange, ultra-filtration and reverse osmosis membrane filtration.

Table 5.8 : Economics of treatment scheme for recovery of water and common salt

Particulars	RO System	Naofiltration	Multiple effect evaporation
Designed feed KLD	300	30	70
Average feed, KLD	180	20	45
Recovery of water, KLD	161	18	33
Recovery of salt kg/day (@ 28069 mg/l),	-	50s	-
Cost of recovered water, Rs./day (@ Rs. 0.054/l)	8694/-	972/-	1782/-
Cost of recovered salt , Rs./day (@ Rs. 5.6/kg)	-	2829/-	-
Operating cost, Rs./day	8100/- (@ 0.045 Rs./l feed)	900/- (@ 0.045 Rs./l feed)	11250/- (@ 0.25 Rs./l feed)
Total cost of recovered water and salt Rs./day	8694 + 972 + 1782 + 2829 = 14277/-		
Total operating cost, Rs./day	8100 + 900 + 11250 = 20250/-		
Saving, Rs./day	14277 – 20250 = (-) 5973/-		

5.3.1 Treatment Scheme

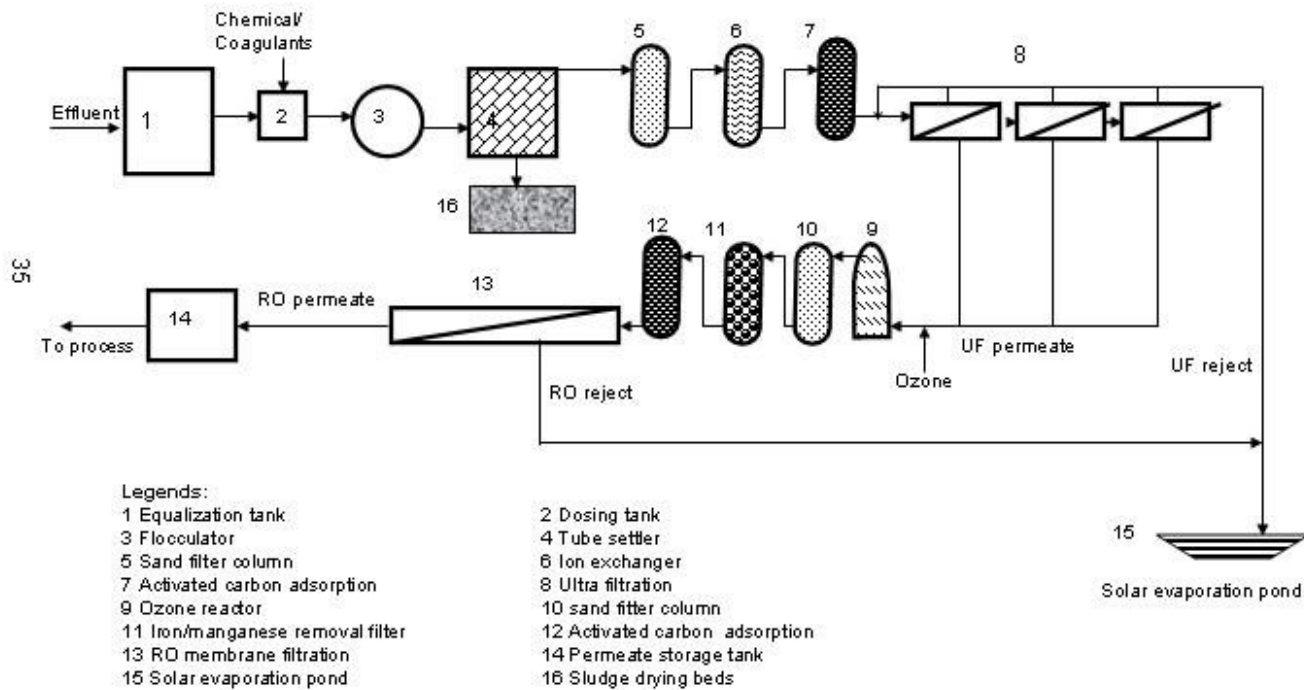
Total discharge of effluent is 575 KLD. The treatment schemes consists of primary treatment, ion exchange, activated carbon adsorption, ultra-filtration and reverse osmosis membrane filtration. The systems gives water recovery to the tune of 70 per cent of the effluent which is recycled in the process. **Fig. 5.5** shows flow diagram of treatment scheme. The combined effluent is received in an underground equalization tank which has provision for compressed air mixing. In the chemical treatment unit, lime ferrous sulphate and polyelectrolyte are used. The effluent after dosing enters flocculator and then settled in tube settler. The supernatant effluent is passed though sand bed filter column which is to remove residual suspended solids. The next stage of treatment unit is ion exchange for removal of hardness. The effluent is then taken to activated carbon adsorption filter for removal of residual organic matter and colour.

The above treated effluent is collected in a buffer tank, from where it is pumped to ultra-filtration unit at a pressure of 8-10 kg/cm². The membrane is in housed in steel tube module of size 8" diameter and 40" long. Three modules in series makes one treatment unit. In the first module, about 15 % of water is recovered. The second tube module gives a recovery of 12 %. The last module gives recovery of about 7-8 %. As such the total recovery in one pass is about 35 %. The eject stream is recycled back into the ultra-filtration unit along with other effluent for more recovery.

The permeate of the ultra-filtration is treated in RO membrane filtration unit. Before RO unit the effluent once again processed in sand bed filter and activated carbon adsorption columns. The effluent is now pumped to RO unit at a pressure of 18 kg/cm². The reject which is about 30 per cent is disposed to solar evaporation pond. Balance 70 per cent is the permeate which is recycled in the process.

Mass balance of treatment scheme is shown in **Fig. 5.6**

Fig. 5.5 : Treatment scheme for recovery of water



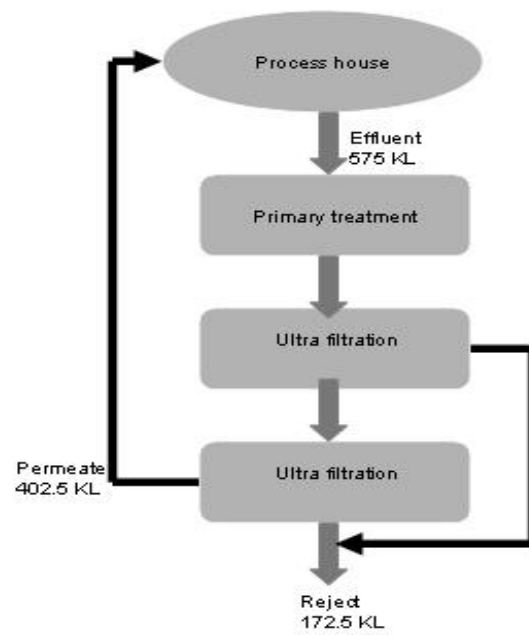


Fig. 5.6: Water balance of treatment scheme for recovery of water

5.3.2 Results

Characteristics of effluent at different stages of treatment is given in **Table 5.9**. TDS level in combined effluent is 11358 mg/l, which after primary, exchange and adsorption treatment measures 8178 mg/l. The ultra filtration and RO membrane filtration further reduce TDS to 5034 mg/l and 642 mg/l respectively. COD and BOD values were observed as 553 mg/l and 220 mg/l in influent. These parameters after treatment up to RO stage reduce to 81 mg/l and 1 mg/l respectively, Chloride and sulphate from their initial values of 4720 mg/l and 1395 mg/l reduce 2200 mg/l and 285 mg/l after ultrafiltration and 240 mg/l and 17 after RO filtration. It can also be seen that colour content also attends value of 20 hazen units from its initial level of 250 hazen units. In the reject, values of TDS, COD and BOD, Chloride and sulphate go considerably higher.

Table 5.9: Performance of treatment scheme for recovery of water

Parameters	Influent	Primary/ ion exchange/ adsorption	Ultra- filtration	RO permeate	RO reject
pH	9.30	9.08	6.93	7.15	7.47
Total suspended solids, mg/l	164	76	36	10	79
Total dissolved solids, mg/l	11358	8178	5034	642	12444
Chemical oxygen demand, mg/l	553	325	88	81	106
Biochemical oxygen demand, mg/l	220	171	5	1	8
Total harness, mg/l	88			80	2620
Chloride, mg/l	4720	3240	2200	240	4600
Sulphate, mg/l	1395	800	285	17	505
Colour, Hazen units	250	60	20	20	25

5.3.3 Economics of Treatment Scheme

The capital cost, power consumption and recurring cost of primary treatment, ultra-filtration and RO treatment units are presented in **Table 5.10**. Total installation cost of the treatment and recycling plant including primary, ultra-filtration and RO is Rs. 145 lakh which is equivalent to Rs. 25,217 per KLD of

effluent. The operation and maintenance cost of primary treatment is Rs. 5.85 lakh per month i.e. Rs. 34.08/ per KL. Primary and ultra-filtration system put together, the recurring cost comes to 9.04 lakh per month which works out to Rs. 52.40 per KL. The recurring cost of the entire system has been reported 12.63 lakh per month. When calculated in terms of Rs./KL it comes to be Rs. 73.22. The economics analysis of treatment and recycling plant is given in **Table 5.11**.

Table 5.10: Capital and operation costs of treatment scheme for recovery of water

Treatment unit	Capital cost (Rs. Lakh)	Recurring cost (Rs.Lakh/m)
Primary treatment	30.0	5.88
Ultra-filtration	60.64	4.03
RO Plant	54.36	2.72
Total	145	12.63

5.3.4 Findings

- The industry generates 575 KLD of waste water bearing pollution of TSS 164 mg/l, TDS 11358 mg/l, COD 553 mg/l, BOD 220 mg/l and colour 250 hazen units.
- The levels of TSS, TDS, COD, BOD and colour after the primary treatment, ion exchange and activated carbon adsorption filter treatment systems are 76 mg/l, 8175 mg/l, 325 mg/l, 171 mg/l and 60 hazen units respectively. Percent reduction at this stage of treatment works out to be TSS 53 %, COD 41 %, BOD 22 %, and colour 76 percent.
- The ultra-filtration which achieves TSS level of 36 mg/l, TDS of 5034 mg/l, COD of 88 mg/l, and BOD of 5 mg/l. Colour content was observed to be 20 hazen units.
- The treated effluent quality from RO unit is observed as, TSS 10 mg/l, TDS 642, mg/l, COD 81 mg/l BOD 1 mg/l and colour content 20 hazen units.
- Total recovery of the water by primary, ion exchange, activated carbon adsorption, ultrafiltration and RO filtration is measured 70 % of the total waste water i.e. 402.5 KLD which is reused in the process. Rest of the effluent i.e. 172.5 KLD is the reject stream of RO plant which contains TDS of 12444 mg/l and is disposed of through evaporation pond.

- The ultra-filtration process has been provided to remove suspended impurities. This process therefore helps in improving operational efficiency of subsequent treatment unit i.e. RO system.
- The treatment and recycling plant gives water recovery to the tune of 70 % (i.e. 402.5 KLD) of the total effluent. The treated effluent contains very low pollution. Levels of TSS, TDS and COD were found to be 10 mg/l, and 642 mg/l respectively. The raw water available to the industry has been reported to have TDS level of about 1800 mg/l.

Table 5.11: Economics of treatment scheme for recovery of water

Particulars	Primary treatment system	Primary + ultrafiltration system	Primary + ultrafiltration + reverse osmosis
Capital cost (Rs. Lakhs)	30.0	90.64	145
Annualized capital cost [@ 15% p.a. interests & depreciation, plant life 10 years] (Rs. Lakh)]	5.79	18.06	29.69
Operation and maintenance cost (Rs. Lskh/annum)	5.88	7.04	12.63
Annual burden (Annualised cost + O&M cost) Rs. Lakh	11.85	27.1	42.5
Treatment cost Rs./KL (without interest & depreciation)	34.08	52.40	73.22

6.0 TREATMENT METHODS AND THEIR SUITABILITY FOR PROCESS WATER REQUIREMENTS

The quality of treated effluent from different membrane filtration systems installed for recovery and recycling is complied and presented in **Table 6.1**. The standards for process water for textile industry as published in IS: 201:1992 are also given in the Table for comparison. It can be seen that TSS level in RO permeates varies from 3 to 10 mg/l. There is also large variations in TDS level i.e. 196 to 922 mg/l. COD values were observed in the range of 21 to 26 mg/l. In one RO unit its values was found 81 mg/l. BOD values were observed between 1 and 6 mg/l. It is also observed that RO permeates has zero hardens in two units. In one unit its values was found 80 mg/l. RO permeate shows chloride level between 34 and 314 mg/l. As far sulphate is concerned, its value in one unit was observed to be 17 mg/l. Colour content of permeate in two units was found as nil whereas 20 hazen units were was found in one unit.



Raw Effect Samples



Treated Effluent Samples

Table 6.1: Treated Effluent Quality and Standards for Process Water

Parameter	Membrane filtration system						Standards for process water for textile industry (IS: 241-1992)		
	Reverse osmosis filtration				Nano filtration	Ultra filtration	General purpose	Wool Scouring	Bleaching dyeing & subsequent processes
	1	2	3	4	1	1			
pH	6.03	5.76	7.51	7.15	8.19	6.93	6.0-8.5	6.0-8.5	6.0-8.5
Total suspended solids, mg/l	6	6	3	10	105	36			
Total dissolved solids, mg/l	922	196	462	642	45680	5034			
Chemical oxygen demand, mg/l	26	17	21	81	364	88			
Biochemical oxygen demand, mg/l	1	2	6	1	65	5			
Total harness, mg/l		Nil	Nil	80	51		50	2	2
Chloride, mg/l	314	34	190	240	38069	2200	100		
Sulphate, mg/l				17		285	100		
Colour, Hazen units	Colourless	Colourless		20		20	20	70	5
Iron/manganese, mg/l	1.30			0.32			0.25	0.1	0.1

The quality of brine water i.e permeate of nanofiltration shows TSS, TDS, COD, BOD and hardness as 105 mg/l, 45680 mg/l, 364 mg/l, 65 mg/l and 51 mg/l respectively. The brine water contains chloride of 28069 mg/l. This water is used in dyeing process.

Ultrafiltration unit is effective in removal of TSS, organic content and colour, The values of TSS, TDS, COD, BOD and colour were measured as 36 mg/l, 88 mg/l, 5 mg/l and 20 hazen units respectively. . TDS was found to be 5034 mg/l. .

Out of parameters discussed above, pH, total hardness, chloride, sulphate, iron/manganese and colour are also relevant parameter as far as BIS standards concurred when effluent is intended for reuse. For use in textile processes, water must be clear. Turbidity and colour are undesirable for many textile purposes because it may contain putrefactive organisms which could cause spots or degradation of dressing or finishing solution. The colour contributed by organic compounds can exert chlorine demand in bleaching process and thereby reduce effectiveness of chlorine as bleaching agent. Iron salts could be harmful in textile processing in many ways. In scouring and bleaching, they impart a yellow tinge to white material. Ions of heavy metals may act as catalysts in the decomposition of bleaching agents and cause activated attack with subsequent degradation of the cloth. In dyeing stage, iron may combine with some dyes and cause a dulling effect in shade.

Hardness in water arises from the presence of calcium and magnesium salts. In scouring process, presence of these impurities forms insoluble sticky soaps which are to some extent deposited on the fabric. This leads to soiling and even impairing the feel of the cloth. Usually, they are not deposited evenly and cause unevenness in subsequent dyeing. Moreover, calcium and magnesium ions will precipitate some dyes. Other metal ions such as iron, strontium etc. react in the same way and could contribute to hardness. These ions can be in small amounts compared with calcium and magnesium ions.

BIS standards for hardness is 50 mg/l for general purpose water. In case of two RO units, zero hardness was observed. One RO unit gives chloride below standards of 100 mg/l. Sulphate was also found below 100 mg/l. The RO as well as UF filtration meets colour standards. Two RO units produce colourless permeate water. Iron content in the permeates was observed to be 1.30 mg/l and 0.32 mg/l.

7.0 BENEFITS OF ADVANCE TREATMENT METHODS

Application of appropriate advance treatment methods while reducing the pollution problems, enable industry to recover water and salt. The quality of permeate from membrane filtration systems is reasonably good for reuse in textile operation. Returns on account of reuse of water and salt can off set recurring cost of treatment system.

The reverse osmosis system can produce permeate water with TDS as low as 196 mg/l. Low TDS water when used in textile processing minimizes consumption of sequestering agents which are added to suppress effect of TDS in chemical treatment of cloth.

Use of reverse osmosis permeate can lead to water conservation by way of reduction in number of washes in fabric processing. More washes may be required where normal water is used in order to wash out hardness already held in the fabric.

The permeate water has negligible hardness. This avoids use of chemicals required for water softening. Corrosion and scale formation in sensitive parts like flow sensors, temperature sensors etc. can be minimized, which leads to less maintenance cost, less breakdown and more output.

When the condensate water from evaporation system having low TDS is used as boiler feed water, the efficiency of boiler can be improved since formation of scale on the boiler tubes is reduced. This intern reduces fuel consumption and maintenance cost.

Use of nanofiltration system permeates salt water (brine) but rejects other contaminants from effluent stream. The brine when reused in dyeing requires less additional salt. Crystallization also facilitates recovery of salt. While recovering the salts these methods also reduce problems relating to disposal of high TDS effluent streams of the Textile Industry.

The recycling and reuse of the treated effluent and salt directly conserve natural resources and a step towards sustainable development. Installation of advance treatment methods along with recycling arrangement gives goodwill in the market.

8.0 LIMITATIONS OF ADVANCE TREATMENT METHODS

For advance treatment like reverse osmosis, different units such as sand filter, activated carbon adsorption, iron and manganese filter etc. may be required to meet the feed effluent requirement. Maintaining desired effluent quality at each stage requires regular monitoring. The treatment system may require trained manpower to operate. In some cases suppliers man the system.

Activated carbon and other media are periodically required to be replaced or regenerated. Regeneration is a specialized operation.

Performance of membrane filtration largely depends on the performance of primary treatment system. Consistency in primary treatment system is of prime importance.

The evaporators used for effluent volume reduction or concentration are not free from trouble. They require frequent cleaning to remove scale deposition on tube walls.

In some membrane units, COD value in treated water was observed to be as high as 81 mg/l. Colour content was also found to be 20 hazen units. These pollutants can cause adverse effect on some of the textile processing operations like bleaching.

Reverse osmosis technology is extensively being used for water purification. However, its application for industrial use is quite new. There is also problem in disposal of reject from membrane as it has high pollution load and its treatment is difficult.

9.0 CONCLUSIONS

In the treatment scheme covered for study, membrane filtrations have been in operation. Other treatment system like activated carbon adsorption, ozonation etc. are used to make the effluent suitable for use in membrane filtration. Multiple effect evaporation system has been in use for minimizing effluent volume. The multiple effect evaporation with crystallizer has been installed for recovery glauber salt.

The analysis results indicate that reverse osmosis membrane filtration can produce colourless treated effluent with dissolved solids as low as 196 mg/l and zero hardness. Nanofiltration on other hand allows passage of maximum salt with

the permeate, which when used in dyeing process, requires less addition of common salt.

The membrane filtration particularly, reverse osmosis is extensively being used for water purification purposes. However, its application for industrial effluent treatment is relatively new experience in India. There is also problem associated with safe disposal of membrane rejects, which contain high pollution

The reuse of textile industry effluent is assuming greater importance in recent times primarily due to scarcity of water resources and increasingly stringent regulatory requirements for the disposal of the effluent. With suitable treatment, effluent can be made fit for reuse or recycle in the production process for which technological options are available. The returns on account of water and chemical recovery can off set operating cost of effluent treatment recycling system. The recycling and reuse of the treated effluent directly conserve natural resources and a step towards sustainable development.

10.0 RECOMMENDATIONS FOR EFFLUENT MANAGEMENT IN TEXTILE INDUSTRIES

Textile industry effluent can be treated with or without segregation of effluent streams. Treatment of effluent streams collectively can give recovery of water but the recovery of salt may not be feasible. Segregation of effluent streams on other hand makes it possible to recover both water and salts. The highly polluting effluent streams such as spent dye bath has low volume, which is normally 10 per cent of the total effluent discharge. The remaining 90 per cent of effluent is contributed by low polluting streams like wash water. Segregation of these streams could be so managed that low polluting stream contains nominal dissolved solids so that it meets quality requirement for its reuse or disposal after treatment. Advance treatment methods can be appropriately applied to manage both the effluent streams. The advance treatment methods, while reducing the pollution problems also give scope for recovery and recycle of water and salts. For effective management of effluent in textile industries, some options are as below:

- The highly polluting effluent stream can be segregated and treated separately. This stream has low volume and as such, it can be disposed of through solar evaporation pond where adequate land is available. In case of land constraints, this waste steam can be concentrated to further reduce volume using suitable evaporation system.

The other low polluting streams can be given primary/secondary/tertiary treatment to meet the disposal standards or for use in industry for appropriate operations. With the application of reverse osmosis, the effluent stream can be made suitable for reuse in production process itself. The reject stream of reverse osmosis to is be treated along with high polluting effluent stream.

- Spent dye bath effluent can be segregated and treated with recovery of salt. This effluent can be treated using a primary treatment followed by evaporation and crystallization. Glauber salt (Sodium Sulthate decahydrate, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$) based dyeing enables recovery of the salt. The other effluent stream i.e. wash water can be treated separately in primary/secondary/tertiary treatment to meet the disposal standards or for reuse. It can also be treated with reverse osmosis system to recover and recycle water.
- Segregate spent dye bath effluent from wash water streams for further treatment. Dye bath effluent is to be treated using a nanofiltration system and wash water effluent with reverse osmosis. Nanofiltration allows maximum passage of the salt with no colour in the permeate. As such, the permeate can be directly recycled back to dye bath so as to minimize fresh addition of salt. For this option common salt (Sodium Chloride, NaCl) is advised to be used in dyeing process. The rejects of reverse osmosis and naofiltration can be disposed of through solar evaporation ponds or other evaporation system.
- The effluent stream arising out of textile processing can be collectively treated using primary/secondary/tertiary treatment to meet the disposal standards. In case water is intended to be reused, the treated water can be further purified with use of reverse osmosis or other methods. The reject stream of reverse osmosis can be disposed of through solar evaporation ponds or other evaporation system.

The options are further delineated in **Table 10.1**. While recovering the water and salts, these schemes also reduce problems relating to disposal of effluents in industries. Returns on account of reuse of water and salt can off set recurring cost of treatment system to a large extent and can be advantageous in places where there is water scarcity.

Table 10.1: Some options for effluent management in textile industries

Treatment method	Option I		Option II		Option III		Option IV	
	Segregation of effluent streams		Segregation of effluent streams		Segregation of streams		Combined effluent treatment	Combined effluent treatment
	High polluting	Low polluting	High polluting	Low polluting	High polluting	Low polluting		
Primary ¹ treatment	√	√		√		√	√	√
Secondary ² /tertiary ³ treatment		√		√		√	√	√
Reverse osmosis		√		√			√	
Nanofiltration			√					
Evaporation/drying system/ solar evaporation etc.	√	√	√	√	√		√	
Crystallization	√							
Potential benefits:								
Recycling/reuse of treated effluent		√		√			√	
Reuse/disposal of treated effluent						√		√
Recycling/reuse of salt	√		√					
Zero discharge	√		√				√	

¹Oil and grease removal, coagulation, settling, neutralization, filtration etc.

²Biological treatment units.

³Adsorption, ion exchange, oxidation including ozonation/chlorination, iron/manganese removal etc.

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